Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Bear River, Upper	Mercury	May, J.T., R.L. Hothem, C.N. Alpers, M.A. Law. 2000. *Mercury Bioaccumulation in Fish in a Region Affected by Historic Gold Mining: The South Yuba River, Deer Creek, and Bear River Watersheds, California, 1999.* U.S. Geological Survey. Sacramento, CA. 2000.	1; HU:516 & 517
Bear River, Upper	Mercury	Montoya, B. and X. Pan. 1992. *Inactive Mine Drainage in the Sacramento Valley, California.* California Regional Water Quality Control Board, Central Valley Region Report. July 1992.	1; HU:516 & 517
Bear River, Upper	Mercury	Nevada County, Department of Environmental Health. 2000. *Press Release, Three County Environmental Health Agencies Issue Interim Public Health Notification on Mercury in Fish.* (http://www.co.nevada.ca.us/ehealth/hg/press_release_10-03-00.htm)	1; HU:516 & 517
Black Butte Res	Mercury	Fact Sheet	1; Black Butte
Black Butte Reservoir	Mercury	Brodberg, R. K. and G. A. Pollock. 1999. *Prevalence of Selected Target Chemical Contaminants in Sport Fish from Two California Lakes: Public Health Designed Screening Study.* California Environmental Protection Agency, Office of Environmental Health Hazard Assessment Final Report. June 1999. Sacramento, California.	1; Black Butte
Black Butte Reservoir	Mercury	OEHHA (Office of Environmental Health Hazard Assessment). 2000. Draft Evaluation of Potential Health Effects of Eating Fish From 1; Black Butte Reservoir (Glenn and Tehama Counties): Guidelines for Sport Fish Consumption, Pesticide and Environmental Toxicology Section, California Environmental Protection Agency, Office of Environmental Health Hazard Assessment.	1; Black Butte
Butte Slough	Diazinon	Fact Sheet	1; Bear and Butte Crks
Butte Slough	Diazinon	Chilcott, J. 1992. *Agenda Item #11 for Meeting of California Regional Water Quality Control Board, Central Valley Region. September 25, 1992. Fresno, CA.* Staff Report on Consideration of Water Body Designations to Comply with Provisions of the Water Quality Control Plan for Inland Surface Waters of California. Including Appendix B.	1; Bear and Butte Crks
Butte Slough	Diazinon	Dileanis, P.D., J.L. Domagalski, and K.P. Bennett. 2000. *Occurrence and Transport of Diazinon in the Sacramento River and its Tributaries During Three Winter Storms, January-February 2000.* U.S. Geological Survey Water Resources Investigations Report, Draft. Sacramento, CA.	1; Bear and Butte Crks
Butte Slough	Diazinon	Holmes, R., C. Foe, and V. de Vlaming. 2000. *Sources and Concentrations of Diazinon in the Sacramento Watershed During the 1994 Orchard Dormant Spray Season.* California Regional Water Quality Control Board – Central Valley Region. Sacramento, CA. (CDPR and hard copy)	1; Bear and Butte Crks
Butte Slough	Diazinon	NCWA (Northern California Water Association). *The Lower Butte Creek Project.* (http://norcalwater.org/lower_butte_creek_project.htm). Last updated Sept 4, 2001.	1; Bear and Butte Crks
Butte Slough	Molinate	Fact Sheet	1; Bear and Butte Crks
Butte Slough	Molinate	California Rice Commission. 2001. *CA Rice.* Chapter 3: Water Quality in Relation to Rice Farming http://www.calrice.org/frame.tpl?_page=environment/balance-sheet/	1; Bear and Butte Crks
Butte Slough	Molinate	CDPR. 2001. Surface Water Database. Access formatted database, using the parameters of Butte Slough and molinate	1; Disk 1
Butte Slough	Molinate	Gorder, N.K.N., J.M. Lee, and K. Newhart. 1995. *Information on Rice 2; Pesticides Submitted to the California Regional Water Quality Control Board Central Valley Region.* Environmental Monitoring and Pest Management Branch, Department of Pesticide Regulation, Sacramento, CA. December 28, 1995.	1; Bear and Butte Crks

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Mokulmne River	Zinc	CDFG (California Department of Fish and Game). 1991. *Lower Mokelumne River Fisheries Plan.* The Resources Agency, Department of Fish and Game, Stream flow Requirements Program. November 1991.	1; Camanche Res
Mokulmne River	Zinc	CH2MHILL. 2000a. *Closure Report: Penn Mine Environmental Restoration Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. Oakland, California. December 2000.	1; Camanche Res
Mokulmne River	Zinc	CH2MHILL. 2000b. *(Draft) Post-Restoration Final Effectiveness Report: Penn Mine Environmental Restoration Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. Oakland, California. September 2000.	1; Camanche Res
Mokulmne River	Zinc	EBMUD (East Bay Municipal Utility District). 2001. Unpublished dissolved copper concentration data for the lower Mokelumne River downstream of Camanche Dam, generated as part of EBMUD's NPDES requirements. Provided electronically by Alexander R. Coate (Manger of Regulatory Compliance, EBMUD) to Michelle L. Wood (Environmental Specialist, Central Valley Regional Water Quality Control Board) on August 2, 2001.	1; Camanche Res
Mokulmne River	Zinc	EDAW, Inc. 1992. *Draft EIS/EIR for the Updated Water Supply Management Program, Volume III, Technical Appendices B1 and B2.* Prepared for: East Bay Municipal Utility District. Oakland, California. December 1992.	1; Camanche Res
Mokulmne River	Zinc	Montoya, B., and X. Pan. 1992. *Inactive Mine Drainage in the Sacramento Valley, California.* California Regional Water Quality Control Board, Central Valley Region Report. July 1992.	1; Camanche Res
Mokulmne River	Zinc	SCH EIR. 1996. *Draft EIR for The Penn Mine Site, Long-Term Solution Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. SCH EIR No. 95103036.	1; Camanche Res
Mosher Slough	Chlorpyrifos, Diazinon	Fact Sheet	3; Change: General
Mosher Slough	Chlorpyrifos, Diazinon	DeLorme 1998. Northern California Atlas and Gazetteer- Detailed Topographic Maps. 1:150,000 Scale. Fourth Edition. (http://www.delorme.com.)	NA
Mosher Slough	Chlorpyrifos, Diazinon	Horizons Technology, Inc., 1997. Sure! MAPS® RASTER Map Sets (U.S. Geological Survey 7.5' Topographic Quadrangles), Version 2.1.2.	NA
San Carlos Creek	Hg	Fact Sheet	3; Change: New Idrea
San Carlos Creek	Hg	USGS (United States Geological Survey). 1969-1981. Ciervo Mountain (1969), Idria (1969), San Benito Mountain (1981), and Tumey Hills (1971). California 7.5' Topographic Quadrangle, as presented by TopoZone.com (© 2000 Maps a la carte, Inc.). Accessed on March 13, 2001 (http://www.topozone.com/default.asp).	NA
San Carlos Creek	Hg	CRWQCB-CVR. 1971-1995. *Futures Foundation, New Idria Mine File.* Electronic database of all water sampling results for San Carlos Creek and New Idria Mine drainage. Mercury data for water samples collected June 1971 to December 1995.	1; Disk 2
San Carlos Creek	Hg	CRMP (Panoche/Silver Creek Coordinated Resource Management Plan) TRC (Technical Review Committee). 1996. *Draft Water Quality Report.* February 29, 1996.	3; Change: New Idrea
Stanislaus River	Diazinon, GAP, UTX	Fact Sheet	3; Change: General

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Butte Slough	Molinate	Gorder, N.K.N., J.M. Lee, and K. Newhart. 1996. *Information on Rice 2; Pesticides Submitted to the California Regional Water Quality Control Board Central Valley Region.* Environmental Monitoring and Pest Management Branch, Department of Pesticide Regulation, Sacramento, CA. December 31, 1996.	1; Bear and Butte Crks
Butte Slough	Molinate	NCWA (Northern California Water Association). *The Lower Butte Creek Project.* (http://norcalwater.org/lower_butte_creek_project.htm). Last updated Sept 4, 2001.	1; Bear and Butte Crks
Butte Slough	Molinate	Newhart, K., D. Jones, and S. Ceesay. 2000. *Information on Rice 2; Pesticides-Submitted to the California Regional Water Quality Control Board.* California Environmental Protection Agency, Department of Pesticide Regulation. Environmental Monitoring and Pest Management Branch. Environmental Hazards Assessment Program. December 31, 2000.	1; Bear and Butte Crks
Butte Slough	Molinate	Newhart, K. and K. Bennett. 1999. *Information on Rice 2; Pesticides-Submitted to the California Regional Water Quality Control Board.* California Environmental Protection Agency, Department of Pesticide Regulation. Environmental Monitoring and Pest Management Branch. Environmental Hazards Assessment Program. December 31, 1999.	1; Bear and Butte Crks
Calaveras River, Lower	Dissolved Oxygen	Fact Sheet	2; Low DO
Calaveras River, Lower	Dissolved Oxygen	*CALFED Bay-Delta Program. 2000. Water Quality Program Plan, Final Programmatic EIS/EIR Technical Appendix. July 2000.	2; Low DO
Calaveras River, Lower	Dissolved Oxygen	Lee G.F. Dissolved Oxygen Depletion in the Stockton Sloughs. August 2000. (Prepared for DeltaKeeper)	2; Low DO
Calaveras River, Lower	Dissolved Oxygen	Lee, G.F. and A. Jones-Lee. 2001b. *Review of the City of Stockton Urban Stormwater Runoff Aquatic Life Toxicity Studies Conducted by the Central Valley Regional Water Quality Control Board, DeltaKeeper, and the University of California, Davis, Aquatic Toxicology Laboratory between 1994 and 1999.* Final Report. November 2001. G. Fred Lee & Associates. El Macero, CA. (Prepared for DeltaKeeper).	2; Putah Creek
Calaveras River, Lower	Pathogens	Fact Sheet	1; Bacteria
Calaveras River, Lower	Pathogens	Jennings, B. 2001. Letter from Bill Jennings (DeltaKeeper A Project of San Francisco BayKeeper) to Mr. Jerry Bruns and Mr. Joe Karkoski (California Regional Water Quality Control Board, Central Valley Region) dated May 14, 2001, regarding DeltaKeeper comments on section 303(d) list update.	1; Bacteria
Camanche Reservoir	Aluminum	Fact Sheet	1; Camanche Res
Camanche Reservoir	Aluminum	Buer, S.M., S.R. Phillippe, and T.R. Pinkos. 1979. *Inventory and Assessment of Water Quality Problems related to Abandoned and Inactive Mines in the Central Valley Region of California.* CRWQCB-CVR (California Regional Water Quality Control Board, Central Valley Region), Report.	1; Camanche Res
Camanche Reservoir	Aluminum	CDFG (California Department of Fish and Game). 1991. *Lower Mokelumne River Fisheries Plan.* The Resources Agency, Department of Fish and Game, Stream flow Requirements Program. November 1991.	1; Camanche Res
Camanche Reservoir	Aluminum	CH2MHILL. 2000a. *Closure Report: Penn Mine Environmental Restoration Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. Oakland, California. December 2000.	1; Camanche Res
Camanche Reservoir	Aluminum	CH2MHILL. 2000b. *(Draft) Post-Restoration Final Effectiveness Report: Penn Mine Environmental Restoration Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. Oakland, California. September 2000.	1; Camanche Res

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Camanche Reservoir	Aluminum	EBMUD (East Bay Municipal Utility District). 2000. All About EBMUD. EBMUD Public Affairs Office publication. Available: http://www.ebmud.com/pubs/annual/allaboutebmud_2000.pdf. Accessed: August 2, 2001.	1; Camanche Res
Camanche Reservoir	Aluminum	EDAW, Inc. 1992. *Draft EIS/EIR for the Updated Water Supply Management Program, Volume III, Technical Appendices B1 and B2.* Prepared for: East Bay Municipal Utility District. Oakland, California. December 1992.	1; Camanche Res
Camanche Reservoir	Aluminum	SCH EIR. 1996. *Draft EIR for The Penn Mine Site, Long-Term Solution Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. SCH EIR No. 95103036. May 1996.	1; Camanche Res
Camanche Reservoir	Aluminum	SWRCB (State Water Resources Control Board). 1990. *Water Quality Problems Associated with Operation of Pardee and Camanche Reservoir.* State Water Resources Control Board, Division of Water Quality staff report.	1; Camanche Res
Camp Far West Reservoir	Mercury	Fact Sheet	2; 516 & 517-Mercury
Camp Far West Reservoir	Mercury	Alpers, C.N., M.P. Hunerlach. 2000. *Mercury Contamination from Historic Gold Mining in California.* U.S. Geological Survey. Fact Sheet FS-061-00. May 2000.	2; 516 & 517-Mercury
Camp Far West Reservoir	Mercury	May, J.T., R.L. Hothem, C.N. Alpers, M.A. Law. 2000. *Mercury Bioaccumulation in Fish in a Region Affected by Historic Gold Mining: The South Yuba River, Deer Creek, and Bear River Watersheds, California, 1999.* U.S. Geological Survey. Sacramento, CA. 2000.	2; 516 & 517-Mercury
Camp Far West Reservoir	Mercury	Montoya, B. and X. Pan. 1992. *Inactive Mine Drainage in the Sacramento Valley, California.* California Regional Water Quality Control Board, Central Valley Region Report. July 1992.	2; 516 & 517
Camp Far West Reservoir	Mercury	Nevada County, Department of Environmental Health. 2000. Press Release, Three County Environmental Health Agencies Issue Interim Public Health Notification on Mercury in Fish. (http://www.co.nevada.ca.us/ehealth/hg/press_release_10-03-00.htm)	2; 516 & 517-Mercury
Camp Far West Reservoir	Mercury	Slotton, D.G., S.M. Ayers, J.E. Reuter, C.R. Goldman. 1996. Gold Mining Impacts on Food Chain Mercury in Northwestern Sierra Nevada Streams (1996 Revision). Division of Environmental Studies, University of California, Davis. December 1996.	2; 516 & 517-Mercury
Clover Creek	Fecal Coliform	Fact Sheet	1; cow creek
Clover Creek	Fecal Coliform	Hannaford MJ and North State Institute for Sustainable Communities. 2000. Preliminary Water Quality Assessment of 1; cow creek Tributaries. Department of Fish and Game. May 15, 2000. (http://www.delta.dfg.ca.gov/afrp/documents/cowcrk.rpt.pdf).	1; cow creek
Colusa Drain	Azinphos Methyl	Fact Sheet	1; CBD
Colusa Drain	Azinphos Methyl	CDPR. 2001. Surface Water Database. Access formatted database, using the parameters of Colusa Drain and Azinphos Methyl.	1; Disk 1
Colusa Drain	Azinphos Methyl	Domagalski, J.L. 2000. *Pesticide Monitoring in the Sacramento River Basin for the USGS National Water Quality Assessment Program.* Report in prep. USGS. As presented in CDPR, 2000a.	1; Disk 1
Colusa Drain	Diazinon	Fact Sheet	1; CBD

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Colusa Drain	Diazinon	Holmes, R., C. Foe, and V. de Vlaming. 2000. *Sources and Concentrations of Diazinon in the Sacramento Watershed During the 1994 Orchard Dormant Spray Season*. California Regional Water Quality Control Board – Central Valley Region. Sacramento, CA. (CDPR and hard copy)	1; Bear and Butte Crks
Colusa Drain	Molinate	Fact Sheet	1; CBD
Colusa Drain	Molinate	CDPR. 2001. Surface Water Database. Access formatted database, using the parameters of Colusa Drain and molinate.	1; CBD
Colusa Drain	Molinate	Domagalski, J.L. 2000. *Pesticide Monitoring in the Sacramento River Basin for the USGS National Water Quality Assessment Program.* Report in prep. USGS. As presented in CDPR, 2000a.	1; Disk 1
Colusa Drain	Molinate	Gorder, N.K.N., J.M. Lee, and K. Newhart. 1995. Information on Rice 2; Pesticides Submitted to the California Regional Water Quality Control Board Central Valley Region. Environmental Monitoring and Pest Management Branch, Department of Pesticide Regulation, Sacramento, CA. December 28, 1995.	1; CBD
Colusa Drain	Molinate	Gorder, N.K.N., J.M. Lee, and K. Newhart. 1996. *Information on Rice 2; Pesticides Submitted to the California Regional Water Quality Control Board Central Valley Region.* Environmental Monitoring and Pest Management Branch, Department of Pesticide Regulation, Sacramento, CA. December 31, 1996.	1; CBD
Colusa Drain	Molinate	Gorder, N.K.N., J.M. Lee, and K. Newhart. 1997. *Information on Rice 2; Pesticides Submitted to the California Regional Water Quality Control Board Central Valley Region.* Environmental Monitoring and Pest Management Branch, Department of Pesticide Regulation, Sacramento, CA. December 31, 1997.	1; CBD
Colusa Drain	Molinate	Gorder, N.K.N., J.M. Lee, and K. Newhart. 1998. *Information on Rice 2; Pesticides Submitted to the California Regional Water Quality Control Board Central Valley Region.* Environmental Monitoring and Pest Management Branch, Department of Pesticide Regulation, Sacramento, CA. December 31, 1998.	1; CBD
Colusa Drain	Molinate	Holmes, R., C. Foe and V. de Vlaming. 1998. *Sources and Concentrations of Diazinon in the Sacramento Watershed During the 1994 Orchard Dormant Spray Season.* Central Valley Regional Water Quality Control Board. Draft, June 1998.	1; Bear and Butte Crks
Colusa Drain	Molinate	Newhart, K. and K. Bennett. 1999. *Information on Rice 2; Pesticides-Submitted to the California Regional Water Quality Control Board.* California Environmental Protection Agency, Department of Pesticide Regulation. Environmental Monitoring and Pest Management Branch. Environmental Hazards Assessment Program. December 31, 1999.	1; Bear and Butte Crks
Colusa Drain	Molinate	Newhart, K., D. Jones, and S. Ceesay. 2000. *Information on Rice 2; Pesticides-Submitted to the California Regional Water Quality Control Board.* California Environmental Protection Agency, Department of Pesticide Regulation. Environmental Monitoring and Pest Management Branch. Environmental Hazards Assessment Program. December 31, 2000.	1; Bear and Butte Crks
Colusa Drain	Diazinon	CDPR. 2001. Surface Water Database. Access formatted database, using the parameters of Colusa Drain and diazinon.	1; Disk 1
Colusa Drain	Diazinon	Dileanis, P., J. Domagalski, and K.P. Bennett. 2001. *Occurrence and Transport of Diazinon in the Sacramento River and its Tributaries During Three Winter Storms, January-February 2000.* U.S. Geological Survey Water Resources Investigations Report, Draft. Sacramento, CA	1; Bear and Butte Crks
Colusa Drain	Diazinon	Domagalski, J.L. 2000. *Pesticide Monitoring in the Sacramento River Basin for the USGS National Water Quality Assessment Program.* Report in prep. USGS. As presented in CDPR, 2000a.	1; Disk 1

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Del Puerto Crk	Chlorpyrifos	Fact Sheet	2; Pesticides
Del Puerto Crk	Chlorpyrifos	CDPR. 2001. Surface Water Database. Access formatted database, using the parameters of Del Puerto Crk and chlorpyrifos	1; Disk 1
Del Puerto Crk	Chlorpyrifos	Foe, C. 1995. *Insecticide Concentrations and Invertebrate Bioassay Mortality in Agricultural Return Water from the San Joaquin Basin.* Central Valley Regional Water Quality Control Board. Sacramento, CA December 1995.	2; Pesticides
Del Puerto Crk	Chlorpyrifos	Fujimura, R. 1991a. *Chemical and Toxicity Test Results from the San Joaquin River at Three Sites from July 2 to September 13, 1991.* Memorandum to Lisa Ross, Department of Pesticide Regulation. Sacramento, CA. November 6, 1991. As presented in CDPR, 2000a.	1; Disk 1
Del Puerto Crk	Chlorpyrifos	Fujimura, R. 1991b. *Chemical and Toxicity Test Results from the San Joaquin River and Tributaries During March 4 to April 26, 1991.* Memorandum to Lisa Ross, Department of Pesticide Regulation. Sacramento, CA. November 6, 1991. As presented in CDPR, 2000a.	1; Disk 1
Del Puerto Crk	Chlorpyrifos	Fujimura, R. 1993a. *Chemical Analyses and Bioassay Test Results for Samples Collected from December 29 to February 25,, 1993.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 26, 1993. As presented in CDPR, 2000a.	1; Disk 1
Del Puerto Crk	Chlorpyrifos	Fujimura, R. 1993b. *Chemical Analyses and Bioassay Test Results for Samples Collected from July 9 to September 9, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 23, 1993. As presented in CDPR, 2000a.	1; Disk 1
Del Puerto Crk	Chlorpyrifos	Fujimura, R. 1993c. *Chemical Analyses and Bioassay Test Results for Samples Collected from March 16 to April 30, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 22, 1993. As presented in CDPR, 2000a.	1; Disk 1
Del Puerto Crk	Chlorpyrifos	Fujimura, R. 1993d. *Chemical Analyses and Bioassay Test Results for Samples Collected from December 23, 1991 to February 27, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. February 23, 1993. As presented in CDPR, 2000a.	1; Disk 1
Del Puerto Crk	Chlorpyrifos	Ross, L. 1992. Preliminary Results of the San Joaquin River Study; Summer, 1991. Memorandum to Kean Goh. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. May 21, 1992. As presented in CDPR, 2000a.	1; Disk 1
Del Puerto Crk	Chlorpyrifos	Ross, L. 1993. Preliminary Results of the San Joaquin River Study; Summer, 1992. Memorandum to Kean Goh. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. September 22, 1993. As presented in CDPR, 2000a.	1; Disk 1

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Del Puerto Crk	Chlorpyrifos	Ross, L., J. Stein, J. Hsu, J. White, and K. Hefner. 1996. Distribution and Mass Loading of Insecticides in the San Joaquin River, California: Winter 1991-92 and 1992-93. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. Report EH 96-02. November, 1996. As presented in CDPR, 2000a.	1; Disk 1
Del Puerto Crk	Chlorpyrifos	Ross, L., J. Stein, J. Hsu, J. White, and K. Hefner. 1999. Distribution and Mass Loading of Insecticides in the San Joaquin River, California: Spring 1991 and 1992. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. Report EH 99-01. April, 1999. As presented in CDPR, 2000a.	1; Disk 1
Del Puerto Crk	Diazinon	Fact Sheet	2; Pesticides
Del Puerto Crk	Diazinon	CDPR. 2001. Surface Water Database. Access formatted database, using the parameters of Del Puertro Creek and diazinon.	1; Disk 1
Del Puerto Crk	Diazinon	Foe, C. 1995. *Insecticide Concentrations and Invertebrate Bioassay Mortality in Agricultural Return Water from the San Joaquin Basin.* Central Valley Regional Water Quality Control Board. Sacramento, CA December 1995.	2; Pesticides
Del Puerto Crk	Diazinon	Fujimura, R. 1991a. *Chemical and Toxicity Test Results from the San Joaquin River at Three Sites from July 2 to September 13, 1991.* Memorandum to Lisa Ross, Department of Pesticide Regulation. Sacramento, CA. November 6, 1991. As presented in CDPR, 2000a.	1; Disk 1
Del Puerto Crk	Diazinon	Fujimura, R. 1991b. *Chemical and Toxicity Test Results from the San Joaquin River and Tributaries During March 4 to April 26, 1991.* Memorandum to Lisa Ross, Department of Pesticide Regulation. Sacramento, CA. November 6, 1991. As presented in CDPR, 2000a.	1; Disk 1
Del Puerto Crk	Diazinon	Fujimura, R. 1993a. *Chemical Analyses and Bioassay Test Results for Samples Collected from December 29 to February 25,, 1993.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 26, 1993. As presented in CDPR, 2000a.	1; Disk 1
Del Puerto Crk	Diazinon	Fujimura, R. 1993b. *Chemical Analyses and Bioassay Test Results for Samples Collected from July 9 to September 9, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 23, 1993. As presented in CDPR, 2000a.	1; Disk 1
Del Puerto Crk	Diazinon	Fujimura, R. 1993c. *Chemical Analyses and Bioassay Test Results for Samples Collected from March 16 to April 30, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 22, 1993. As presented in CDPR, 2000a.	1; Disk 1
Del Puerto Crk	Diazinon	Fujimura, R. 1993d. *Chemical Analyses and Bioassay Test Results for Samples Collected from December 23, 1991 to February 27, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. February 23, 1993. As presented in CDPR, 2000a.	1; Disk 1
Del Puerto Crk	Diazinon	Ross, L. 1992. Preliminary Results of the San Joaquin River Study; Summer, 1991. Memorandum to Kean Goh. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. May 21, 1992.	1; Disk 1

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Del Puerto Crk	Diazinon	Ross, L. 1993. Preliminary Results of the San Joaquin River Study; Summer, 1992. Memorandum to Kean Goh. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. September 22, 1993.	1; Disk 1
Del Puerto Crk	Diazinon	Ross, L., J. Stein, J. Hsu, J. White, and K. Hefner. 1996. Distribution and Mass Loading of Insecticides in the San Joaquin River, California: Winter 1991-92 and 1992-93. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. Report EH 96-02. November, 1996.	1; Disk 1
Del Puerto Crk	Diazinon	Ross, L., J. Stein, J. Hsu, J. White, and K. Hefner. 1999. Distribution and Mass Loading of Insecticides in the San Joaquin River, California: Spring 1991 and 1992. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. Report EH 99-01. April, 1999.	1; Disk 1
Don Pedro Lake	Mercury	Fact Sheet	1; Don Pedro Lake
Don Pedro Lake	Mercury	DWR (California Department of Water Resources). 1993. Dams within Jurisdiction of the State of California. DWR Bulletin 17, as presented by the Berkeley Digital Library Project. Accessed on August 23, 2001 (http://elib.cs.berkeley.edu/dams/about.html).	1; Don Pedro Lake
Don Pedro Lake	Mercury	OMR. 2000. California's Abandoned Mines – A Report on the Magnitude and Scope of the Issue in the State. California Department of Conservation, Office of Mine Reclamation, Abandoned Mine Lands Unit (OMR). http://www.consrv.ca.gov/omr/AMLU/amlurpt/Sacramento, CA. June 2000.	1; Don Pedro Lake
Don Pedro Lake	Mercury	SWRCB (State Water Resources Control Board, Division of Water Quality). 1995. Toxic Substances Monitoring Program: Freshwater Bioaccumulation Monitoring Program: Data Base (Metals_Wet).	1; Disk 1
Five Mile Slough	Dissolved Oxygen	Fact Sheet	2; Low DO
Five Mile Slough	Dissolved Oxygen	Lee G.F. *Dissolved Oxygen Depletion in the Stockton Sloughs*. August 2000. (Prepared for DeltaKeeper)	2; Low DO
Five Mile Slough	Dissolved Oxygen	Lee, G.F. and A. Jones-Lee. 2001b. *Review of the City of Stockton Urban Stormwater Runoff Aquatic Life Toxicity Studies Conducted by the Central Valley Regional Water Quality Control Board, DeltaKeeper, and the University of California, Davis, Aquatic Toxicology Laboratory between 1994 and 1999*. Final Report. November 2001. G. Fred Lee & Associates. El Macero, CA. (Prepared for DeltaKeeper).	2; Smith Canal
Five Mile Slough	Pathogens	Fact Sheet	1; Bacteria
Five Mile Slough	Pathogens	Jennings, B. 2001. Letter from Bill Jennings (DeltaKeeper A Project of San Francisco BayKeeper) to Mr. Jerry Bruns and Mr. Joe Karkoski (California Regional Water Quality Control Board, Central Valley Region) dated May 14, 2001, regarding DeltaKeeper comments on section 303(d) list update.	1; Bacteria
Ingram/ Hospital Crk	Chlorpyrifos	Fact Sheet	2; Pesticides
Ingram/ Hospital Crk	Chlorpyrifos	CDPR. 2001. Surface Water Database. Access formatted database, using the parameters of Ingram/Hospital Creek and chlorpyrifos.	1; Disk 1

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Ingram/ Hospital Crk	Chlorpyrifos	Foe, C. 1995. *Insecticide Concentrations and Invertebrate Bioassay Mortality in Agricultural Return Water from the San Joaquin Basin.* Central Valley Regional Water Quality Control Board. Sacramento, CA December 1995.	2; Pesticides
Ingram/ Hospital Crk	Chlorpyrifos	Fujimura, R. 1991a. *Chemical and Toxicity Test Results from the San Joaquin River at Three Sites from July 2 to September 13, 1991.* Memorandum to Lisa Ross, Department of Pesticide Regulation. Sacramento, CA. November 6, 1991. As presented in CDPR, 2000a.	1; Disk 1
Ingram/ Hospital Crk	Chlorpyrifos	Fujimura, R. 1991b. *Chemical and Toxicity Test Results from the San Joaquin River and Tributaries During March 4 to April 26, 1991.* Memorandum to Lisa Ross, Department of Pesticide Regulation. Sacramento, CA. November 6, 1991. As presented in CDPR, 2000a.	1; Disk 1
Ingram/ Hospital Crk	Chlorpyrifos	Fujimura, R. 1993a. *Chemical Analyses and Bioassay Test Results for Samples Collected from December 29 to February 25,, 1993.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 26, 1993. As presented in CDPR, 2000a.	1; Disk 1
Ingram/ Hospital Crk	Chlorpyrifos	Fujimura, R. 1993b. *Chemical Analyses and Bioassay Test Results for Samples Collected from July 9 to September 9, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 23, 1993. As presented in CDPR, 2000a.	1; Disk 1
Ingram/ Hospital Crk	Chlorpyrifos	Fujimura, R. 1993c. *Chemical Analyses and Bioassay Test Results for Samples Collected from March 16 to April 30, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 22, 1993. As presented in CDPR, 2000a.	1; Disk 1
Ingram/ Hospital Crk	Chlorpyrifos	Fujimura, R. 1993d. *Chemical Analyses and Bioassay Test Results for Samples Collected from December 23, 1991 to February 27, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. February 23, 1993. As presented in CDPR, 2000a.	1; Disk 1
Ingram/ Hospital Crk	Chlorpyrifos	Ross, L. 1992. Preliminary Results of the San Joaquin River Study; Summer, 1991. Memorandum to Kean Goh. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. May 21, 1992.	1; Disk 1
Ingram/ Hospital Crk	Chlorpyrifos	Ross, L. 1993. Preliminary Results of the San Joaquin River Study; Summer, 1992. Memorandum to Kean Goh. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. September 22, 1993.	1; Disk 1
Ingram/ Hospital Crk	Chlorpyrifos	Ross, L., J. Stein, J. Hsu, J. White, and K. Hefner. 1996. Distribution and Mass Loading of Insecticides in the San Joaquin River, California: Winter 1991-92 and 1992-93. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. Report EH 96-02. November, 1996.	1; Disk 1
Ingram/ Hospital Crk	Chlorpyrifos	Ross, L., J. Stein, J. Hsu, J. White, and K. Hefner. 1999. Distribution and Mass Loading of Insecticides in the San Joaquin River, California: Spring 1991 and 1992. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. Report EH 99-01. April, 1999. As presented in CDPR, 2000a.	1; Disk 1

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Ingram/ Hospital Crk	Diazinon	Fact Sheet	2; Pesticides
Ingram/ Hospital Crk	Diazinon	CDPR. 2001. Surface Water Database. Access formatted database, using the parameters of Ingram/Hospital Creek and diazinon	1; Disk 1
Ingram/ Hospital Crk	Diazinon	Foe, C. 1995. *Insecticide Concentrations and Invertebrate Bioassay Mortality in Agricultural Return Water from the San Joaquin Basin.* Central Valley Regional Water Quality Control Board. Sacramento, CA December 1995.	2; Pesticides
Ingram/ Hospital Crk	Diazinon	Fujimura, R. 1991a. *Chemical and Toxicity Test Results from the San Joaquin River at Three Sites from July 2 to September 13, 1991.* Memorandum to Lisa Ross, Department of Pesticide Regulation. Sacramento, CA. November 6, 1991. As presented in CDPR, 2000a.	1; Disk 1
Ingram/ Hospital Crk	Diazinon	Fujimura, R. 1991b. *Chemical and Toxicity Test Results from the San Joaquin River and Tributaries During March 4 to April 26, 1991.* Memorandum to Lisa Ross, Department of Pesticide Regulation. Sacramento, CA. November 6, 1991. As presented in CDPR, 2000a.	1; Disk 1
Ingram/ Hospital Crk	Diazinon	Fujimura, R. 1993a. *Chemical Analyses and Bioassay Test Results for Samples Collected from December 29 to February 25,, 1993.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 26, 1993. As presented in CDPR, 2000a.	1; Disk 1
Ingram/ Hospital Crk	Diazinon	Fujimura, R. 1993b. *Chemical Analyses and Bioassay Test Results for Samples Collected from July 9 to September 9, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 23, 1993. As presented in CDPR, 2000a.	1; Disk 1
Ingram/ Hospital Crk	Diazinon	Fujimura, R. 1993c. *Chemical Analyses and Bioassay Test Results for Samples Collected from March 16 to April 30, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 22, 1993. As presented in CDPR, 2000a.	1; Disk 1
Ingram/ Hospital Crk	Diazinon	Fujimura, R. 1993d. *Chemical Analyses and Bioassay Test Results for Samples Collected from December 23, 1991 to February 27, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. February 23, 1993. As presented in CDPR, 2000a.	1; Disk 1
Ingram/ Hospital Crk	Diazinon	Ross, L. 1992. Preliminary Results of the San Joaquin River Study; Summer, 1991. Memorandum to Kean Goh. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. May 21, 1992. As presented in CDPR, 2000a.	1; Disk 1
Ingram/ Hospital Crk	Diazinon	Ross, L. 1993. Preliminary Results of the San Joaquin River Study; Summer, 1992. Memorandum to Kean Goh. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. September 22, 1993. As presented in CDPR, 2000a.	1; Disk 1
Ingram/ Hospital Crk	Diazinon	Ross, L., J. Stein, J. Hsu, J. White, and K. Hefner. 1996. Distribution and Mass Loading of Insecticides in the San Joaquin River, California: Winter 1991-92 and 1992-93. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. Report EH 96-02. November, 1996. As presented in CDPR, 2000a.	1; Disk 1

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Ingram/ Hospital Crk	Diazinon	Ross, L., J. Stein, J. Hsu, J. White, and K. Hefner. 1999. Distribution and Mass Loading of Insecticides in the San Joaquin River, California: Spring 1991 and 1992. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. Report EH 99-01. April, 1999. As presented in CDPR, 2000a.	1; Disk 1
Jack Slough	Diazinon	Fact Sheet	1; Bear and Butte Crks
Jack Slough	Diazinon	CDPR. 2001. Surface Water Database. Access formatted database, using the parameters of Jack Slough and diazinon	1; Disk 1
Jack Slough	Diazinon	Dileanis, P.D., J.L. Domagalski, and K.P. Bennett. 2000. Occurrence and Transport of Diazinon in the Sacramento River and its Tributaries During Three Winter Storms, January-February 2000. Water-Resources Investigations Draft Report. U.S. Geological Survey. Sacramento, CA.	1; Bear and Butte Crks
Jack Slough	Diazinon	Holmes, R. 2001. Personal Communication with C. Spector. CVRWQCB. August 28, 2001.	1; Bear and Butte Crks
Jack Slough	Diazinon	Holmes, R., C. Foe, and V. de Vlaming. 2000. *Sources and Concentrations of Diazinon in the Sacramento Watershed During the 1994 Orchard Dormant Spray Season.* California Regional Water Quality Control Board – Central Valley Region. Sacramento, CA. (CDPR and hard copy)	1; Bear and Butte Crks
Lake Combie	Mercury	Fact Sheet	2; HU:516 & 517
Lake Combie	Mercury	Alpers, C.N., M.P. Hunerlach. 2000. *Mercury Contamination from Historic Gold Mining in California.* U.S. Geological Survey. Fact Sheet FS-061-00. May 2000.	2; HU:516 & 517
Lake Combie	Mercury	May, J.T., R.L. Hothem, C.N. Alpers, M.A. Law. 2000. *Mercury Bioaccumulation in Fish in a Region Affected by Historic Gold Mining: The South Yuba River, Deer Creek, and Bear River Watersheds, California, 1999.* U.S. Geological Survey. Sacramento, CA. 2000.	2; HU:516 & 517
Lake Combie	Mercury	Montoya, B. and X. Pan. 1992. *Inactive Mine Drainage in the Sacramento Valley, California.* California Regional Water Quality Control Board, Central Valley Region Report. July 1992.	2; HU:516 & 517
Lake Combie	Mercury	Nevada County, Department of Environmental Health. 2000. *Press Release, Three County Environmental Health Agencies Issue Interim Public Health Notification on Mercury in Fish.* (http://www.co.nevada.ca.us/ehealth/hg/press_release_10-03-00.htm)	2; HU:516 & 517
Lake Englebright	Mercury	Fact Sheet	2; HU:516 & 517
Lake Englebright	Mercury	Alpers, C.N., M.P. Hunerlach. 2000. *Mercury Contamination from Historic Gold Mining in California.* U.S. Geological Survey. Fact Sheet FS-061-00. May 2000.	2; HU:516 & 517
Lake Englebright	Mercury	May, J.T., R.L. Hothem, C.N. Alpers, M.A. Law. 2000. *Mercury Bioaccumulation in Fish in a Region Affected by Historic Gold Mining: The South Yuba River, Deer Creek, and Bear River Watersheds, California, 1999.* U.S. Geological Survey. Sacramento, CA. 2000.	2; HU:516 & 517
Lake Englebright	Mercury	Montoya, B. and X. Pan. 1992. *Inactive Mine Drainage in the Sacramento Valley, California.* California Regional Water Quality Control Board, Central Valley Region Report. July 1992.	2; HU:516 & 517
Lake Englebright	Mercury	Nevada County, Department of Environmental Health. 2000. *Press Release, Three County Environmental Health Agencies Issue Interim Public Health Notification on Mercury in Fish.* (http://www.co.nevada.ca.us/ehealth/hg/press_release_10-03-00.htm)	2; HU:516 & 517

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Lake Englebright	Mercury	Slotton, D.G., S.M. Ayers, J.E. Reuter, C.R. Goldman. 1996. *Gold Mining Impacts on Food Chain Mercury in Northwestern Sierra Nevada Streams (1996 Revision).* Division of Environmental Studies, University of California, Davis. December 1996.	2; HU:516 & 517
Little Deer Creek	Mercury	Fact Sheet	2; HU:516 & 517
Little Deer Creek	Mercury	Alpers, C.N., M.P. Hunerlach. 2000. *Mercury Contamination from Historic Gold Mining in California.* U.S. Geological Survey. Fact Sheet FS-061-00. May 2000.	2; HU:516 & 517
Little Deer Creek	Mercury	May, J.T., R.L. Hothem, C.N. Alpers, M.A. Law. 2000. *Mercury Bioaccumulation in Fish in a Region Affected by Historic Gold Mining: The South Yuba River, Deer Creek, and Bear River Watersheds, California, 1999.* U.S. Geological Survey. Sacramento, CA. 2000.	2; HU:516 & 517
Little Deer Creek	Mercury	Montoya, B. and X. Pan. 1992. *Inactive Mine Drainage in the Sacramento Valley, California.* California Regional Water Quality Control Board, Central Valley Region Report. July 1992.	2; HU:516 & 517
Little Deer Creek	Mercury	Nevada County, Department of Environmental Health. 2000. *Press Release, Three County Environmental Health Agencies Issue Interim Public Health Notification on Mercury in Fish.* (http://www.co.nevada.ca.us/ehealth/hg/press_release_10-03-00.htm)	2; HU:516 & 517
Little Deer Creek	Mercury	Slotton, D.G., S.M. Ayers, J.E. Reuter, C.R. Goldman. 1996. *Gold Mining Impacts on Food Chain Mercury in Northwestern Sierra Nevada Streams (1996 Revision).* Division of Environmental Studies, University of California, Davis. December 1996.	2; HU:516 & 517
Mokelumne River, Lower	Aluminum	Fact Sheet	1; Camanche Res
Mokelumne River, Lower	Aluminum	Buer, S.M., S.R. Phillippe, and T.R. Pinkos. 1979. *Inventory and Assessment of Water Quality Problems related to Abandoned and Inactive Mines in the Central Valley Region of California.* CRWQCB-CVR (California Regional Water Quality Control Board, Central Valley Region), Report.	1; Camanche Res
Mokelumne River, Lower	Aluminum	CDFG (California Department of Fish and Game). 1991. *Lower Mokelumne River Fisheries Plan.* The Resources Agency, Department of Fish and Game, Stream flow Requirements Program. November 1991.	1; Camanche Res
Mokelumne River, Lower	Aluminum	CH2MHILL. 2000a. *Closure Report: Penn Mine Environmental Restoration Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. Oakland, California. December 2000.	1; Camanche Res
Mokelumne River, Lower	Aluminum	CH2MHILL. 2000b. *(Draft) Post-Restoration Final Effectiveness Report: Penn Mine Environmental Restoration Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. Oakland, California. September 2000.	1; Camanche Res
Mokelumne River, Lower	Aluminum	EBMUD (East Bay Municipal Utility District). 2000. All About EBMUD. EBMUD Public Affairs Office publication. Available: http://www.ebmud.com/pubs/annual/allaboutebmud_2000.pdf. Accessed: August 2, 2001.	1; Camanche Res
Mokelumne River, Lower	Aluminum	EDAW, Inc. 1992. *Draft EIS/EIR for the Updated Water Supply Management Program, Volume III, Technical Appendices B1 and B2.* Prepared for: East Bay Municipal Utility District. Oakland, California. December 1992.	1; Camanche Res
Mokelumne River, Lower	Aluminum	SCH EIR. 1996. *Draft EIR for The Penn Mine Site, Long-Term Solution Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. SCH EIR No. 95103036. May 1996.	1; Camanche Res

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Mokelumne River, Lower	Aluminum	SWRCB (State Water Resources Control Board). 1990. *Water Quality Problems Associated with Operation of Pardee and Camanche Reservoir.* State Water Resources Control Board, Division of Water Quality staff report.	1; Camanche Res
Mokelumne River, Lower	Aluminum	USFWS (U.S. Fish & Wildlife Service). 1992. *Before the State Water Resources Control: In the Matter of the Water Rights Hearing for the Lower Mokelumne River – Closing Statement, Enclosure 2 (EBMUD Data – Aluminum, Cadmium, Zinc, Iron and Zinc).* Prepared by J.W. Burke, III (Regional Solicitor, USFWS Pacific Southwest Region) and Lynn Cox (Assistant Regional Solicitor, USFWS Pacific Southwest Region).	1; Camanche Res
Mokelumne River, Lower	Aluminum	USGS (U.S. Geological Survey). 1976. Lodi North, California. 7.5' Topographic Quadrangles, as presented by TopoZone.com (© 2000 Maps a la carte, Inc.). Accessed on August 6, 2001 (http://www.topozone.com/default.asp).	1; Camanche Res
Mormon Slough	Dissolved Oxygen	Fact Sheet	2; Low DO
Mormon Slough	Dissolved Oxygen	Lee G.F. Dissolved Oxygen Depletion in the Stockton Sloughs. August 2000. (Prepared for DeltaKeeper)	2; Low DO
Mormon Slough	Dissolved Oxygen	Lee, G.F. and A. Jones-Lee. 2001b. *Review of the City of Stockton Urban Stormwater Runoff Aquatic Life Toxicity Studies Conducted by the Central Valley Regional Water Quality Control Board, DeltaKeeper, and the University of California, Davis, Aquatic Toxicology Laboratory between 1994 and 1999.* Final Report. November 2001. G. Fred Lee & Associates. El Macero, CA. (Prepared for DeltaKeeper).	2; Smith Canal
Mormon Slough	Pathogens	Fact Sheet	1; Bacteria
Mormon Slough	Pathogens	Jennings, B. 2001. Letter from Bill Jennings (DeltaKeeper A Project of San Francisco BayKeeper) to Mr. Jerry Bruns and Mr. Joe Karkoski (California Regional Water Quality Control Board, Central Valley Region) dated May 14, 2001, regarding DeltaKeeper comments on section 303(d) list update.	1; Bacteria
Mosher Slough	Dissolved Oxygen	Fact Sheet	2; Low DO
Mosher Slough	Dissolved Oxygen	Lee G.F. Dissolved Oxygen Depletion in the Stockton Sloughs. August 2000. (Prepared for DeltaKeeper)	2; Low DO
Mosher Slough	Dissolved Oxygen	Lee, G.F. and A. Jones-Lee. 2001b. *Review of the City of Stockton Urban Stormwater Runoff Aquatic Life Toxicity Studies Conducted by the Central Valley Regional Water Quality Control Board, DeltaKeeper, and the University of California, Davis, Aquatic Toxicology Laboratory between 1994 and 1999.* Final Report. November 2001. G. Fred Lee & Associates. El Macero, CA. (Prepared for DeltaKeeper).	2; Smith Canal
Mosher Slough	Pathogens	Fact Sheet	1; Bacteria
Mosher Slough	Pathogens	Jennings, B. 2001. Letter from Bill Jennings (DeltaKeeper A Project of San Francisco BayKeeper) to Mr. Jerry Bruns and Mr. Joe Karkoski (California Regional Water Quality Control Board, Central Valley Region) dated May 14, 2001, regarding DeltaKeeper comments on section 303(d) list update.	1; Bacteria
Newman Wasteway	Chlorpyrifos	Fact Sheet	2; Pesticides
Newman Wasteway	Chlorpyrifos	CDPR. 2001. Surface Water Database. Access formatted database, using the parameters of Newman Wasteway and chlorpyrifos	1; Disk 1

Waterbody	**Pollutant**	**Sources**	**Location: Folder #; Tab Title**
Newman Wasteway	Chlorpyrifos	Foe, C. 1995. *Insecticide Concentrations and Invertebrate Bioassay Mortality in Agricultural Return Water from the San Joaquin Basin.* Central Valley Regional Water Quality Control Board. Sacramento, CA December 1995.	2; Pesticides
Newman Wasteway	Chlorpyrifos	Fujimura, R. 1991a. *Chemical and Toxicity Test Results from the San Joaquin River at Three Sites from July 2 to September 13, 1991.* Memorandum to Lisa Ross, Department of Pesticide Regulation. Sacramento, CA. November 6, 1991. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Chlorpyrifos	Fujimura, R. 1991b. *Chemical and Toxicity Test Results from the San Joaquin River and Tributaries During March 4 to April 26, 1991.* Memorandum to Lisa Ross, Department of Pesticide Regulation. Sacramento, CA. November 6, 1991. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Chlorpyrifos	Fujimura, R. 1993a. *Chemical Analyses and Bioassay Test Results for Samples Collected from December 29 to February 25,, 1993.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 26, 1993. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Chlorpyrifos	Fujimura, R. 1993b. *Chemical Analyses and Bioassay Test Results for Samples Collected from July 9 to September 9, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 23, 1993. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Chlorpyrifos	Fujimura, R. 1993c. *Chemical Analyses and Bioassay Test Results for Samples Collected from March 16 to April 30, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 22, 1993. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Chlorpyrifos	Fujimura, R. 1993d. *Chemical Analyses and Bioassay Test Results for Samples Collected from December 23, 1991 to February 27, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. February 23, 1993. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Chlorpyrifos	Ross, L. 1992. Preliminary Results of the San Joaquin River Study; Summer, 1991. Memorandum to Kean Goh. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. May 21, 1992. As presented in CDPR, 2000a.	1; Disk 1

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Newman Wasteway	Chlorpyrifos	Ross, L. 1993. Preliminary Results of the San Joaquin River Study; Summer, 1992. Memorandum to Kean Goh. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. September 22, 1993. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Chlorpyrifos	Ross, L., J. Stein, J. Hsu, J. White, and K. Hefner. 1996. Distribution and Mass Loading of Insecticides in the San Joaquin River, California: Winter 1991-92 and 1992-93. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. Report EH 96-02. November, 1996. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Chlorpyrifos	Ross, L., J. Stein, J. Hsu, J. White, and K. Hefner. 1999. Distribution and Mass Loading of Insecticides in the San Joaquin River, California: Spring 1991 and 1992. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. Report EH 99-01. April, 1999. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Diazinon	Fact Sheet	2; Pesticides
Newman Wasteway	Diazinon	CDPR. 2001. Surface Water Database. Access formatted database, using the parameters of Newman Wasteway and diazinon.	1; Disk 1
Newman Wasteway	Diazinon	Foe, C. 1995. *Insecticide Concentrations and Invertebrate Bioassay Mortality in Agricultural Return Water from the San Joaquin Basin.* Central Valley Regional Water Quality Control Board. Sacramento, CA December 1995.	2; Pesticides
Newman Wasteway	Diazinon	Fujimura, R. 1991a. *Chemical and Toxicity Test Results from the San Joaquin River at Three Sites from July 2 to September 13, 1991.* Memorandum to Lisa Ross, Department of Pesticide Regulation. Sacramento, CA. November 6, 1991. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Diazinon	Fujimura, R. 1991b. *Chemical and Toxicity Test Results from the San Joaquin River and Tributaries During March 4 to April 26, 1991.* Memorandum to Lisa Ross, Department of Pesticide Regulation. Sacramento, CA. November 6, 1991. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Diazinon	Fujimura, R. 1993a. *Chemical Analyses and Bioassay Test Results for Samples Collected from December 29 to February 25,, 1993.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 26, 1993. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Diazinon	Fujimura, R. 1993b. *Chemical Analyses and Bioassay Test Results for Samples Collected from July 9 to September 9, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 23, 1993. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Diazinon	Fujimura, R. 1993c. *Chemical Analyses and Bioassay Test Results for Samples Collected from March 16 to April 30, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 22, 1993. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Diazinon	Fujimura, R. 1993d. *Chemical Analyses and Bioassay Test Results for Samples Collected from December 23, 1991 to February 27, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. February 23, 1993. As presented in CDPR, 2000a.	1; Disk 1

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Newman Wasteway	Diazinon	Ross, L. 1992. Preliminary Results of the San Joaquin River Study; Summer, 1991. Memorandum to Kean Goh. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. May 21, 1992. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Diazinon	Ross, L. 1993. Preliminary Results of the San Joaquin River Study; Summer, 1992. Memorandum to Kean Goh. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. September 22, 1993. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Diazinon	Ross, L., J. Stein, J. Hsu, J. White, and K. Hefner. 1996. Distribution and Mass Loading of Insecticides in the San Joaquin River, California: Winter 1991-92 and 1992-93. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. Report EH 96-02. November, 1996. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Diazinon	Ross, L., J. Stein, J. Hsu, J. White, and K. Hefner. 1999. Distribution and Mass Loading of Insecticides in the San Joaquin River, California: Spring 1991 and 1992. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. Report EH 99-01. April, 1999. As presented in CDPR, 2000a.	1; Disk 1
Oak Run Creek	Fecal Coliform	Fact Sheet	1; cow creek
Oak Run Creek	Fecal Coliform	Hannaford MJ and North State Institute for Sustainable Communities. 2000. Preliminary Water Quality Assessment of 1; cow creek Tributaries. Department of Fish and Game. May 15, 2000. (http://www.delta.dfg.ca.gov/afrp/documents/cowcrk.rpt.pdf).	1; cow creek
Orestimba Creek	Azinphos Methyl	Fact Sheet	2; Pesticides
Orestimba Creek	Azinphos Methyl	CDPR. 2001. Surface Water Database. Access formatted database, using the parameters of Orestimba and azinphos methyl	1; Disk 1
Orestimba Creek	Azinphos Methyl	Fujimura, R. 1991a. *Chemical and Toxicity Test Results from the San Joaquin River at Three Sites from July 2 to September 13, 1991.* Memorandum to Lisa Ross, Department of Pesticide Regulation. Sacramento, CA. November 6, 1991. As presented in CDPR, 2000a.	1; Disk 1
Orestimba Creek	Azinphos Methyl	Fujimura, R. 1991b. *Chemical and Toxicity Test Results from the San Joaquin River and Tributaries During March 4 to April 26, 1991.* Memorandum to Lisa Ross, Department of Pesticide Regulation. Sacramento, CA. November 6, 1991. As presented in CDPR, 2000a.	1; Disk 1
Orestimba Creek	Azinphos Methyl	Fujimura, R. 1993a. *Chemical Analyses and Bioassay Test Results for Samples Collected from December 29 to February 25,, 1993.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 26, 1993. As presented in CDPR, 2000a.	1; Disk 1
Orestimba Creek	Azinphos Methyl	Fujimura, R. 1993b. *Chemical Analyses and Bioassay Test Results for Samples Collected from July 9 to September 9, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 23, 1993. As presented in CDPR, 2000a.	1; Disk 1

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Orestimba Creek	Azinphos Methyl	Fujimura, R. 1993c. *Chemical Analyses and Bioassay Test Results for Samples Collected from March 16 to April 30, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 22, 1993. As presented in CDPR, 2000a.	1; Disk 1
Orestimba Creek	Azinphos Methyl	Fujimura, R. 1993d. *Chemical Analyses and Bioassay Test Results for Samples Collected from December 23, 1991 to February 27, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. February 23, 1993. As presented in CDPR, 2000a.	1; Disk 1
Orestimba Creek	Azinphos Methyl	Panshin, S.Y., N.M. Dubrovsky, J.M. Gronberg, and J.L. Domagalski. 1998. Occurrence and Distribution of Dissolved 2; Pesticides in the San Joaquin River Basin, California. USGS National Water Quality Assessment Program, Water Resources Investigations report No. 98-4032.	1; Disk 1
Orestimba Creek	Azinphos Methyl	Ross, L. 1992. Preliminary Results of the San Joaquin River Study; Summer, 1991. Memorandum to Kean Goh. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. May 21, 1992. As presented in CDPR, 2000a.	1; Disk 1
Orestimba Creek	Azinphos Methyl	Ross, L. 1993. Preliminary Results of the San Joaquin River Study; Summer, 1992. Memorandum to Kean Goh. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. September 22, 1993. As presented in CDPR, 2000a.	1; Disk 1
Orestimba Creek	Azinphos Methyl	Ross, L., J. Stein, J. Hsu, J. White, and K. Hefner. 1996. Distribution and Mass Loading of Insecticides in the San Joaquin River, California: Winter 1991-92 and 1992-93. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. Report EH 96-02. November, 1996. As presented in CDPR, 2000a.	1; Disk 1
Orestimba Creek	Azinphos Methyl	Ross, L., J. Stein, J. Hsu, J. White, and K. Hefner. 1999. Distribution and Mass Loading of Insecticides in the San Joaquin River, California: Spring 1991 and 1992. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. Report EH 99-01. April, 1999. As presented in CDPR, 2000a.	1; Disk 1
Orestimba Creek	DDE	Fact Sheet	2; Pesticides
Orestimba Creek	DDE	CDPR. 2001. Surface Water Database. Access formatted database, using the parameters of Orestimba and DDE	1; Disk 1
Orestimba Creek	DDE	Panshin, S.Y., N.M. Dubrovsky, J.M. Gronberg, and J.L. Domagalski. 1998. Occurrence and Distribution of Dissolved 2; Pesticides in the San Joaquin River Basin, California. USGS National Water Quality Assessment Program, Water Resources Investigations report No. 98-4032.	1; Disk 1
Putah Creek, Lower	Mercury	Fact Sheet	2; Putah Creek
Putah Creek, Lower	Mercury	Slotton, D.G., S.M. Ayers, J.E. Reuter, C.R. Goldman. 1999. *Lower 2; Putah Creek 1997-1998 Mercury Biological Distribution Study. February 1999.* Dept. of Environmental Science and Policy, University of California, Davis. February 1999.	2; Putah Creek
Putah Creek, Lower	Mercury	USDHHS- ATSDR, 1998. *Fish Sampling in 2; Putah Creek (Phase II), Laboratory for Energy Related Health Research, Davis, Yolo County California, Cerclis No. CA2890190000.* Agency for Toxic Substance and Disease Registry. September 1998.	2; Putah Creek

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Putah Creek, Lower	Mercury	USDHHS-ATSDR, 1997. *Fish Sampling in 2; Putah Creek, 1996, Laboratory for Energy Related Health Research, Davis, Yolo County California, Cerclis No. CA2890190000.* Agency for Toxic Substance and Disease Registry (ATSDR). April 1997.	2; Putah Creek
Putah Creek, Lower	Unknown Toxicity	Fact Sheet	2; Putah Creek
Putah Creek, Lower	Unknown Toxicity	Larsen K, M McGraw, V Connor, L Deanovic, T Kimball, and D Hinton. 2000. *Cache Creek and 2; Putah Creek Watersheds Toxicity Monitoring Results: 1998-1999* Final Report. November 2000.	2; Putah Creek
Putah Creek, Upper	Unknown Toxicity	Fact Sheet	2; Putah Creek
Putah Creek, Upper	Unknown Toxicity	Larsen K, M McGraw, V Connor, L Deanovic, T Kimball, and D Hinton. 2000. *Cache Creek and 2; Putah Creek Watersheds Toxicity Monitoring Results: 1998-1999* Final Report. November 2000.	2; Putah Creek
Rollins Reservoir	Mercury	Fact Sheet	2; HU:516 & 517
Rollins Reservoir	Mercury	Alpers, C.N., M.P. Hunerlach. 2000. *Mercury Contamination from Historic Gold Mining in California.* U.S. Geological Survey. Fact Sheet FS-061-00. May 2000.	2; HU:516 & 517
Rollins Reservoir	Mercury	May, J.T., R.L. Hothem, C.N. Alpers, M.A. Law. 2000. *Mercury Bioaccumulation in Fish in a Region Affected by Historic Gold Mining: The South Yuba River, Deer Creek, and Bear River Watersheds, California, 1999.* U.S. Geological Survey. Sacramento, CA. 2000.	2; HU:516 & 517
Rollins Reservoir	Mercury	Montoya, B. and X. Pan. 1992. *Inactive Mine Drainage in the Sacramento Valley, California.* California Regional Water Quality Control Board, Central Valley Region Report. July 1992.	2; HU:516 & 517
Rollins Reservoir	Mercury	Nevada County, Department of Environmental Health. 2000. *Press Release, Three County Environmental Health Agencies Issue Interim Public Health Notification on Mercury in Fish.* (http://www.co.nevada.ca.us/ehealth/hg/press_release_10-03-00.htm)	2; HU:516 & 517
Rollins Reservoir	Mercury	SWRCB-DWQ (State Water Resources Control Board, Division of Water Quality). 1995. *Toxic Substances Monitoring Program: Freshwater Bioaccumulation Monitoring Program: Data Base (Met_Wet).*	1; Disk 1
San Joaquin River	Mercury	Fact Sheet	2; SJR
San Joaquin River	Mercury	Davis, J. A. and M. D. May. 2000. *Contaminant Concentrations in Fish from the Sacramento-San Joaquin Delta and Lower San Joaquin River – 1998.* San Francisco Estuary Institute report. Richmond, California. September 2000.	2; Pesticides
San Joaquin River	Mercury	Slotton, D. G., T.H. Suchanek, and S.M. Ayers. 2000. Delta Wetlands Restoration and the Mercury Question: Year 2 Findings of the CALFED UC Davis Mercury Study. IEP Newsletter. 13(4): 34-44.	2; SJR
San Joaquin River	Mercury	SWRCB (State Water Resources Control Board, Division of Water Quality). 1995. Toxic Substances Monitoring Program: Freshwater Bioaccumulation Monitoring Program: Data Base (Metals_Wet).	1; Disk 1
Scott's Flat Reservoir	Mercury	Fact Sheet	2; HU:516 & 517
Scott's Flat Reservoir	Mercury	Alpers, C.N., M.P. Hunerlach. 2000. *Mercury Contamination from Historic Gold Mining in California.* U.S. Geological Survey. Fact Sheet FS-061-00. May 2000.	2; HU:516 & 517

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Scott's Flat Reservoir	Mercury	Nevada County, Department of Environmental Health. 2000. *Press Release, Three County Environmental Health Agencies Issue Interim Public Health Notification on Mercury in Fish.* (http://www.co.nevada.ca.us/ehealth/hg/press_release_10-03-00.htm)	2; HU:516 & 517
Scott's Flat Reservoir	Mercury	Slotton, D.G., S.M. Ayers, J.E. Reuter, C.R. Goldman. 1996. *Gold Mining Impacts on Food Chain Mercury in Northwestern Sierra Nevada Streams (1996 Revision).* Division of Environmental Studies, University of California, Davis. December 1996.	2; HU:516 & 517
Smith Canal	Dissolved Oxygen	Fact Sheet	2; Low DO
Smith Canal	Dissolved Oxygen	CDM (Camp Dresser & McKee Inc). 1999. Assessment of Water Quality Data from 2; Smith Canal Canal. July 27, 1999. (Appendix B-2 to City of Stockton & San Joaquin County Storm Water Management Program).	2; Low DO
Smith Canal	Dissolved Oxygen	Chen C., and Tsai W. *Application of Stockton's Water Quality Model to Evaluate Stormwater Impact on 2; Smith Canal Cana*l. February 23, 1999. (Attachment to March 17, 1999 letter from City of Stockton, G. Birdzell)	2; Low DO
Smith Canal	Dissolved Oxygen	Lee, G.F. and A. Jones-Lee. 2001b. *Review of the City of Stockton Urban Stormwater Runoff Aquatic Life Toxicity Studies Conducted by the Central Valley Regional Water Quality Control Board, DeltaKeeper, and the University of California, Davis, Aquatic Toxicology Laboratory between 1994 and 1999.* Final Report. November 2001. G. Fred Lee & Associates. El Macero, CA. (Prepared for DeltaKeeper).	2; Smith Canal

Waterbody	**Pollutant**	**Sources**	**Location: Folder #; Tab Title**
Smith Canal	Dissolved Oxygen	Larsen, K., K.A. Cortright., P.Young, V. Connor, L.A.Deanovic, D.E. Hinton. 1998. *Stockton Fish Kills Associated With Urban Storm Runoff: The Role of Low Dissolved Oxygen.* CRWQCB-CVR. June 1998.	2; Low DO
Smith Canal	Dissolved Oxygen	Lee G.F. *2000. Dissolved Oxygen Depletion in the Stockton Sloughs.* August 2000. (Prepared for DeltaKeeper)	2; Low DO
Smith Canal	Organo-phosphorus Pesticides	Fact Sheet	2; Smith Canal
Smith Canal	Organo-phosphorus Pesticides	Larsen K, M McGraw, V Connor, L Deanovic, T Kimball, and D Hinton. 2000. *Cache Creek and 2; Putah Creek Watersheds Toxicity Monitoring Results: 1998-1999* Final Report. November 2000.	2; Putah Creek
Smith Canal	Organo-phosphorus Pesticides	Lee G.F., and A. Jones – Lee. 2001. Review of the City of Stockton Urban Stormwater Runoff Aquatic Life Toxicity Studies Conducted by the CVRWQCB, DeltaKeeper and the University of California, Davis, Aquatic Toxicology Laboratory between 1994 and 1999. April 1, 2001.	2; Smith Canal
Smith Canal	Pathogens	Fact Sheet	1; Bacteria
Smith Canal	Pathogens	Jennings, B. 2001. Letter from Bill Jennings (DeltaKeeper A Project of San Francisco BayKeeper) to Mr. Jerry Bruns and Mr. Joe Karkoski (California Regional Water Quality Control Board, Central Valley Region) dated May 14, 2001, regarding DeltaKeeper comments on section 303(d) list update.	1; Bacteria
South cow creek	Fecal Coliform	Fact Sheet	1; cow creek
South cow creek	Fecal Coliform	Hannaford MJ and North State Institute for Sustainable Communities. 2000. Preliminary Water Quality Assessment of 1; cow creek Tributaries. Department of Fish and Game. May 15, 2000. (http://www.delta.dfg.ca.gov/afrp/documents/cowcrk.rpt.pdf).	1; cow creek
Stanislaus River, Lower	Mercury	Fact Sheet	2; SJR
Stanislaus River, Lower	Mercury	USBR (U.S. Bureau of Reclamation). 2001. *U.S. Bureau of Reclamation DataWeb: Power Plants, Dams & Reservoirs.* Accessed on August 22, 2001 (http://dataweb.usbr.gov/).	NA
Stanislaus River, Lower	Mercury	SWRCB (State Water Resources Control Board). 1995. *Toxic Substances Monitoring Program: Freshwater Bioaccumulation Monitoring Program: Data Base.* As presented in TSMP database (Metals_Wet).	1; Disk 1
Stanislaus River, Lower	Mercury	Davis, J.A., M.D. May, G. Ichikawa, and D. Crane. 2000. *Contaminant Concentrations in Fish from the Sacramento-San Joaquin Delta and Lower San Joaquin River – 1998.* San Francisco Estuary Institute report. Richmond, California. September 2000.	2; Pesticides
Stanislaus River, Lower	Mercury	OMR (Office of Mine Reclamation). 2000. *California's Abandoned Mines – A Report on the Magnitude and Scope of the Issue in the State.* California Department of Conservation, Office of Mine Reclamation, Abandoned Mine Lands Unit (OMR). Sacramento, CA. June 2000.	1; Don Pedro Lake
Stockton Deep Water Channel	Pathogens	Fact Sheet	1; Bacteria
Stockton Deep Water Channel	Pathogens	Jennings, B. 2001. Letter from Bill Jennings (DeltaKeeper A Project of San Francisco BayKeeper) to Mr. Jerry Bruns and Mr. Joe Karkoski (California Regional Water Quality Control Board, Central Valley Region) dated May 14, 2001, regarding DeltaKeeper comments on section 303(d) list update.	1; Bacteria

Waterbody	**Pollutant**	**Sources**	**Location: Folder #; Tab Title**
Sutter Bypass	Diazinon	Fact Sheet	2; Pesticides
Sutter Bypass	Diazinon	CDPR. 2001. Surface Water Database. Access formatted database, using the parameters of Sutter Bypass and Diazinon	1; Disk 1
Sutter Bypass	Diazinon	Nordmark, C. In prep. *Preliminary Results of Acute and Chronic Toxicity Testing of Surface Water Monitored in the Sacramento River Watershed, Winter 1999-00.* Memorandum to Don Weaver, Environmental Monitoring and Pest Management, Department of Pesticide Regulation. Sacramento, CA. As presented in CDPR, 2000a.	1; Disk 1
Sutter Bypass	Diazinon	Nordmark, C. 1998. *Preliminary Results of Acute and Chronic Toxicity Testing of Surface Water Monitored in the Sacramento River Watershed, Winter 1998-99.* Memorandum to Don Weaver, Environmental Monitoring and Pest Management, Department of Pesticide Regulation. Sacramento, CA. July 31, 1998 As presented in CDPR, 2000a.	1; Disk 1
Sutter Bypass	Diazinon	Nordmark, C. 1999. *Preliminary Results of Acute and Chronic Toxicity Testing of Surface Water Monitored in the Sacramento River Watershed, Winter 1998-99.* Memorandum to Don Weaver, Environmental Monitoring and Pest Management, Department of Pesticide Regulation, Sacramento, CA. May 26, 1999. As presented in CDPR, 2000a.	1; Disk 1
Sutter Bypass	Diazinon	Nordmark, C.E., K.P. Bennett, H. Feng, J. Hernandez, and P. Lee. 1998. Occurrence of aquatic toxicity and dormant spray pesticide detections in the Sacramento River watershed. Winter 1996-97. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. Department of Pesticide Regulation. Sacramento, CA. Report EH98-01. February, 1998. As presented in CDPR, 2000a.	1; Disk 1
Walker Slough	Pathogens	Fact Sheet	1; Bacteria
Walker Slough	Pathogens	Jennings, B. 2001. Letter from Bill Jennings (DeltaKeeper A Project of San Francisco BayKeeper) to Mr. Jerry Bruns and Mr. Joe Karkoski (California Regional Water Quality Control Board, Central Valley Region) dated May 14, 2001, regarding DeltaKeeper comments on section 303(d) list update.	1; Bacteria
Wolf Creek	Fecal Coliform	Fact Sheet	1; Bacteria
Wolf Creek	Fecal Coliform	City of Grass Valley. 2000. *Discharger self-monitoring reports (DSMRs) for Grass Valley Waste Water Treatment Plant.*	NA
Wolf Creek	Fecal Coliform	City of Grass Valley. 2001. *Discharger self-monitoring reports (DSMRs) for Grass Valley Waste Water Treatment Plant.*	NA
Wolf Creek	Fecal Coliform	Jennings, B. 2001. Letter from Bill Jennings (DeltaKeeper A Project of San Francisco BayKeeper) to Mr. Jerry Bruns and Mr. Joe Karkoski (California Regional Water Quality Control Board, Central Valley Region) dated May 14, 2001, regarding DeltaKeeper comments on section 303(d) list update.	1; Bacteria

Documents Supporting Changing to Information Presented on the 1998 303(d) List

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Cache Creek	UTX, Hg	Fact Sheet	3 ; Change: Mines
Cache Creek	UTX, Hg	Buer, S.M., S.R. Phillippe, and T.R. Pinkos. 1979. Inventory and Assessment of Water Quality Problems Related to Abandoned and Inactive Mines in the Central Valley Region of California. California Regional Water Quality Control Board, Central Valley Region Draft Report, 1979.	3; Change: Mines
Cache Creek	UTX, Hg	Foe, C. and W. Croyle. 1998. Mercury Concentrations and Loads from the Sacramento River and from Cache Creek to the Sacramento-San Joaquin Delta Estuary. California Regional Water Quality Control Board, Central Valley Region. June 1998.	1; Bear Crk
Cache Creek	UTX, Hg	Montoya, B. and X. Pan. 1992. Inactive Mine Drainage in the Sacramento Valley, California. California Regional Water Quality Control Board, Central Valley Region Report. July 1992.	2; HU: 516 & 517
Camanche Reservoir	Copper	Fact Sheet	1 ; Camanche Res
Camanche Reservoir	Copper	Buer, S.M., S.R. Phillippe, and T.R. Pinkos. 1979. *Inventory and Assessment of Water Quality Problems related to Abandoned and Inactive Mines in the Central Valley Region of California.* CRWQCB-CVR (California Regional Water Quality Control Board, Central Valley Region), Report.	1; Camanche Res
Camanche Reservoir	Copper	CDFG (California Department of Fish and Game). 1991. *Lower Mokelumne River Fisheries Plan.* The Resources Agency, Department of Fish and Game, Stream flow Requirements Program. November 1991.	1; Camanche Res
Camanche Reservoir	Copper	CH2MHILL. 2000a. *Closure Report: Penn Mine Environmental Restoration Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. Oakland, California. December 2000.	1; Camanche Res
Camanche Reservoir	Copper	CH2MHILL. 2000b. *(Draft) Post-Restoration Final Effectiveness Report: Penn Mine Environmental Restoration Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. Oakland, California. September 2000.	1; Camanche Res
Camanche Reservoir	Copper	EBMUD (East Bay Municipal Utility District). 2001. Unpublished dissolved copper concentration data for the lower Mokelumne River downstream of Camanche Dam, generated as part of EBMUD's NPDES requirements. Provided electronically by Alexander R. Coate (Manger of Regulatory Compliance, EBMUD) to Michelle L. Wood (Environmental Specialist, Central Valley Regional Water Quality Control Board) on August 2, 2001.	1; Camanche Res
Camanche Reservoir	Copper	EDAW, Inc. 1992. *Draft EIS/EIR for the Updated Water Supply Management Program, Volume III, Technical Appendices B1 and B2.* Prepared for: East Bay Municipal Utility District. Oakland, California. December 1992.	1; Camanche Res
Camanche Reservoir	Copper	Montoya, B., and X. Pan. 1992. *Inactive Mine Drainage in the Sacramento Valley, California.* California Regional Water Quality Control Board, Central Valley Region Report. July 1992.	2; HU: 516 & 517
Camanche Reservoir	Copper	SCH EIR. 1996. *Draft EIR for The Penn Mine Site, Long-Term Solution Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. SCH EIR No. 95103036.	1; Camanche Res

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Camanche Reservoir	Zinc	Fact Sheet	1; Camanche Res
Camanche Reservoir	Zinc	Buer, S.M., S.R. Phillippe, and T.R. Pinkos. 1979. *Inventory and Assessment of Water Quality Problems related to Abandoned and Inactive Mines in the Central Valley Region of California*. CRWQCB-CVR (California Regional Water Quality Control Board, Central Valley Region), Report.	1; Camanche Res
Camanche Reservoir	Zinc	CDFG (California Department of Fish and Game). 1991. *Lower Mokelumne River Fisheries Plan.* The Resources Agency, Department of Fish and Game, Stream flow Requirements Program. November 1991.	1; Camanche Res
Camanche Reservoir	Zinc	CH2MHILL. 2000a. *Closure Report: Penn Mine Environmental Restoration Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. Oakland, California. December 2000.	1; Camanche Res
Camanche Reservoir	Zinc	CH2MHILL. 2000b. *(Draft) Post-Restoration Final Effectiveness Report: Penn Mine Environmental Restoration Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. Oakland, California. September 2000.	1; Camanche Res
Camanche Reservoir	Zinc	EBMUD (East Bay Municipal Utility District). 2001. Unpublished dissolved copper concentration data for the lower Mokelumne River downstream of Camanche Dam, generated as part of EBMUD's NPDES requirements. Provided electronically by Alexander R. Coate (Manger of Regulatory Compliance, EBMUD) to Michelle L. Wood (Environmental Specialist, Central Valley Regional Water Quality Control Board) on August 2, 2001.	1; Camanche Res
Camanche Reservoir	Zinc	EDAW, Inc. 1992. *Draft EIS/EIR for the Updated Water Supply Management Program, Volume III, Technical Appendices B1 and B2.* Prepared for: East Bay Municipal Utility District. Oakland, California. December 1992.	1; Camanche Res
Camanche Reservoir	Zinc	Montoya, B., and X. Pan. 1992. *Inactive Mine Drainage in the Sacramento Valley, California.* California Regional Water Quality Control Board, Central Valley Region Report. July 1992.	1; Camanche Res
Camanche Reservoir	Zinc	SCH EIR. 1996. *Draft EIR for The Penn Mine Site, Long-Term Solution Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. SCH EIR No. 95103036.	1; Camanche Res
Delta	2; Low DO	Fact Sheet	3; Change: General
Delta	All (except 2; Low DO)	Fact Sheet	3; Change: General
Delta	All	NA (extent of impairment corrected)	NA
Dunn Creek	Hg, Metals	Fact Sheet	3; Change: Mt Diablo
Dunn Creek	Hg, Metals	Buer, S.M., S.R. Phillippe, and T.R. Pinkos. 1979. Inventory and Assessment of Water Quality Problems Related to Abandoned and Inactive Mines in the Central Valley Region of California. CRWQCB-CVR.	3; Change: Mines
Dunn Creek	Hg, Metals	Iovenitti, J.L., Weiss Associates, and J. Wessman. 1989. Mount Diablo Mine: Surface Impoundment Technical Report. Pleasant Hill, Ca.	3; Change:Mt Diablo
Dunn Creek	Hg, Metals	Slotton DG, SM Ayers, and JE Reuter. 1996. Marsh Creek Watershed: 1995 Mercury Assessment Project. March 1996.	3; Change:Mt Diablo
Fall Creek	Sedimentation/Siltation	Fact Sheet	3; Change: Fall Crk

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Fall Creek	Sedimentation/Siltation	CRWQCB-CVR (California Regional Water Quality Control Board, Central Valley Region). 1982. Fall River Water Quality Monitoring Survey. July 1982.	3; Change: Fall Crk
Fall Creek	Sedimentation/Siltation	CDWR (Department of Water Resources). 1998. Aquatic Monitoring and Assessment for the Upper Fall River, Memorandum Report. May 1998.	3; Change: Fall Crk
Fall Creek	Sedimentation/Siltation	North State Resources and T Holmes (prepared for the Fall River Resource Conservation District). A study of the Habitat Characteristics of the Aquatic Vegetation of the Upper Fall River: Final Report. Redding, Ca. December 8, 1997.	3; Change: Fall Crk
Fall Creek	Sedimentation/Siltation	Tetra Tech, Inc (for the Fall River Resource Conservation District). 1998. Analysis of Sedimentation and Action Plan Development for the Upper Fall River, Shasta County, California. San Francisco, Ca. May 20, 1998.	3; Change: Fall Crk
Fall Creek	Sedimentation/Siltation	USDA (United States Department of Agriculture), River Basin Planning Staff, in cooperation with Fall River Resource Conservation District. 1983. Fall River Watershed Area Study, Summary Report. Davis, Ca. June 1983.	3; Change: Fall Crk
French Ravine	Bacteria	Fact Sheet	3; Change: General
French Ravine	Bacteria	Horizons Technology, Inc., 1997. Sure! MAPS® RASTER Map Sets (U.S. Geological Survey 7.5' Topographic Quadrangles), Version 2.1.2.	NA
Horse Creek	Metals	Fact Sheet	3; Change: Mines
Horse Creek	Metals	Montoya, B., and X. Pan. 1992. *Inactive Mine Drainage in the Sacramento Valley, California.* California Regional Water Quality Control Board, Central Valley Region Report. July 1992.	2; HU: 516 & 517
Humbug Creek	Sedimentation/Siltation, Metals, Hg	Fact Sheet	3; Change: Mines
Humbug Creek	Sedimentation/Siltation, Metals, Hg	Montoya, B., and X. Pan. 1992. *Inactive Mine Drainage in the Sacramento Valley, California.* California Regional Water Quality Control Board, Central Valley Region Report. July 1992.	2; HU: 516 & 517
James Creek	Hg, Ni	Fact Sheet	3; Change: Mines
James Creek	Hg, Ni	Buer, S.M., S.R. Phillippe, and T.R. Pinkos. 1979. *Inventory and Assessment of Water Quality Problems Related to Abandoned and Inactive Mines in the Central Valley Region of California.* California Regional Water Quality Control Board, Central Valley Region Draft Report. 1979.	3; Change: Mines
James Creek	Hg, Ni	Montoya, B. and Pan, X., 1992. *Inactive Mine Drainage in the Sacramento Valley, California.* California Regional Water Quality Control Board, Central Valley Region Report. July 1992.	2; HU: 516 & 517
Marsh Creek	Metals	Fact Sheet	3; Change: Mt Diablo
Marsh Creek	Hg	Fact Sheet	3; Change: Mt Diablo

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Marsh Creek	Metals, Hg	Buer, S.M., S.R. Phillippe, and T.R. Pinkos. 1979. Inventory and Assessment of Water Quality Problems Related to Abandoned and Inactive Mines in the Central Valley Region of California. CRWQCB-CVR.	3; Change : Mines
Marsh Creek	Metals, Hg	CRWQCB-CVR. 1978. *Waste Discharge Requirements for Mount Diablo Quicksilver Mine, Contra Costa County.* Sacramento, Ca: CRWQCB.	3; Change: Mt Diablo
Marsh Creek	Metals, Hg	Iovenitti, J.L., Weiss Associates, and J. Wessman. 1989. Mount Diablo Mine: Surface Impoundment Technical Report. Pleasant Hill, Ca.	3; Change: Mt Diablo
Marsh Creek	Metals, Hg	Slotton DG, SM Ayers, and JE Reuter. 1996. Marsh Creek Watershed: 1995 Mercury Assessment Project. March 1996.	3; Change: Mt Diablo
Mokulmne River, Lower	Copper	Fact Sheet	1 ; Camanche Res
Mokulmne River, Lower	Copper	Buer, S.M., S.R. Phillippe, and T.R. Pinkos. 1979. *Inventory and Assessment of Water Quality Problems related to Abandoned and Inactive Mines in the Central Valley Region of California.* CRWQCB-CVR (California Regional Water Quality Control Board, Central Valley Region), Report.	1; Camanche Res
Mokulmne River	Copper	CDFG (California Department of Fish and Game). 1991. *Lower Mokelumne River Fisheries Plan.* The Resources Agency, Department of Fish and Game, Stream flow Requirements Program. November 1991.	1; Camanche Res
Mokulmne River	Copper	CH2MHILL. 2000a. *Closure Report: Penn Mine Environmental Restoration Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. Oakland, California. December 2000.	1; Camanche Res
Mokulmne River	Copper	CH2MHILL. 2000b. *(Draft) Post-Restoration Final Effectiveness Report: Penn Mine Environmental Restoration Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. Oakland, California. September 2000.	1; Camanche Res
Mokulmne River	Copper	EBMUD (East Bay Municipal Utility District). 2001. Unpublished dissolved copper concentration data for the lower Mokelumne River downstream of Camanche Dam, generated as part of EBMUD's NPDES requirements. Provided electronically by Alexander R. Coate (Manger of Regulatory Compliance, EBMUD) to Michelle L. Wood (Environmental Specialist, Central Valley Regional Water Quality Control Board) on August 2, 2001.	1; Camanche Res
Mokulmne River	Copper	EDAW, Inc. 1992. *Draft EIS/EIR for the Updated Water Supply Management Program, Volume III, Technical Appendices B1 and B2.* Prepared for: East Bay Municipal Utility District. Oakland, California. December 1992.	1; Camanche Res
Mokulmne River	Copper	Montoya, B., and X. Pan. 1992. *Inactive Mine Drainage in the Sacramento Valley, California.* California Regional Water Quality Control Board, Central Valley Region Report. July 1992.	2; HU: 516 & 517
Mokulmne River	Copper	SCH EIR. 1996. *Draft EIR for The Penn Mine Site, Long-Term Solution Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. SCH EIR No. 95103036.	1; Camanche Res
Mokulmne River	Zinc	Fact Sheet	1; Camanche Res
Mokulmne River	Zinc	Buer, S.M., S.R. Phillippe, and T.R. Pinkos. 1979. *Inventory and Assessment of Water Quality Problems related to Abandoned and Inactive Mines in the Central Valley Region of California.* CRWQCB-CVR (California Regional Water Quality Control Board, Central Valley Region), Report.	1; Camanche Res

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Stanislaus River	Diazinon, GAP, UTX	USBR (U.S. Bureau of Reclamation). 2001. *U.S. Bureau of Reclamation DataWeb: Power Plants, Dams & Reservoirs.* Accessed on August 22, 2001 (http://dataweb.usbr.gov/).	NA
Stanislaus River	Diazinon, GAP, UTX	USGS (United States Geological Survey). 1987, 1991. *Knights Ferry* (1987) and *Ripon* (1991). California 7.5' Topographic Quadrangles, as presented by TopoZone.com (© 2000 Maps a la carte, Inc.). Accessed on August 22, 2001 (http://www.topozone.com/default.asp).	NA
Tuolumne River	Diazinon	Fact Sheet	3; Change: General
Tuolumne River	GAP, UTX	Fact Sheet	3; Change: General
Tuolumne River	Diazinon, GAP, UTX	USGS (United States Geological Survey). 1987, 1991, 1969. La Grange (1987), Westley (1991), and Brush Lake (1969). California 7.5' Topographic Quadrangles, as presented by TopoZone.com (© 2000 Maps a la carte, Inc.). Accessed on August 23, 2001 (http://www.topozone.com/default.asp).	NA

Documents Supporting Delisting a Waterbody-Pollutant from the 2002 303(d) List

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
American River, Lower	Group A 2; Pesticides	Fact Sheet	3; Removals
American River, Lower	Group A 2; Pesticides	Davis, J.A., M.D. May, G. Ichikawa, and D. Crane. 2000. Contaminant Concentrations in Fish from the Sacramento-San Joaquin Delta and Lower San Joaquin River, 1998. San Francisco Estuary Institute, Richmond, CA. September 1998	2; Pesticides
American River, Lower	Group A 2; Pesticides	Larry Walker Associates. 2001b. *Sacramento River Watershed Program Annual Monitoring Report: 1999-2000.* Prepared for the Sacramento River Watershed Program by Larry Walker Associates, Davis, California.	3; Removals
American River, Lower	Group A 2; Pesticides	SWRCB-DWQ (State Water Resources Control Board, Division of Water Quality). 1995. *Toxic Substances Monitoring Program: Freshwater Bioaccumulation Monitoring Program: Data Base (Org_Wet).*	1; Disk 1
Grasslands Marshes	Selenium	Grober, L.F. 1999. *Selenium Total Maximum Daily Load for the Grassland Marshes.* California Regional Water Quality Control Board, Central Valley Region.	NA
Salt Slough	Selenium	Grober, L. 2000. *Selenium Total Maximum Daily Load for Salt Slough.* California Regional Water Quality Control Board, Central Valley Region.	NA

B.1.6 Upper Bear River, Mercury

Summary of Proposed Action

The California Regional Water Quality Control Board, Central Valley Region (Regional Board) recommends the addition of the upper Bear River to California's Clean Water Act Section 303(d) list due to impairment by mercury. Information available to the Regional Board on mercury levels in fish tissue samples indicates that water quality objectives are not being attained in the upper Bear River between Rollins Reservoir and Lake Combie. The description for the basis for this determination is given below.

Table B-1. 303(d) Listing/TMDL Information

Waterbody Name	Upper Bear River	**Pollutants/Stressors**	Mercury
Hydrologic Unit	516.33	**Sources**	Resource Extraction (abandoned mines)
Total Length	70 miles	**TMDL Priority**	
Size Affected	8 miles	**TMDL Start Date (Mo/Yr)**	
Extent of Impairment	Rollins Reservoir to Lake Combie	**TMDL End Date (Mo/Yr)**	
Upstream Extent Latitude	39° 08' 02"	**Upstream Extent Longitude**	120° 57' 14"
Downstream Extent Latitude	39° 01' 52"	**Downstream Extent Longitude**	121° 01' 48"

Watershed Characteristics

The Bear River basin comprises 232,800 watershed acres. The river extends approximately 70 miles from its headwaters near Emigrant Gap in the Sierra Nevada Mountains to its confluence with the Feather River north of the town of Nicholaus. From upstream to downstream, the Bear River is intersected by three reservoirs: Rollins Reservoir, Lake Combie, and Camp Far West Reservoir. Water uses include hydroelectric generation, recreational, agricultural, and municipal uses, among others. The Bear River basin is bound by the Yuba River basin on the north, the Little Truckee River basin on the east, and the American River basin on the south. The headwaters are located in the Sierra Nevada snowfields at elevations ranging up to 9,100 feet above sea level. The impaired section of the upper Bear River extends approximately eight miles, from Rollins Reservoir to Lake Combie.

Water Quality Objectives Not Attained

The narrative objective for toxicity is not being attained for mercury in the upper Bear River between Rollins Reservoir and Lake Combie. The narrative toxicity objective in the Basin Plan states, in part, "All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life." The narrative toxicity objective further states that "The Regional Water Board will also consider ... numerical criteria and guidelines for toxic substances developed by the State Water Board, the California Office of Environmental Health Hazard Assessment, the California Department of Health Services (OEHHA), the U.S. Food and Drug Administration, the National Academy of Sciences, the U.S. Environmental Protection Agency, and other appropriate organizations to evaluate compliance with this objective" (CRWQCB-CVR, 1998; http://www.swrcb.ca.gov/~rwqcb5/bsnplnab.pdf).

Numeric criteria for mercury in fish tissue have been developed for both human health and wildlife protection. The U.S. Environmental Protection Agency (USEPA) recently established a human health protection criterion of 0.3 milligrams per kilogram (mg/kg; equivalent to parts per million [ppm]) methylmercury in the edible portions of fish (USEPA, 2001b). This criterion is used to determine attainment with the narrative toxicity objective.

Evidence of Impairment

The U.S. Geological Survey (USGS) collected fish tissue samples on September 23, 1999 from the upper Bear River at Dog Bar Road (May *et al*, 2000). Only trophic level 3 fish were collected by the study. Trophic level 3 fish feed on zooplankton, phytoplankton, and benthic invertebrates. Trophic level 4 fish consume trophic level 3 fish as part of their diet. Methylmercury and total mercury bioaccumulates in aquatic organisms and tends to increase with increasing trophic levels (USEPA, 1997a). The USGS sampled three trophic level 3 fish (two brown trout and one rainbow trout). The TL3 fish had a range of mercury concentrations from 0.38 to 0.43 ppm, and an average mercury concentration of 0.40 ppm, which exceeds the USEPA criterion of 0.3 ppm. Placer, Yuba, and Nevada counties have issued an interim public health notification for all lakes and watercourses within these counties based on the USGS data. OEHHA is in the process of developing a state advisory (Nevada County, 2000).

Extent of Impairment
The upper Bear River flows for eight miles between Rollins Reservoir and Lake Combie. The entire eight-mile section is impaired by mercury.

Potential Sources
The upper Bear River watershed was historically mined extensively for its hardrock and placer gold deposits and has been affected by hydraulic mining (Alpers and Hunerlach, 2000). Several inactive gold mines exist upstream of Rollins Reservoir in the upper Bear River watershed (Montoya and Pan, 1992).

B.1.13 Camp Far West Reservoir, Mercury

Summary of Proposed Action

The California Regional Water Quality Control Board, Central Valley Region (Regional Board) recommends the addition of Camp Far West Reservoir to California's Clean Water Act Section 303(d) list due to impairment by mercury. Information available to the Regional Board on mercury levels in fish tissue samples indicates that water quality objectives are not being attained in Camp Far West Reservoir. The description for the basis for this determination is given below.

Table B-1. 303(d) Listing/TMDL Information

Waterbody Name	Camp Far West Reservoir	**Pollutants/Stressors**	Mercury
Hydrologic Unit	516.31	**Sources**	Resource extraction (historic mines)
Total Length	2,002 surface acres	**TMDL Priority**	
Size Affected	2,002 surface acres	**TMDL Start Date (Mo/Yr)**	
Extent of Impairment	All of Camp Far West Reservoir	**TMDL End Date (Mo/Yr)**	

Watershed Characteristics

The Bear River flows into Rollins Reservoir and Lake Combie before reaching Camp Far West Reservoir. The South Sutter Water District constructed Camp Far West Reservoir as a partial surface water supply in response to declining ground water resources. The Bear River basin has covers over 232,800 acres. Water usage in the basin includes recreational, agricultural, municipal, and hydroelectric generation. The Bear River basin is bounded by the Yuba River basin on the north, the Little Truckee River basin on the east, and the American River basin on the south. The headwaters are located in the Sierra Nevada snowfields at elevations ranging up to 9,100 feet above sea level.

Water Quality Objectives Not Attained

The narrative objective for toxicity is not being attained for mercury in Camp Far West Reservoir. The narrative toxicity objective in the Basin Plan states, in part, "All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life." The narrative toxicity objective further states that "The Regional Water Board will also consider ... numerical criteria and guidelines for toxic substances developed by the State Water Board, the California Office of Environmental Health Hazard Assessment, the California Department of Health Services, the U.S. Food and Drug Administration, the National Academy of Sciences, the U.S. Environmental Protection Agency, and other appropriate organizations to evaluate compliance with this objective" (CRWQCB-CVR, 1998; http://www.swrcb.ca.gov/~rwqcb5/bsnplnab.pdf).

Numeric criteria for mercury in fish tissue have been developed for both human health and wildlife protection. The U.S. Environmental Protection Agency (USEPA) recently established a human health protection criterion of 0.3 milligrams per kilogram (mg/kg; equivalent to parts per million [ppm]) methylmercury in the edible portions of fish (USEPA, 2001b). This criterion is used to determine attainment with the narrative toxicity objective.

Evidence of Impairment

The U.S. Geological Survey (USGS) and Toxic Substances Monitoring Program (TSMP) collected fish tissue samples from the midsection, the dam area, and the Bear River and Rock Creek Arms of Camp Far West Reservoir. Both studies collected trophic level 3 and 4 fish. Trophic level 3 fish feed on zooplankton, phytoplankton, and benthic invertebrates. Trophic level 4 fish consume trophic level 3 fish as part of their diet. Methylmercury and total mercury bioaccumulate in aquatic organisms and tend to increase with increasing trophic levels (USEPA, 1997a). The TSMP and USGS sampled 36 trophic level (TL) 4 fish (largemouth bass, smallmouth bass, spotted bass, and channel catfish) between 1987 and 1999. The TL4 fish had an average mercury concentration of 0.69 ppm, which exceeds the USEPA criterion of 0.3 ppm. Placer, Yuba, and Nevada counties have issued an interim public health notification for all lakes and watercourses within these counties based on the USGS data. OEHHA is in the process of developing a state advisory (Nevada County, 2000).

Extent of Impairment
Camp Far West Reservoir covers 2,002 surface acres. Fish collected throughout the reservoir had mercury levels exceeding the USEPA criterion. The entire waterbody is impaired by mercury.

Potential Sources
The Bear River watershed was historically mined extensively for its hardrock and placer gold deposits and has been affected by hydraulic mining (Alpers and Hunerlach, 2000). Several inactive gold and copper mines exist upstream of Camp Far West Reservoir in the Bear River watershed. The Dairy Farm Mine is located along the reservoir's southern shoreline. It is an inactive copper, gold, and silver mine that used underground and open pit mining methods. An open adit has been observed when reservoir levels are low (Montoya and Pan, 1992). Despite being associated with acid mine drainage, Dairy Farm Mine does not discharge perennially.

B.1.26 Lake Combie, Mercury

Summary of Proposed Action

The California Regional Water Quality Control Board, Central Valley Region (Regional Board) recommends the addition of Lake Combie to California's Clean Water Act Section 303(d) list due to impairment by mercury. Information available to the Regional Board on mercury levels in fish tissue samples indicates that water quality objectives are not being attained in Lake Combie. The description for the basis for this determination is given below.

Table B-1. 303(d) Listing/TMDL Information

Waterbody Name	Lake Combie	**Pollutants/Stressors**	Mercury
Hydrologic Unit	516.33	**Sources**	Resource Extraction (abandoned mines)
Total Length	360 acres	**TMDL Priority**	
Size Affected	360 acres	**TMDL Start Date (Mo/Yr)**	
Extent of Impairment	All of Lake Combie	**TMDL End Date (Mo/Yr)**	

Watershed Characteristics

The Bear River basin comprises over 232,800 acres. Water uses include hydroelectric generation, recreational, agricultural, and municipal uses, among others. The basin is bound by the Yuba River on the north, the Little Truckee River basin on the east, and the American River basin on the south. The headwaters are located in the Sierra Nevada snowfields at elevations ranging up to 9,100 feet above sea level. The Bear River flows into Rollins Reservoir before reaching Lake Combie.

Water Quality Objectives Not Attained

The narrative objective for toxicity is not being attained for mercury in Lake Combie. The narrative toxicity objective in the Basin Plan states, in part, "All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life." The narrative toxicity objective further states that "The Regional Water Board will also consider … numerical criteria and guidelines for toxic substances developed by the State Water Board, the California Office of Environmental Health Hazard Assessment, the California Department of Health Services, the U.S. Food and Drug Administration, the National Academy of Sciences, the U.S. Environmental Protection Agency, and other appropriate organizations to evaluate compliance with this objective." (CRWQCB-CVR, 1998; http://www.swrcb.ca.gov/~rwqcb5/bsnplnab.pdf).

Numeric criteria for mercury in fish tissue have been developed for both human health and wildlife protection. The U.S. Environmental Protection Agency (USEPA) recently established a human health protection criterion of 0.3 milligrams per kilogram (mg/kg; equivalent to parts per million [ppm]) methylmercury in the edible portions of fish (USEPA, 2001b). This criterion is used to determine attainment with of the narrative toxicity objective.

Evidence of Impairment

The U.S. Geological Survey (USGS) collected trophic level 3 and 4 fish tissue samples from Lake Combie. Trophic level 3 fish feed on zooplankton, phytoplankton, and benthic invertebrates. Trophic level 4 fish consume trophic level 3 fish as part of their diet. Methylmercury and total mercury bioaccumulates in aquatic organisms and tends to increase with increasing trophic levels (USEPA, 1997a). The USGS sampled nine trophic level 4 fish (largemouth bass) in 1999. The trophic level 4 fish had an average mercury concentration of 0.91 ppm, which exceeds the USEPA criterion of 0.3 ppm. Placer, Yuba, and Nevada counties have issued an interim public health notification for all lakes and watercourses within these counties based on the USGS data. OEHHA is in the process of developing a state advisory (Nevada County, 2000).

Extent of Impairment

Lake Combie covers 360 surface acres. The entire waterbody is impaired by mercury.

Potential Sources

The Bear River watershed was historically mined extensively for its hardrock and placer gold deposits and has been affected by hydraulic mining (Alpers and Hunerlach, 2000). Several inactive gold mines exist upstream of Lake Combie in the Bear River watershed (Montoya and Pan, 1992).

B.1.27 Lake Englebright, Mercury

Summary of Proposed Action

The California Regional Water Quality Control Board, Central Valley Region (Regional Board) recommends the addition of Lake Englebright to California's Clean Water Act Section 303(d) list due to impairment by mercury. Information available to the Regional Board on mercury levels in fish tissue samples indicates that water quality objectives are not being attained in Lake Englebright. The description for the basis for this determination is given below.

Table B-1. 303(d) Listing/TMDL Information

Waterbody Name	Lake Englebright	**Pollutants/Stressors**	Mercury
Hydrologic Unit	517.14	**Sources**	Resource extraction (abandoned mines)
Total Length	815 acres	**TMDL Priority**	
Size Affected	815 acres	**TMDL Start Date (Mo/Yr)**	
Extent of Impairment	All of Lake Englebright	**TMDL End Date (Mo/Yr)**	

Watershed Characteristics

Lake Englebright is located in the Yuba River watershed in the Sierra Nevada foothills, approximately 21 miles east of Marysville. Water usage includes recreational, agricultural, hydroelectric generation, and municipal uses, among others. The basin is bound by the Feather River basin on the north, by the Little Truckee River basin on the east, and by the Bear River and American River basins on the south. The headwaters are in the Sierra Nevada snowfields at elevations ranging up to 9,100 feet above sea level. The North Fork of the Yuba River flows into Bullard's Bar Reservoir. Water is released at the Bullard's Bar Dam and goes downstream to join flows from the Middle and South Forks of the Yuba River, which flow into Lake Englebright. From the Englebright Dam some water is diverted to a North and South Irrigation ditch but the majority of discharge continues downstream through Marysville and flows into the Feather River. Englebright Dam was constructed primarily to prevent upstream hydraulic mining debris from moving downstream into the Yuba River floodplain.

Water Quality Objectives Not Attained

The narrative objective for toxicity is not being attained for mercury in Lake Englebright. The narrative toxicity objective in the Basin Plan states, in part, "All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life." The narrative toxicity objective further states that "The Regional Water Board will also consider … numerical criteria and guidelines for toxic substances developed by the State Water Board, the California Office of Environmental Health Hazard Assessment, the California Department of Health Services, the U.S. Food and Drug Administration, the National Academy of Sciences, the U.S. Environmental Protection Agency, and other appropriate organizations to evaluate compliance with this objective." (CRWQCB-CVR, 1998; http://www.swrcb.ca.gov/~rwqcb5/bsnplnab.pdf).

Numeric criteria for mercury in fish tissue have been developed for both human health and wildlife protection. The U.S. Environmental Protection Agency (USEPA) recently established a human health protection criterion of 0.3 milligrams per kilogram (mg/kg; equivalent to parts per million [ppm]) methylmercury in the edible portions of fish (USEPA, 2001b). This criterion is used to determine attainment with the narrative toxicity objective.

Evidence of Impairment

The U.S. Geological Survey (USGS) and University of California, Davis Division of Environmental Studies (UCD) collected fish tissue samples from the midsection, the South Yuba River Arm, and Hogsback Ravine Arm of Lake Englebright (May *et al*, 2000; Slotton *et al*, 1996b). Both studies collected trophic level 3 and 4 fish. Trophic level 3 fish feed on zooplankton, phytoplankton, and benthic invertebrates Trophic level 4 fish consume trophic level 3 fish as part of their diet. Methylmercury and total mercury bioaccumulates in aquatic organisms and tends to increase with increasing trophic levels (USEPA, 1997a). The USGS and UCD sampled 21 trophic level 4 fish (largemouth bass, smallmouth bass, and spotted bass) and 9 trophic level 3 fish (carp, green sunfish, hardhead, and Sacramento sucker) between 1996 and 1999. The TL4 fish and TL3 fish had average mercury concentrations of 0.55 ppm and 0.51 ppm, respectively, which exceed the USEPA criterion of 0.3 ppm. Placer, Yuba, and Nevada counties have issued an interim public health notification for all lakes and watercourses within these counties based on the USGS data. OEHHA is in the process of developing a state advisory (Nevada County, 2000).

Extent of Impairment
Lake Englebright is about 227 feet deep at the dam and covers 815 surface acres. It is 9 miles in length and has 24 miles of shoreline. Fish collected throughout the lake had mercury levels above the USEPA criterion. The entire waterbody is impaired by mercury.

Potential Sources
Several inactive and partially active gold mines exist upstream of Englebright Dam in the Yuba River watershed. The Yuba watershed was historically mined extensively for its hardrock and placer gold deposits and has been affected by hydraulic mining (Alpers and Hunerlach, 2000).

B.1.28 Little Deer Creek, Mercury

Summary of Proposed Action

The California Regional Water Quality Control Board, Central Valley Region (Regional Board) recommends the addition of Little Deer Creek to California's Clean Water Act Section 303(d) list due to impairment by mercury. Information available to the Regional Board on mercury levels in fish tissue samples indicates that water quality objectives are not being attained in Little Deer Creek. The description for the basis for this determination is given below.

Table B-1. 303(d) Listing/TMDL Information

Waterbody Name	Little Deer Creek	**Pollutants/Stressors**	Mercury
Hydrologic Unit	517.20	**Sources**	Resource extraction (abandoned mines)
Total Length	4 miles	**TMDL Priority**	
Size Affected	4 miles	**TMDL Start Date (Mo/Yr)**	
Extent of Impairment	All of Little Deer Creek	**TMDL End Date (Mo/Yr)**	
Upstream Extent Latitude	39° 15' 13"	**Upstream Extent Longitude**	120° 57' 00"
Downstream Extent Latitude	39° 15' 44"	**Downstream Extent Longitude**	121° 00' 58"

Watershed Characteristics

Little Deer Creek is in the Sierra foothills directly east of Nevada City within the Yuba River basin. Water usage ranges from recreational to agricultural and municipal to hydroelectric generation, among others. The Yuba River basin is bound by the Feather River basin on the north, by the Little Truckee River basin on the east, and by the Bear River and American River basins on the south. Little Deer Creek flows for approximately 4 miles from its headwaters at approximately 3,500 feet above mean sea level (msl) to its confluence with Deer Creek at approximately 2,600 feet above msl in Nevada City. Deer Creek flows into the Yuba River downstream of Lake Englebright.

Water Quality Objectives Not Attained

The narrative objective for toxicity is not being attained for mercury in Little Deer Creek. The narrative toxicity objective in the Basin Plan states, in part, "All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life." The narrative toxicity objective further states that "The Regional Water Board will also consider … numerical criteria and guidelines for toxic substances developed by the State Water Board, the California Office of Environmental Health Hazard Assessment, the California Department of Health Services (OEHHA), the U.S. Food and Drug Administration, the National Academy of Sciences, the U.S. Environmental Protection Agency, and other appropriate organizations to evaluate compliance with this objective" (CRWQCB-CVR, 1998; http://www.swrcb.ca.gov/~rwqcb5/bsnplnab.pdf).

Numeric criteria for mercury in fish tissue have been developed for both human health and wildlife protection. The U.S. Environmental Protection Agency (USEPA) recently established a human health protection criterion of 0.3 milligrams per kilogram (mg/kg; equivalent to parts per million [ppm]) methylmercury in the edible portions of fish (USEPA, 2001b). This criterion is used to determine attainment with the narrative toxicity objective.

Evidence of Impairment

The U.S. Geological Survey (USGS) collected fish tissue samples from Little Deer Creek at Pioneer Park, less than ½ mile from the confluence with Deer Creek. Only trophic level 3 fish were collected in the study. Trophic level 3 fish feed on zooplankton, phytoplankton, and benthic invertebrates. Methylmercury and total mercury bioaccumulates in aquatic organisms and tends to increase with increasing trophic levels (USEPA, 1997a). The USGS sampled six brown trout on October 6, 1999. These TL3 fish had an average mercury concentration of 0.32 ppm, which exceeds the USEPA criterion of 0.3 ppm. Placer, Yuba, and

Nevada counties have issued an interim public health notification for all lakes and watercourses within these counties based on the USGS data. OEHHA is in the process of developing a state advisory (Nevada County, 2000).

Extent of Impairment
Little Deer Creek runs for approximately 4 miles and drains into the mainstem of Deer Creek. The entire waterbody is impaired by mercury.

Potential Sources
The inactive Banner Mine is within the watershed of Little Deer Creek, about 2.5 miles upstream from the confluence with Deer Creek. Several inactive and partially active gold mines exist within the Yuba River watershed. The Yuba watershed was historically mined extensively for its hardrock and placer gold deposits and has been affected by hydraulic mining (Alpers and Hunerlach, 2000).

B.1.42 Rollins Reservoir, Mercury

Summary of Proposed Action

The California Regional Water Quality Control Board, Central Valley Region (Regional Board) recommends the addition of Rollins Reservoir to California's Clean Water Act Section 303(d) list due to impairment by mercury. Information available to the Regional Board on mercury levels in fish tissue samples indicates that water quality objectives are not being attained in Rollins Reservoir. The description for the basis for this determination is given below.

Table B-1. 303(d) Listing/TMDL Information

Waterbody Name	Rollins Reservoir	**Pollutants/Stressors**	Mercury
Hydrologic Unit	516.34	**Sources**	Resource Extraction
Total Length	840 acres	**TMDL Priority**	
Size Affected	840 acres	**TMDL Start Date (Mo/Yr)**	
Extent of Impairment	All of Rollins Reservoir	**TMDL End Date (Mo/Yr)**	

Watershed Characteristics

The Bear River basin comprises over 232,800 watershed acres. Water usage ranges from recreational to agricultural and municipal to hydroelectric generation, among others. The basin is bound by the Yuba River on the north, the Little Truckee River basin on the east, and the American River basin on the south. The headwaters are located in the Sierra Nevada snowfields at elevations ranging up to 9,100 feet above sea level. Greenhorn Creek, Steephollow Creek and Bear River flow into Rollins Reservoir. Rollins Reservoir has twenty-six miles of shoreline and its deepest section is 270 feet deep at the dam. At full capacity the reservoir stores 66,000 acre-feet of water and covers 840 surface acres.

Water Quality Objectives Not Attained

The narrative objective for toxicity is not being attained for mercury in Rollins Reservoir. The narrative toxicity objective in the Basin Plan states, in part, "All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life." The narrative toxicity objective further states that "The Regional Water Board will also consider ... numerical criteria and guidelines for toxic substances developed by the State Water Board, the California Office of Environmental Health Hazard Assessment, the California Department of Health Services, the U.S. Food and Drug Administration, the National Academy of Sciences, the U.S. Environmental Protection Agency, and other appropriate organizations to evaluate compliance with this objective (CRWQCB-CVR, 1998; http://www.swrcb.ca.gov/~rwqcb5/bsnplnab.pdf)."

Numeric criteria for mercury in fish tissue have been developed for both human health and wildlife protection. The U.S. Environmental Protection Agency (USEPA) recently established a human health protection criterion of 0.3 milligrams per kilogram (mg/kg; equivalent to parts per million [ppm]) methylmercury in the edible portions of fish (USEPA, 2001b). This criterion is used to determine attainment with the narrative toxicity objective.

Evidence of Impairment

The U.S. Geological Survey (USGS) and Toxic Substances Monitoring Program (TSMP) collected fish tissue samples from the midsection, Bear River Arm, and Greenhorn Creek Arm of Rollins Reservoir (May *et al*, 2000; CRWQCB-SFB *et al*, 1995). The USGS collected trophic level 3 and 4 fish; the TSMP collected only trophic level 4 fish. Trophic level 3 fish feed on zooplankton, phytoplankton, and benthic invertebrates. Trophic level 4 fish consume trophic level 3 fish as part of their diet. Methylmercury and total mercury bioaccumulate in aquatic organisms and tend to increase with increasing trophic levels (USEPA, 1997a). The TSMP and USGS sampled 50 trophic level 4 fish (largemouth bass, smallmouth bass, black crappie, and channel catfish) between 1984 and 1999. The TL4 fish had an average mercury concentration of 0.32 ppm, which exceeds the USEPA criterion of 0.3 ppm. The trophic level 4 fish data from the USGS study are summarized in Table B-2, below. Placer, Yuba, and Nevada counties have issued an interim public health notification for all lakes and watercourses within these counties based on the USGS data. OEHHA is in the process of developing a state advisory (Nevada County, 2000).

Table B-2. Summary of Mercury Concentration Data for Rollins Reservoir River Trophic Level 4 Fish

Sampling Location	Fish Type	# of Fish Sampled	Mean Mercury Concentration (ppm)
Bear River Arm	Largemouth Bass	2	0.25
	Channel Catfish	10	0.365
Greenhorn Creek Arm	Largemouth Bass	5	0.374
	Channel Catfish	3	0.35
	Black Crappie	3	0.31
Midsection of Reservoir	Largemouth Bass	5	0.56
	Channel Catfish	12	0.31
	Smallmouth Bass	10	0.14
Summary	**Trophic Level 4 Fish**	**50**	**0.32**

Extent of Impairment

Rollins Reservoir covers 840 surface acres. Fish collected throughout the reservoir had mercury levels above the USEPA criterion. The entire waterbody is impaired by mercury.

Potential Sources

The Bear River watershed was historically mined extensively for its hardrock and placer gold deposits and has been affected by hydraulic mining (Alpers and Hunerlach, 2000). Several inactive gold exist upstream of Rollins Reservoir in the Bear River watershed (Montoya and Pan, 1992).

B.1.44 Scotts Flat Reservoir, Mercury

Summary of Proposed Action

The California Regional Water Quality Control Board, Central Valley Region, (Regional Board) recommends the addition of Scotts Flat Reservoir to California's Clean Water Act Section 303(d) list due to impairment by mercury. Information available to the Regional Board on mercury levels in fish tissue samples indicates that water quality objectives are not being attained in Scotts Flat Reservoir. The description for the basis for this determination is given below.

Table B-1. 303(d) Listing/TMDL Information

Waterbody Name	Scotts Flat Reservoir	**Pollutants/Stressors**	Mercury
Hydrologic Unit	517.20	**Sources**	Resource extraction (abandoned mines)
Total Length	725 acres	**TMDL Priority**	
Size Affected	725 acres	**TMDL Start Date (Mo/Yr)**	
Extent of Impairment	All of Scotts Flat Reservoir	**TMDL End Date (Mo/Yr)**	

Watershed Characteristics

Scotts Flat Reservoir is located on Deer Creek in the Sierra foothills five miles east of Nevada City within the Yuba River basin. Deer Creek flows approximately 20 miles from Scotts Flat Reservoir to its confluence with the Yuba River downstream from Lake Englebright. The Yuba River basin comprises over 12,700 watershed acres and over 1,900 total river miles. Water usage ranges from recreational to agricultural and municipal to hydroelectric generation, among others. The Yuba River basin is bound by the Feather River basin on the north, by the Little Truckee River basin on the east, and by the Bear River and American River basins on the south. Its headwaters are located in the Sierra Nevada snowfields at elevations ranging up to 9,100 feet above sea level.

Water Quality Objectives Not Attained

The narrative objective for toxicity is not being attained for mercury in Scotts Flat Reservoir. The narrative toxicity objective in the Basin Plan states, in part, "All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life." The narrative toxicity objective further states that "The Regional Water Board will also consider ... numerical criteria and guidelines for toxic substances developed by the State Water Board, the California Office of Environmental Health Hazard Assessment, the California Department of Health Services (OEHHA), the U.S. Food and Drug Administration, the National Academy of Sciences, the U.S. Environmental Protection Agency, and other appropriate organizations to evaluate compliance with this objective" (CRWQCB-CVR, 1998; http://www.swrcb.ca.gov/~rwqcb5/bsnplnab.pdf).

Numeric criteria for mercury in fish tissue have been developed for both human health and wildlife protection. The U.S. Environmental Protection Agency (USEPA) recently established a human health protection criterion of 0.3 milligrams per kilogram (mg/kg; equivalent to parts per million [ppm]) methylmercury in the edible portions of fish (USEPA, 2001b). This criterion is used to determine attainment with of the narrative toxicity objective.

Evidence of Impairment

The U.S. Geological Survey (USGS) sampled trophic level 3 and 4 fish from Scotts Flat Reservoir (May *et al*, 2000). Trophic level 3 fish feed on zooplankton, phytoplankton, and benthic invertebrates. Trophic level 4 fish consume trophic level 3 fish as part of their diet. Methylmercury and total mercury bioaccumulate in aquatic organisms and tend to increase with increasing trophic levels (USEPA, 1997a). The USGS sampled seven trophic level 4 fish (largemouth bass) on September 7 and 8, 1999. These trophic level 4 fish had an average mercury concentration of 0.38 ppm, which exceeds the USEPA criterion of 0.3 ppm. Placer, Yuba, and Nevada counties have issued an interim public health notification for all lakes and watercourses within these counties based on the USGS data. OEHHA is in the process of developing a state advisory (Nevada County, 2000).

Extent of Impairment
Scotts Flat Reservoir covers 725 surface acres with 48,500 acre-feet of storage. The entire waterbody is impaired by mercury.

Potential Sources
Several inactive and partially active gold mines exist upstream of Scotts Flat Reservoir within the Yuba River watershed. The Yuba watershed was historically mined extensively for its hardrock and placer gold deposits and has been affected by hydraulic mining (Alpers and Hunerlach, 2000).

http://ca.water.usgs.gov/

mercury/fs 06100
Camp Far West, Lake Combie,
Lake Englebright, Little
Deer Crk, Rollins Res.

USGS
science for a changing world

Fact Sheet FS-061-00

Mercury Contamination from Historic Gold Mining in California

By Charles N. Alpers and Michael P. Hunerlach

Mercury contamination from historic gold mines represents a potential risk to human health and the environment. This fact sheet provides background information on the use of mercury in historic gold mining and processing operations in California, and describes a new USGS project that addresses the potential risks associated with mercury from these sources, with emphasis on historic hydraulic mining areas.

Miners used mercury (quicksilver) to recover gold throughout the western United States at both placer (alluvial) and hardrock (lode) mines. The vast majority of mercury lost to the environment in California was from placer-gold mines, which used hydraulic, drift, and dredging methods. At hydraulic mines, placer ores were broken down with monitors (or water cannons, fig. 1) and the resulting slurry was directed through sluices and drainage tunnels, where gold particles combined with liquid mercury to form gold–mercury amalgam. Loss of mercury in this process was 10 to 30 percent per season (Bowie, 1905), resulting in highly contaminated sediments at mine sites (fig. 2). Elevated mercury concentrations in present-day mine waters and sediments indicate that hundreds to thousands of pounds of mercury remain at each of the many sites affected by hydraulic mining. High mercury levels in fish, amphibians, and invertebrates downstream of the hydraulic mines are a consequence of historic mercury use. On the basis of USGS studies and other recent work, a better understanding is emerging of mercury distribution, ongoing transport, transformation processes, and the extent of biological uptake in areas affected by historic gold mining. This information will be useful to agencies responsible for prudent land and resource management and for protecting public health.

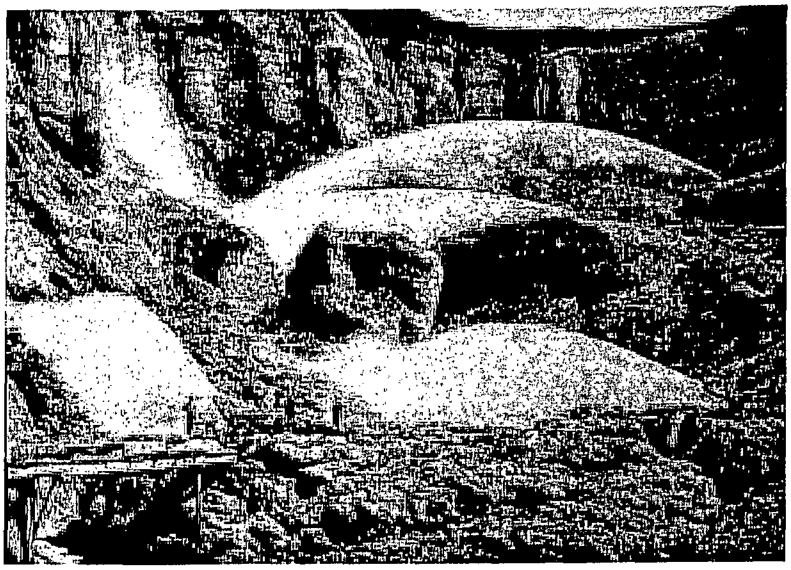


Figure 1. Monitors (water cannons) were used to break down the gold-bearing gravel deposits with tremendous volumes of water under high pressure. Some mines operated several monitors in the same pit. Malakoff Diggings, circa 1860.

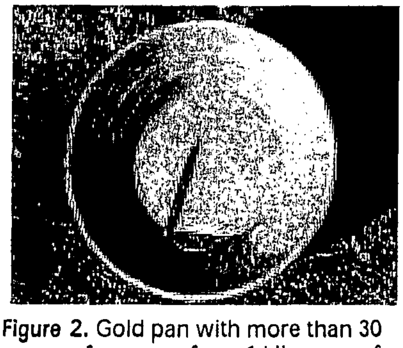


Figure 2. Gold pan with more than 30 grams of mercury from 1 kilogram of mercury-contaminated sediments.

Origins of Hydraulic Mining

Vast gravel deposits from ancestral rivers within the Sierra Nevada gold belt contained large quantities of placer gold, which provided the basis for the first large-scale mining in California. Around 1852, hydraulic mining technology evolved, using monitors (fig.1) to deliver large volumes of water that stripped the ground of soil, sand, and gravel above bedrock. The water and sediment formed slurries that were directed through linear sluices (fig. 3) where the gold was recovered. An extensive water transfer system of ditches, canals, and vertical pipes provided the sustained water pressure necessary for hydraulic mining. As mining progressed into deeper gravels, tunnels were constructed to facilitate drainage and to remove debris from the bottom of hydraulic mine pits. The tunnels provided a protected environment for sluices and a way to discharge processed sediments (placer tailings) to adjacent waterways. Hydraulic mines operated on

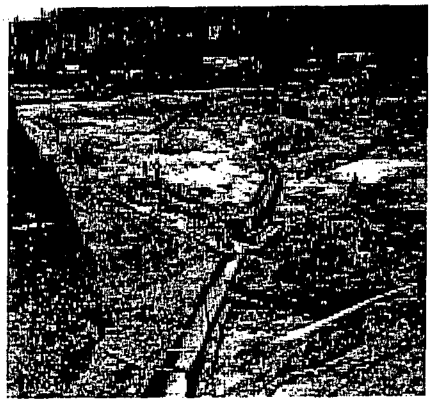


Figure 3. Gravel deposits were washed into sluices (from center to lower part of figure) where gold was recovered.

USGS
science for a changing world

Fact Sheet FS-061-00

Mercury Contamination from Historic Gold Mining in California

By Charles N. Alpers and Michael P. Hunerlach

Mercury contamination from historic gold mines represents a potential risk to human health and the environment. This fact sheet provides background information on the use of mercury in historic gold mining and processing operations in California, and describes a new USGS project that addresses the potential risks associated with mercury from these sources, with emphasis on historic hydraulic mining areas.

Miners used mercury (quicksilver) to recover gold throughout the western United States at both placer (alluvial) and hardrock (lode) mines. The vast majority of mercury lost to the environment in California was from placer-gold mines, which used hydraulic, drift, and dredging methods. At hydraulic mines, placer ores were broken down with monitors (or water cannons, fig. 1) and the resulting slurry was directed through sluices and drainage tunnels, where gold particles combined with liquid mercury to form gold–mercury amalgam. Loss of mercury in this process was 10 to 30 percent per season (Bowie, 1905), resulting in highly contaminated sediments at mine sites (fig. 2). Elevated mercury concentrations in present-day mine waters and sediments indicate that hundreds to thousands of pounds of mercury remain at each of the many sites affected by hydraulic mining. High mercury levels in fish, amphibians, and invertebrates downstream of the hydraulic mines are a consequence of historic mercury use. On the basis of USGS studies and other recent work, a better understanding is emerging of mercury distribution, ongoing transport, transformation processes, and the extent of biological uptake in areas affected by historic gold mining. This information will be useful to agencies responsible for prudent land and resource management and for protecting public health.

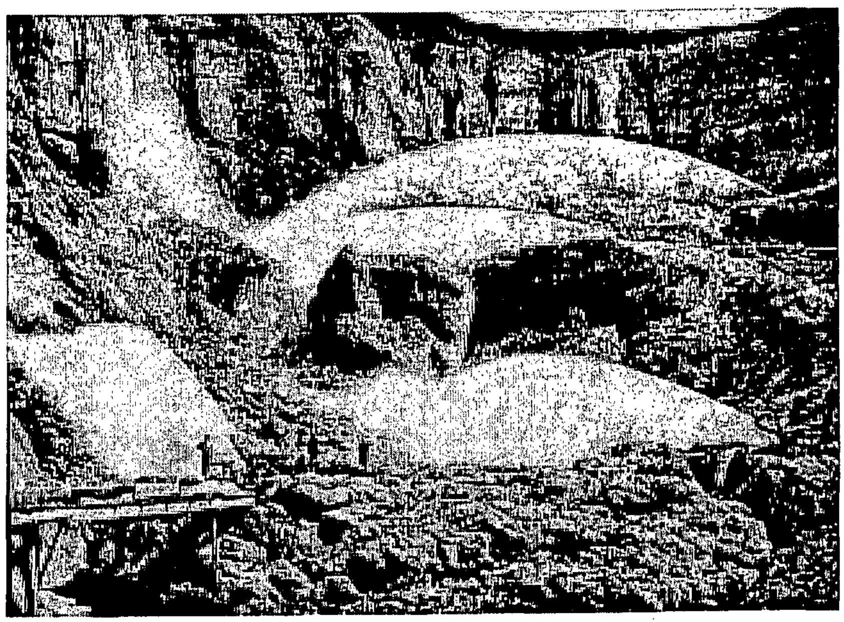


Figure 1. Monitors (water cannons) were used to break down the gold-bearing gravel deposits with tremendous volumes of water under high pressure. Some mines operated several monitors in the same pit. Malakoff Diggings, circa 1860.

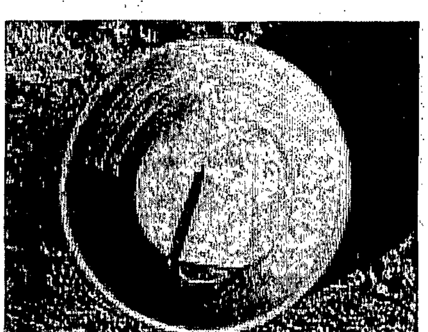


Figure 2. Gold pan with more than 30 grams of mercury from 1 kilogram of mercury-contaminated sediments.

Origins of Hydraulic Mining

Vast gravel deposits from ancestral rivers within the Sierra Nevada gold belt contained large quantities of placer gold, which provided the basis for the first large-scale mining in California. Around 1852, hydraulic mining technology evolved, using monitors (fig. 1) to deliver large volumes of water that stripped the ground of soil, sand, and gravel above bedrock. The water and sediment formed slurries that were directed through linear sluices (fig. 3) where the gold was recovered. An extensive water transfer system of ditches, canals, and vertical pipes provided the sustained water pressure necessary for hydraulic mining. As mining progressed into deeper gravels, tunnels were constructed to facilitate drainage and to remove debris from the bottom of hydraulic mine pits. The tunnels provided a protected environment for sluices and a way to discharge processed sediments (placer tailings) to adjacent waterways. Hydraulic mines operated on

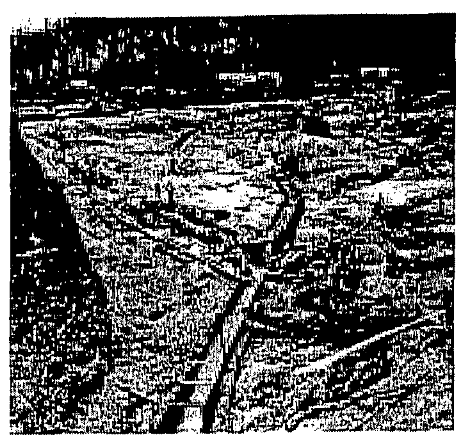


Figure 3. Gravel deposits were washed into sluices (from center to lower part of figure) where gold was recovered.

a large scale from the 1850s to the 1880s in California's northern Sierra Nevada region, where more than 1.5 billion cubic yards of gold-bearing placer gravels were worked. In 1884, the Sawyer Decision prohibited discharge of mining debris in the Sierra Nevada region, but not in the Klamath–Trinity Mountains (fig. 4), where hydraulic mining continued until the 1950s. Underground mining of placer deposits (drift mining) and of hardrock gold–quartz vein deposits produced most of California's gold from the mid-1880s to the early 1900s. Dredging of gold-bearing sediments in the Sierra Nevada foothills has been an important source of gold since the early 1900s. Mercury also was used extensively until the early 1960s in the dredging of flood plain deposits, were over 3.6 billion cubic yards were mined. Mercury is recovered today as a by-product from large- and small-scale dredging operations.

Mercury Mining

Most of the mercury used in gold recovery in California was obtained from the Coast Ranges mercury belt on the west side of California's Central Valley (fig. 4). Historic mercury production peaked in the late 1870s (fig. 5). Total mercury production in California between 1850 and 1981 was more than 220,000,000 lb (pounds) (Churchill, 1999). Although most of this mercury was exported around the Pacific Rim or transported to Nevada and other western states, a significant portion (about 12 percent, or 26,000,000 lb) was used for gold recovery in California, mostly in the Sierra Nevada and Klamath–Trinity Mountains.

Mercury Use in Hydraulic Mining

In a typical sluice, hundreds of pounds of liquid mercury (several 76-lb flasks) were added to riffles and troughs to enhance gold recovery. The density of mercury is between that of gold and the gravel slurry, so gold and gold–mercury amalgam would sink, while the sand and gravel would pass over the mercury and through the sluice. Because such large volumes of turbulent water flowed through the sluice, many of the finer gold and mercury particles were washed through and out of the sluice before they could settle in the mercury-laden riffles. A modification known as an undercurrent (fig. 6) was developed to address this loss. Fine-grained sediment was allowed to drop onto the undercurrent, where gold and amalgam were caught. The entire surface of the undercurrent (as much as 5,000 to 10,000 square feet) typically was covered by copper plates coated with mercury.

Gravel and cobbles that entered the sluices caused the mercury to flour, or break into tiny particles. Flouring was aggravated by agitation, exposure of mercury to air, and other chemical reactions. Eventually, the entire bottom of the sluice became coated with mercury. Some mercury escaped from the sluice through leakage into underlying soils and bedrock, and some was transported downstream with the placer tailings. Some remobilized placer sediments remain close to their source in ravines that drained the hydraulic mines. Minute particles of

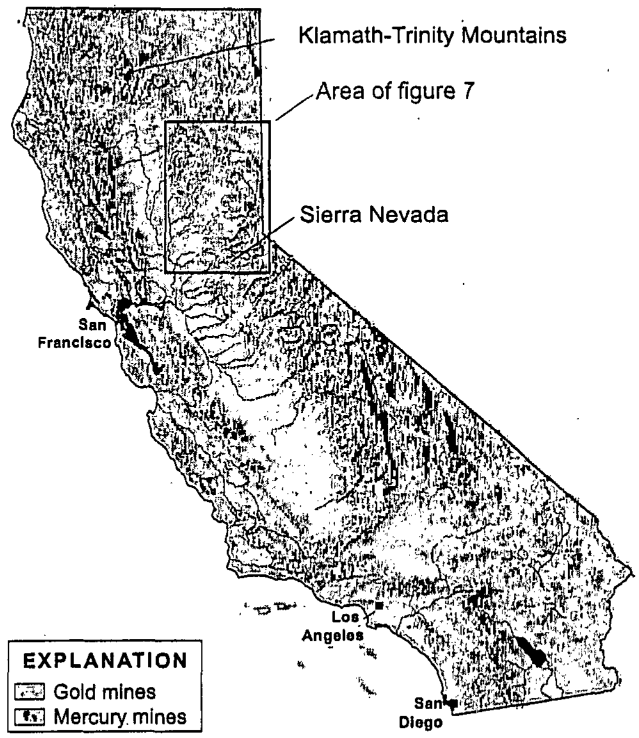


Figure 4. Locations of past-producing gold and mercury mines in California. Source: MAS/MILS (Minerals Availability System/ Mineral Information Location System) database compiled by the former U.S. Bureau of Mines, now archived by the USGS.

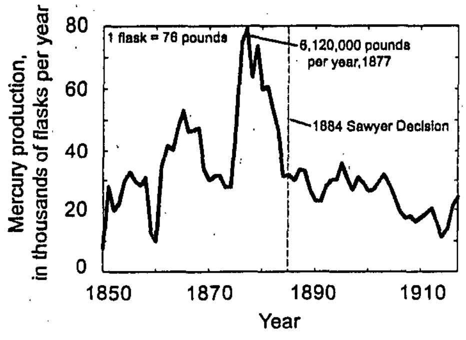


Figure 5. Mercury production from mines in the Coast Ranges of California, 1850-1917 (Bradley, 1918).

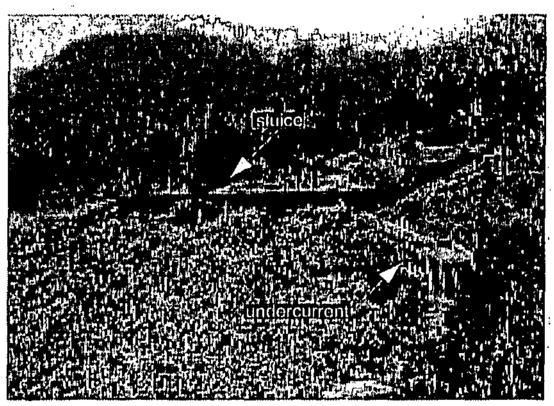


Figure 6. Undercurrent in use, circa 1860, Siskyou County, California.

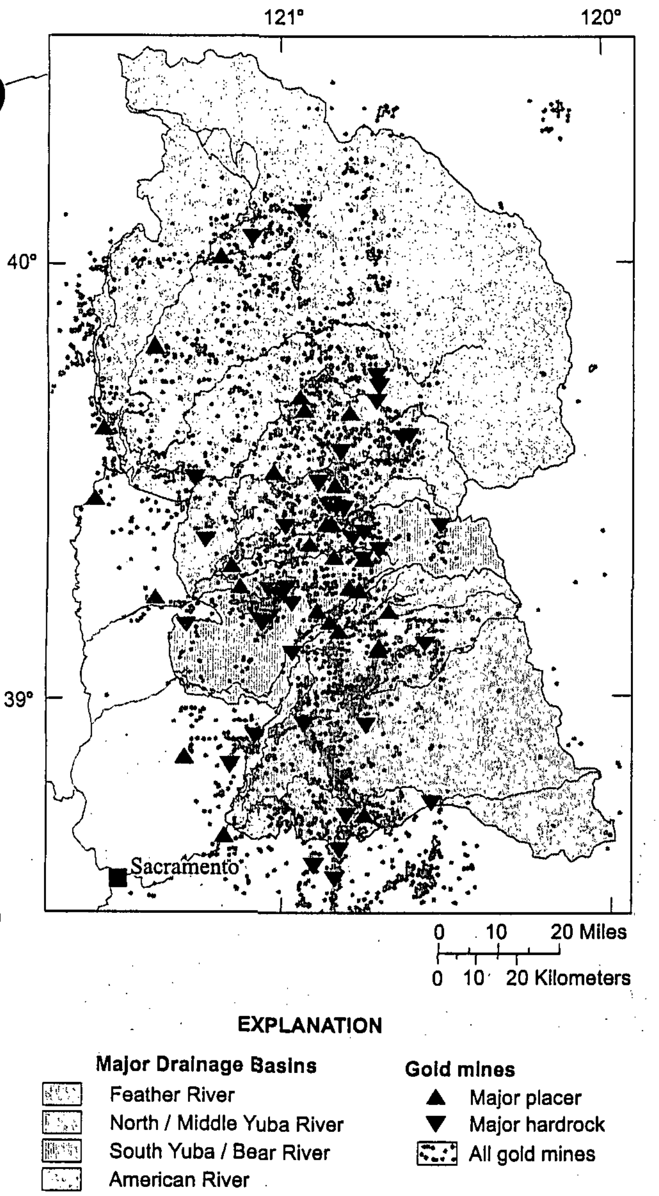


Figure 7. Watersheds in the northwestern Sierra Nevada of California showing past-producing gold mines (as in figure 4) and major placer and hardrock gold mines. Source: USGS KNOWNDEP database (Long and others, 1998).

quicksilver were found floating on surface water as far as 20 miles downstream of mining operations (Bowie, 1905).

Averill (1946) estimated that, under the best operating conditions, 10 percent of the mercury used was lost and, under average conditions, the annual loss of mercury was up to 30 percent. Mercury use varied from 0.1 to 0.36 pounds per square foot of sluice. We estimate that a typical sluice had an area of 2,400 square feet and used up to 800 lb of mercury during initial start-up, after which several additional 76-lb flasks were added weekly to monthly throughout its operating season (generally 6 to 8 months, depending on water availability). Assuming a 10–30 percent loss, the annual loss of mercury from a typical sluice was likely several hundred pounds during the operating season. From the 1860s through the early 1900s, hundreds of hydraulic placer-gold mines operated in the Sierra Nevada. The total amount of mercury lost to the environment from these operations may have been 3–8 million lb or more, from estimates by Churchill (1999) that about 26,000,000 lb of mercury were used in California. Historic records indicate that about 3 million lb of mercury were used at hardrock mines in stamp mills, where ores were crushed. Mercury was also used extensively at drift mines and in dredging operations. The present distribution and fate of the mercury used in historic gold mining operations remains largely unknown, and is the focus of ongoing studies.

The Bear–Yuba Project

The northwestern Sierra Nevada region has been mined extensively for both its hardrock-gold and placer-gold deposits (fig. 7). The American, Bear, Yuba, and Feather River watersheds each have been affected by hydraulic mining. In the northwestern Sierra Nevada, the highest average levels of mercury bioaccumulation occur in the Bear River and South Yuba River watersheds (Slotton and others, 1997). USGS scientists (Hunerlach and others, 1999) have demonstrated a positive correlation of mercury bioaccumulation with intensity of hydraulic gravel mined in the Sierra Nevada (fig. 8). The Bear River and South Yuba River watersheds have been selected by the USGS and federal land management agencies (the Bureau of Land Management and the Forest Service) as well as state and local agencies (see last page) for detailed studies of mercury distribution in relation to historic mine sites. In April 1999, the study team began sampling water, sediment, and biota at mine sites identified as containing mercury "hot spots," where remediation might reduce risks to human health and the environment. The USGS is also analyzing mercury in sport fish from several lakes and streams in the Bear River and South Yuba River watersheds to allow assessment of potential risks to human health from fish consumption.

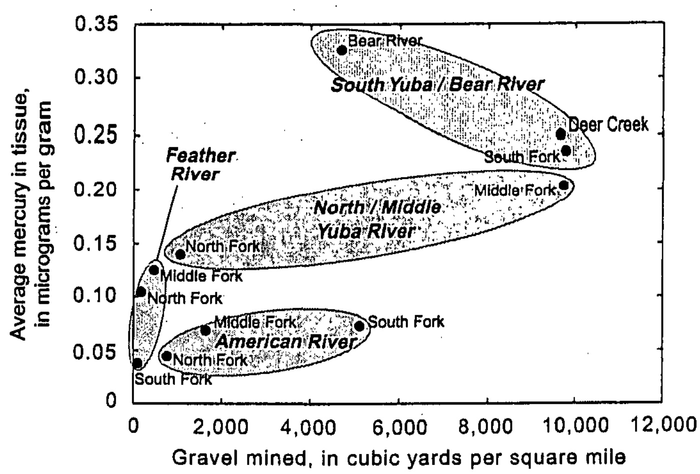


Figure 8. Relationship between intensity of hydraulic mining in Sierra Nevada watersheds and average mercury concentration in tissues of aquatic organisms. Modified from Hunerlach and others (1999). Mercury data from Slotton and others (1997).

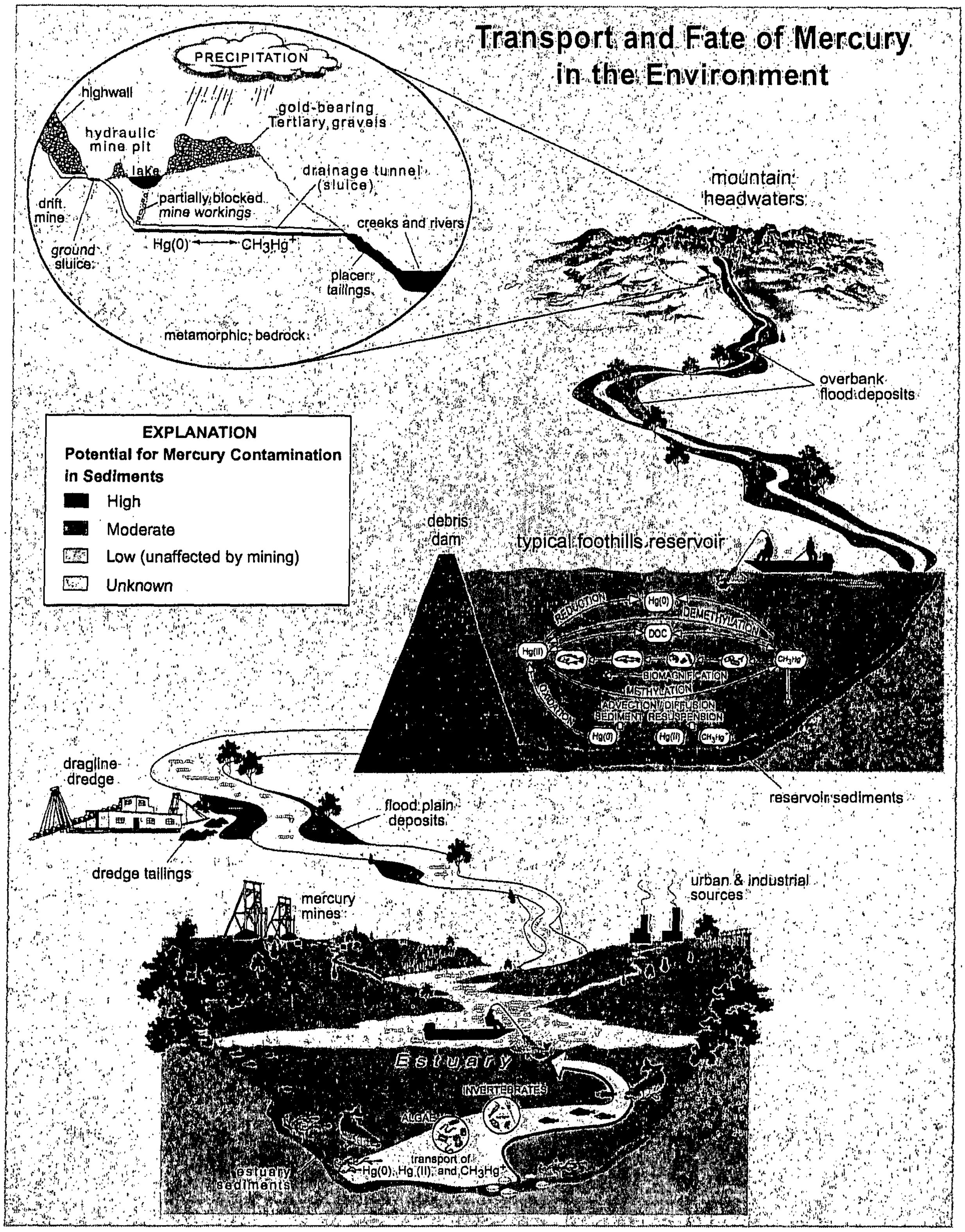


Figure 9. *Schematic diagram showing transport and fate of mercury and potentially contaminated sediments from the mountain headwaters (hydraulic and drift mine environment) through rivers, reservoirs, and the flood plain, and into an estuary. A simplified mercury cycle is shown, including overall methylation reactions and bioaccumulation; the actual cycling is much more complex. Hg(0), elemental mercury; Hg(II), ionic mercury (mercuric ion); CH_3Hg^+, methylmercury; DOC, dissolved organic carbon.*

MERCURY CONTAMINATION: KEY ISSUES

Risks to Human Health

- Consumption of contaminated fish
- Improper handling of contaminated sediments
- Inhalation of mercury vapors
- Low risk in municipal drinking water
- Some mine waters unsafe for consumption

Challenges for Land Management

- Public access to contaminated areas
- Physically hazardous sites
- Environmental consequences of resource development
- Remediation of affected sites

Environmental Fate of Mercury

- "Hot spots" at mine sites
- Contaminated sediments
- Transport to downstream areas
- Bioaccumulation and biomagnification in food chain

Mercury Methylation and Biomagnification

Mercury occurs in several different geochemical forms, including elemental mercury [Hg(0)], ionic (or oxidized) mercury [Hg(II)], and a suite of organic forms, the most important of which is methylmercury (CH_3Hg^+). Methylmercury is the form most readily incorporated into biological tissues and most toxic to humans. The transformation from elemental mercury to methylmercury is a complex biogeochemical process that requires at least two steps, as shown in figure 9: (1) Oxidation of Hg(0) to Hg(II), followed by (2) Transformation from Hg(II) to CH_3Hg^+; step "2" is referred to as ***methylation.*** *Mercury methylation is controlled by sulfate-reducing bacteria and other microbes that tend to thrive in conditions of low dissolved oxygen, such as the sediment–water interface or in algal mats. Numerous environmental factors influence the rates of mercury methylation and the reverse reaction known as demethylation. These factors include temperature, dissolved organic carbon, salinity, acidity (pH), oxidation-reduction conditions, and the form and concentration of sulfur in water and sediments.*

The concentration of CH_3Hg^+ generally increases by a factor of ten or less with each step up the food chain, a process known as ***biomagnification.*** *Therefore, even though the concentrations of Hg(0), Hg(II), and CH_3Hg^+ in water may be very low and deemed safe for human consumption as drinking water, CH_3Hg^+ concentration levels in fish, especially predatory species such as bass and catfish, may reach levels that are considered potentially harmful to humans and fish-eating wildlife, such as bald eagles.*

Fish Consumption Advisories for Mercury

Methylmercury (CH_3Hg^+) is a potent neurotoxin that impairs the nervous system. Fetuses and young children are more sensitive to methylmercury exposure than adults. Methylmercury can cause many types of problems in children, including brain and nervous system damage, retardation of development, mental impairment, seizures, abnormal muscle tone, and problems in coordination. Therefore, the consumption guidelines in areas where CH_3Hg^+ is known to occur in fish at potentially harmful levels tend to be more restrictive for children as well as for pregnant women, nursing mothers, and women of childbearing age.

In the United States, as of 1998, there were a total of 2,506 fish and wildlife consumption advisories for all substances, of which 1,931 (more than 75 percent) were for mercury. Forty states have issued advisories for mercury, and ten states have statewide advisories for mercury in all freshwater lakes and (or) rivers.

In California, as of 1999, there were fish consumption advisories for mercury in 13 waterbodies, including the San Francisco Bay and Delta Region and several areas in the Coast Ranges affected by mercury mining (fig. 10; compare with fig. 4). Data on CH_3Hg^+ levels in fish are presently insufficient for public agencies to determine whether advisories are warranted for lakes and rivers in areas affected by historic gold mining, such as the Sierra Nevada foothills.

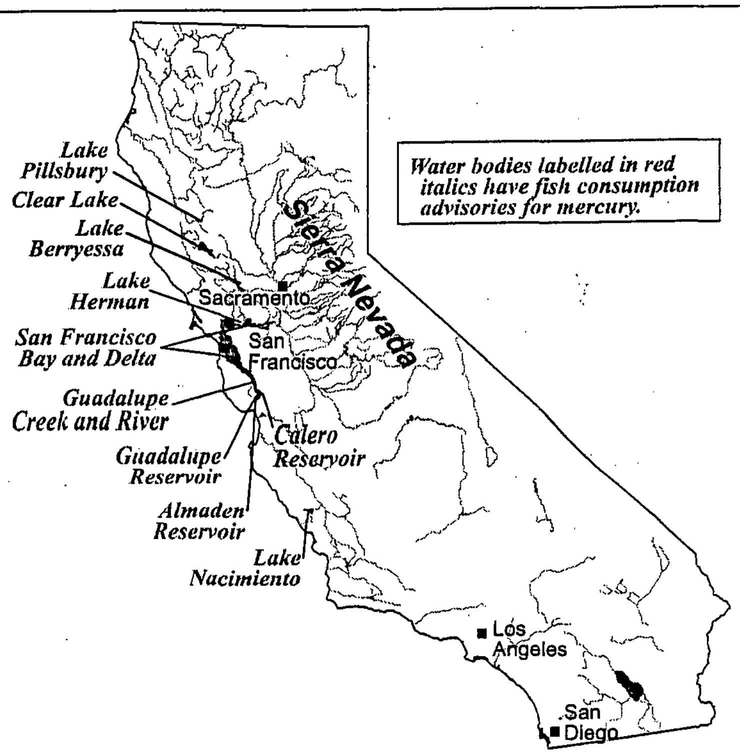


Figure 10. Locations of health advisories for mercury in sport fish consumption in California. Source: California Office of Environmental Health Hazard Assessment, 1999. Lake Pillsbury has interim advisory by Lake County; state advisory pending, as of May 2000.

Lake in hydraulic mine pit caused by blocked drainage tunnel. Acidic water in this pit lake (pH 3.5) caused by oxidation of sulfide minerals in gold-bearing gravel deposits.

Physical hazards at hydraulic mine sites include highwalls (left photo) and open shafts (right photo). Highwalls are steep unstable slopes subject to sudden collapse. Shafts vary from tens to hundreds of feet in depth and connect with horizontal mine workings including drift mines and drainage tunnels.

References Cited

Averill, C.V., 1946, Placer mining for gold in California: California State Division of Mines and Geology Bulletin 135, 336 p.

Bowie, A.J., 1905, A practical treatise on hydraulic mining in California: New York, Van Nostrand, 313 p.

Bradley, E.M., 1918, Quicksilver resources of the state of California: California State Mining Bureau Bulletin 78, 389 p.

California Office of Environmental Health Hazard Assessment, 1999, California Sport Fish Consumption Advisories, 1999: Sacramento, Calif., 9 p.

Churchill, R., 1999, Insights into California mercury production and mercury availability for the gold mining industry from the historical record: Geological Society of America Abstracts with Programs, v. 31, no. 6, p. 45.

Hunerlach, M.P., Rytuba, J.J., and Alpers, C.N., 1999, Mercury contamination from hydraulic placer-gold mining in the Dutch Flat mining district, California: U.S. Geological Survey Water-Resources Investigations Report 99-4018B, p. 179-189.

Long, K.R., DeYoung, J.H., Jr., and Ludington, S.D., 1998, Database of significant deposits of gold, silver, copper, lead, and zinc in the United States: U.S. Geological Survey Open-File Report 98-206A, 33 p.

Slotton, D.G., Ayers, S.M., Reuter, J.E., and Goldman, C.R., 1997, Gold mining impacts on food chain mercury in northwestern Sierra Nevada streams (1997 revision), Appendix B *in* Larry Walker Associates, 1997, Sacramento River watershed mercury control planning project—report for the Sacramento Regional County Sanitation District, 74 p.

Tunnel sluice with mercury-contaminated sediments.

For more information:

Charles N. Alpers
(916) 278-3134
cnalpers@usgs.gov

Michael P. Hunerlach
(916) 278-3133
hunerlac@usgs.gov

U.S. Geological Survey
6000 J Street, Placer Hall
Sacramento, CA 95819-6129

http://ca.water.usgs.gov/mercury/
http://mine-drainage.usgs.gov/mine/
http://amli.usgs.gov/amli/
http://www.usgs.gov/

Cooperating Agencies

U.S. Forest Service

California Department of Conservation

California State Water Resources Control Board

Nevada County Resource Conservation District

Bureau of Land Management

U.S. Environmental Protection Agency

California Department of Parks and Recreation

http://ca.water.usgs.gov/rep/ofr00367/
ofr00367.pdf

Mercury Bioaccumulation in Fish in a Region Affected by Historic Gold Mining:

The South Yuba River, Deer Creek, and Bear River Watersheds, California, 1999

By Jason T. May[1], Roger L. Hothem[2], Charles N. Alpers[3], *and* Matthew A. Law[2]

U.S. GEOLOGICAL SURVEY

Open-File Report 00-367

Prepared in cooperation with

Bureau of Land Management
California State Water Resources Control Board
Nevada County Resource Conservation District
U.S. Department of Agriculture, Forest Service
U.S. Environmental Protection Agency

6231-01

[1]California State University Sacramento Foundation, 6000 J Street, Sacramento, CA 95819-6129

[2]U.S. Geological Survey, Western Ecological Research Center, Davis Field Station, One Shields Avenue, Room 278, Kerr Hall, University of California, Davis, CA 95616-5224

[3]U.S. Geological Survey, 6000 J Street, Placer Hall, Sacramento, CA 95819-6129

Sacramento, California
2000

Scott's Flat

bear
camp far
Lake Combie
Lake Englebright
L. Deer
Rollins

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
Charles G. Groat, Director

For additional information write to:

District Chief
U.S. Geological Survey
Water Resources Division
Placer Hall
6000 J Street
Sacramento, California 95819-6129

Copies of this report can be purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286
Denver, CO 80225-0286

CONTENTS

FIGURES

TABLES

CONVERSION FACTORS, VERTICAL DATUM, ACRONYMS and ABBREVIATIONS, and CHEMICAL ELEMENTS

Conversion Factors

Multiply	By	To obtain
mg/kg (milogram per kilogram)	0.03200	ounce (avoirdupois) per ton
mL (milliliter)	0.0002642	gallon
mm (millimeter)	0.03937	inch
pound (lb)	0.4536	kilogram

Vertical Datum

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Acronyms, Abbreviations, and Chemical Notation

(additional information given in parentheses)

CRV, certified reference value
CVAAS, cold vapor atomic-absorption spectroscopy
CVAFS, cold vapor atomic-fluorescence spectrometry
FDA, Food and Drug Administration
FGS, Frontier Geosciences, Incorporated (Seattle, Washington)
MDL, method detection limit
NRCC, National Research Council of Canada
OEHHA, Office of Environmental Health Hazard Assessment
QA–QC, quality assurance–quality control
RPD, relative percent difference
SRM, standard reference material
SV, screening value
TERL, Trace Element Research Laboratory (College Station, Texas)
TSMP, Toxic Substances Monitoring Program
EPA, U.S. Environmental Protection Agency
USGS, U.S. Geological Survey

g, gram
lb, pound
mL, milliliter
mm, millimeter
ppm, part per million
sp., species (singular)
spp., species (plural)

Mercury Bioaccumulation in Fish in a Region Affected by Historic Gold Mining:

The South Yuba River, Deer Creek, and Bear River Watersheds, California, 1999

By Jason T. May, Roger L. Hothem, Charles N. Alpers, *and* Matthew A. Law

ABSTRACT

Mercury that was used historically for gold recovery in mining areas of the Sierra Nevada continues to enter local and downstream water bodies, including the Sacramento–San Joaquin Delta and the San Francisco Bay of northern California. Methylmercury is of particular concern because it is the most prevalent form of mercury in fish and is a potent neurotoxin that bioaccumulates at successive trophic levels within food webs. In April 1999, the U.S. Geological Survey, in cooperation with several other agencies—the Forest Service (U.S. Department of Agriculture), the Bureau of Land Management, the U.S. Environmental Protection Agency, the California State Water Resources Control Board, and the Nevada County Resource Conservation District—began a pilot investigation to characterize the occurrence and distribution of mercury in water, sediment, and biota in the South Yuba River, Deer Creek, and Bear River watersheds of California. Biological samples consisted of semi-aquatic and aquatic insects, amphibians, bird eggs, and fish.

Fish were collected from 5 reservoirs and 14 stream sites during August through October 1999 to assess the distribution of mercury in these watersheds. Fish that were collected from reservoirs included top trophic level predators (black basses, *Micropterus spp.*), intermediate trophic level predators [sunfish (blue gill, *Lepomis macrochirus*; green sunfish, *Lepomis cyanellus*; and black crappie, *Poxomis nigromaculatus*)], and benthic omnivores (channel catfish, *Ictularus punctatus*). At stream sites, the species collected were upper trophic level salmonids (brown trout, *Salmo trutta)* and upper-to-intermediate trophic level salmonids (rainbow trout, *Oncorhynchus mykiss)*.

Boneless and skinless fillet portions from 161 fish were analyzed for total mercury; 131 samples were individual fish, and the remaining 30 fish were combined into 10 composite samples of three fish each of the same species and size class. Mercury concentrations in samples of black basses (*Micropterus spp.)*, including largemouth, smallmouth, and spotted bass, ranged from 0.20 to 1.5 parts per million (ppm), wet basis. Mercury concentrations in sunfish ranged from less than 0.10 to 0.41 ppm (wet). Channel catfish had mercury concentrations from 0.16 to 0.75 ppm (wet). The range of mercury concentrations observed in rainbow trout was from 0.06 to 0.38 ppm (wet), and in brown trout was from 0.02 to 0.43 ppm (wet). Mercury concentrations in trout were greater than 0.3 ppm in samples from three of 14 stream sites. Mercury at elevated concentrations may pose a health risk to piscivorous wildlife and

to humans who eat fish on a regular basis. Data presented in this report may be useful to local, state, and federal agencies responsible for assessing the potential risks associated with elevated levels of mercury in fish in the South Yuba River, Deer Creek, and Bear River watersheds.

INTRODUCTION

Overview of Mercury Use in Historic Gold Mining

Mercury associated with historic gold mining has likely been contaminating water bodies of the Central Valley, the Sacramento–San Joaquin Delta, and the San Francisco Bay Estuary for the past 150 years. Liquid mercury (quicksilver) was used extensively to aid in the recovery of gold from placer and hard-rock ores (Alpers and Hunerlach, 2000). In California, mercury was mined and refined in the Coast Ranges and then transported to the Sierra Nevada and Klamath and Trinity mountains for use in gold extraction. Churchill (1999) estimated that 26 million lb of mercury were used for the processing of gold in the Sierra Nevada region, mostly during California's historic Gold Rush period (late 1840s to 1880s). A large portion of the mercury used in hydraulic mining of placer ores was lost to the environment; typically, 10 to 30 percent was lost per season of gold processing (Bowie, 1905). Moreover, it is common to find visible quantities of elemental mercury still present in many mining areas of the Sierra Nevada and Trinity Mountains (M.P. Hunerlach, U.S. Geological Survey, oral commun., 2000).

Study Background

Preliminary assessments of mercury bioaccumulation in the northwestern Sierra Nevada indicate that the South Yuba River, Deer Creek, and Bear River watersheds are among the areas most severely affected by hydraulic mining and mercury contamination. Investigations by Slotton and others (1997) of mercury concentrations primarily in stream macroinvertebrates and stream fish at 57 sites in five watersheds in the northwestern Sierra Nevada region indicate that most of the highest concentrations of mercury are in the South Yuba River, Deer Creek, and Bear River watersheds. More recent studies in these watersheds report elevated concentrations of mercury and methylmercury in streambed sediments and water samples (Domagalski, 1998; Hunerlach and others, 1999; U.S. Geological Survey, 2000). Additionally, these watersheds contain extensive federal lands with numerous historic gold mines (fig. 1). For this reason, the South Yuba River, Deer Creek, and Bear River watersheds were selected by the U.S. Geological Survey (USGS), the federal land management agencies (the Bureau of Land Management and the U.S. Department of Agriculture's Forest Service), and state and local agencies as high priority areas for detailed studies of the distribution of mercury contamination (Alpers and Hunerlach, 2000).

The primary objectives of the overall multiagency investigation of abandoned mine lands in the South Yuba, Deer Creek, and Bear River watersheds are to document the occurrence and distribution of mercury in these watersheds and to identify mercury "hot spots" on federal lands for potential remediation. In April 1999, a team of scientists from the USGS and the cooperating agencies began collecting water, sediment, and biological samples, either directly from historic mine sites or from water bodies proximal to the mine sites, as well as from downstream receiving waters. Although biological samples included predatory aquatic and semiaquatic insects, amphibians, bird eggs, and fish, only the data on total mercury concentrations in fish are presented in this report.

Human and Wildlife Health Concerns

Methylmercury (CH_3Hg^+) is a potent neurotoxin and is one of the most toxic forms of mercury. Human fetuses and young children, as well as wildlife, are most sensitive to methylmercury exposure (Davidson and others, 1998; Wolfe and others, 1998). Human exposure to methylmercury comes almost entirely from consumption of contaminated fish; methylmercury accounts for greater than 95 percent of the total mercury in fish tissue (Bloom, 1992). Because of the known ratio of methylmercury to total mercury in fish tissues, and the high costs associated with methylmercury analyses, the U.S. Environmental Protection Agency (EPA) recommends the analysis of total mercury concentration in fish for reconnaissance studies of water bodies potentially contaminated with mercury (U.S. Environmental Protection Agency, 1995).

Levels of mercury contamination in several water bodies in northern California, primarily in the Coast

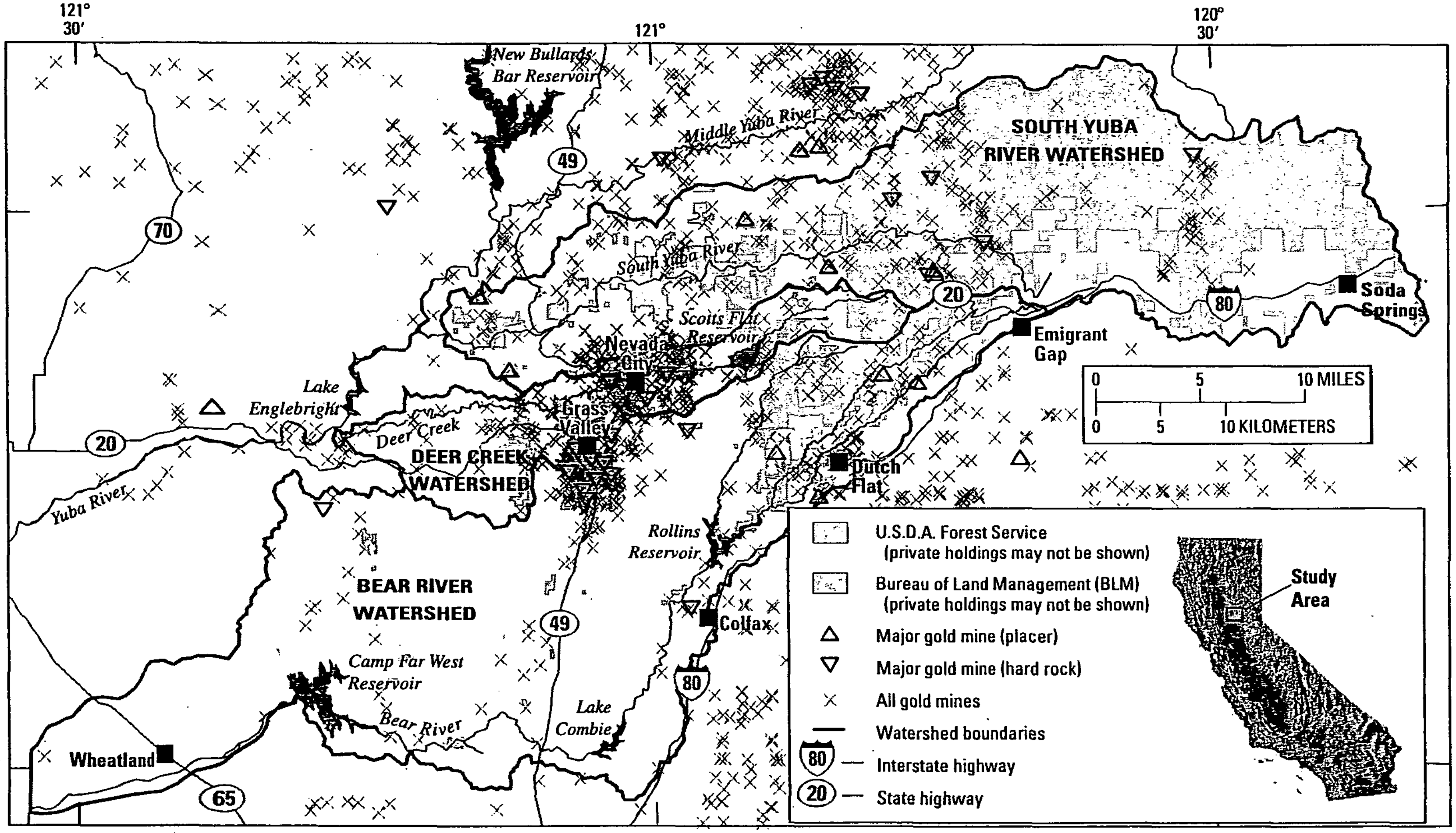


Figure 1. South Yuba River, Deer Creek, and Bear River watersheds, California, and locations of historic gold mines. Federal land ownership displayed only within the three watersheds. Locations for all known gold mines from Causey (1998); locations for major placer and hard-rock gold mines from Long and others (1998).

Ranges, the Sacramento–San Joaquin Delta, and the San Francisco Bay, are sufficiently high that public health advisories have been posted for fish consumption (Office of Environmental Health Hazard Assessment, 1999). In California, public health advisories for fish consumption are issued for individual water bodies by the Office of Environmental Health Hazard Assessment (OEHHA), which is part of the California Environmental Protection Agency. Guidance regarding consumption of mercury-contaminated fish is issued by several federal agencies, including the Food and Drug Administration (FDA), the Agency for Toxic Substances and Disease Registry, and the EPA. The FDA's action level for regulating mercury concentrations in commercial fish is 1.0 mg/kg, wet basis, which is equivalent to 1.0 part per million (ppm) (Foulke, 1994). Both EPA and OEHHA have health risk-assessment procedures with associated screening values (SV) for mercury concentrations in fish. An SV is defined as a contaminant concentration associated with the frequent consumption of contaminated fish that may be of human health concern. SVs are not intended to represent levels at which fish consumption advisories should be issued, but rather are levels at which recommendations may be made for more intensive sampling, analysis, or health evaluation efforts. OEHHA uses an SV of 300 parts per billion or 0.30 ppm for mercury concentrations in fish tissue (Brodberg and Pollock, 1999).

Critical levels of mercury concentrations in fish for wildlife health are somewhat uncertain, because of differences in the sensitivity of specific species. To date, no official mercury SVs are established for the health of piscivorous wildlife. However, mercury concentrations in fish of 0.30 ppm, and lower, have been commonly associated with adverse wildlife health effects (U.S. Environmental Protection Agency, 1997; Wolfe and others, 1998).

Purpose and Scope

The goals of this project are to investigate and identify "hot spots" for mercury contamination and to evaluate bioaccumulation pathways for mercury in the South Yuba River, Deer Creek, and Bear River watersheds, California. This report describes the data from a reconnaissance survey of mercury concentrations in edible fish tissues, from selected species in these watersheds. Predatory sport fish were targeted for collection from reservoirs and streams. In most reservoirs, largemouth bass (*Micropterus salmoides*) was the primary target species. Additional sport fish collected from reservoirs included smallmouth bass (*Micropterus dolomieu*), spotted bass (*Micropterus punctulatus*), channel catfish (*Ictalurus punctatus*), bluegill (*Lepomis macrochirus*), green sunfish (*Lepomis cyanellus*), and black crappie (*Poxomis nigromaculatus*). A small number of brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) were taken from some reservoirs; at stream sites, brown trout and rainbow trout were the only species collected.

The collection of a variety of species provides a qualitative insight into processes of mercury bioaccumulation at different trophic positions within a given fish community. The three black bass species (*Micropterus spp.*) collected in this study are top level predators, but in slightly distinct ecological niches, with diets that include other fish, amphibians, and invertebrates (Moyle, 1976). The bluegill, green sunfish, and black crappie are intermediate predators feeding on invertebrates and small fish. Channel catfish is the only benthic omnivore that was collected in this study. Although both rainbow and brown trout are mostly insectivores in early life stages, brown trout show a greater tendency for piscivory as they mature (Moyle, 1976). Therefore, brown trout are expected to bioaccumulate higher levels of mercury than rainbow trout.

Published data for mercury concentrations in fish tissues for the study area report the presence of elevated levels of mercury in fish from some water bodies of the South Yuba River, Deer Creek, and Bear River watersheds (Slotton and others, 1997; State Water Resources Control Board, accessed July 3, 2000). The available data for Lake Englebright in the South Yuba watershed are taken from nine fish samples representing five different species (Slotton and others, 1997). For Rollins Reservoir in the Bear River watershed, available mercury data from the State of California's Toxic Substance Monitoring Program (TSMP) database consist of four fish samples of three different species, and for Camp Far West Reservoir, also in the Bear River watershed, there are existing data for two samples of largemouth bass (State Water Resources Control Board, accessed July 3, 2000). In addition, Hunerlach and others (1999) reported mercury concentrations for five samples of rainbow trout from the Dutch Flat Afterbay in the Bear River watershed. No data on mercury concentrations in fish had previously been available for Scotts Flat Reservoir in the Deer

Creek watershed or Lake Combie in the Bear River watershed.

Boneless and skinless fillet portions from 161 fish were analyzed for total mercury; 131 samples were individual fish, and the remaining 10 samples were composites of three fish, each of the same species and size class. Total mercury concentrations are presented in this report for 141 samples, both on a dry and wet basis; tissue moisture, the sizes (total length and total mass) of individual fish sampled, and average fish size data for composite samples also are reported. The data included in this report may be helpful to local, state, and federal agencies that are responsible for assessing the potential risks from mercury bioaccumulation to public health and ecosystem integrity in these watersheds.

Acknowledgments

The authors of this study thank the numerous individuals at the USGS and other agencies who made this study possible through their hard work and cooperation. Personnel at the USGS who assisted with this study include D'An M. Brent, Susan G. Davis, Neil M. Dubrovsky, Mary Elizabeth, Yvonne M. Gobert, Ray J. Hoffman, Michael P. Hunerlach, Mark Jennings, Donna L. Knifong, David K. Uyematsu. Individuals from the Bureau of Land Management who helped coordinate and fund the project include Sean Barrow, David Lawler, Richard Forester, and Richard Grabowski. Rick Weaver and Janine Clayton of the Forest Service also helped with coordination and funding. Individuals from the EPA who helped provide analyses of fish from Rollins Reservoir include David Jones, Catherine McCracken, Bradley Shipley, and Christopher Weden. Additionally, Richard Humphreys of the California State Water Resources Control Board, and Curtis Davidson and Ron Zinke of the Nevada County Resource Conservation District assisted with gaining access to sampling sites and in securing funding for this study. Terry Mayfield and several other individuals at the Nevada Irrigation District aided with access to sampling sites. The authors also thank Sydney Brown, Marilyn Murphy, J. Ray Patton, and other staff of the California Department of State Parks and Recreation for access to sampling sites in the Humbug Creek drainage.

Reviews by Jay Davis (San Francisco Estuary Institute), Darell Slotton (University of California, Davis), Robert Brodberg and Gerry Pollock (OEHHA), and Ray J. Hoffman, Rick T. Iwatsubo, and Michael K. Saiki (USGS) greatly improved this report.

STUDY DESIGN AND METHODS

Sample Collection and Processing

During August through October 1999, the USGS collected fish from 5 reservoirs and 14 stream locations in the watersheds of the South Yuba River, Deer Creek, and the Bear River. Fish were collected from Lake Englebright, Scotts Flat Reservoir, Rollins Reservoir, Lake Combie, and Camp Far West Reservoir (fig. 2). The stream sampling sites (fig. 2, table 1) included areas near the reservoirs, historic mine sites, and two "reference" sites upstream of known historic gold-mining activity. Complete site names are given in the Appendix and abbreviated versions are given in table 1.

Most fish were collected from reservoirs and streams using electrofishing equipment; two fish were collected by hook and line, and one fish by dip-netting. Rainbow trout stocked for fishing purposes were not collected during this study; stocked rainbow trout were differentiated from native trout by the presence of fused and bent fin rays. Fish were held in clean buckets or tubs with ambient water until they were weighed, to the nearest gram, and measured for standard and total length, in millimeters. The standard length is the distance from the upper lip to the posterior end of the vertebral column, excluding the caudal fin rays. After recording the length and weight, spines were removed from the channel catfish for age determination (to be published separately). Each fish was then wrapped in clean, heavy-duty aluminum foil, labeled, and placed in a plastic bag on wet ice for less than 8 hours. They were then taken to the laboratory where they were stored frozen until processing.

The processing of fish followed standard procedures (U.S. Environmental Protection Agency, 1995). Fish were handled with powder-free vinyl gloves, and dissections were performed on a new sheet of heavy-duty aluminum foil for each fish. High-quality stainless steel instruments and disposable scalpel blades were used in the processing of fish samples, and instruments were cleaned thoroughly between samples. Cleaning of the instruments involved washing with polished water (deionized water, further refined with an additional step to remove organic compounds) and laboratory detergent, acid washing, and finally

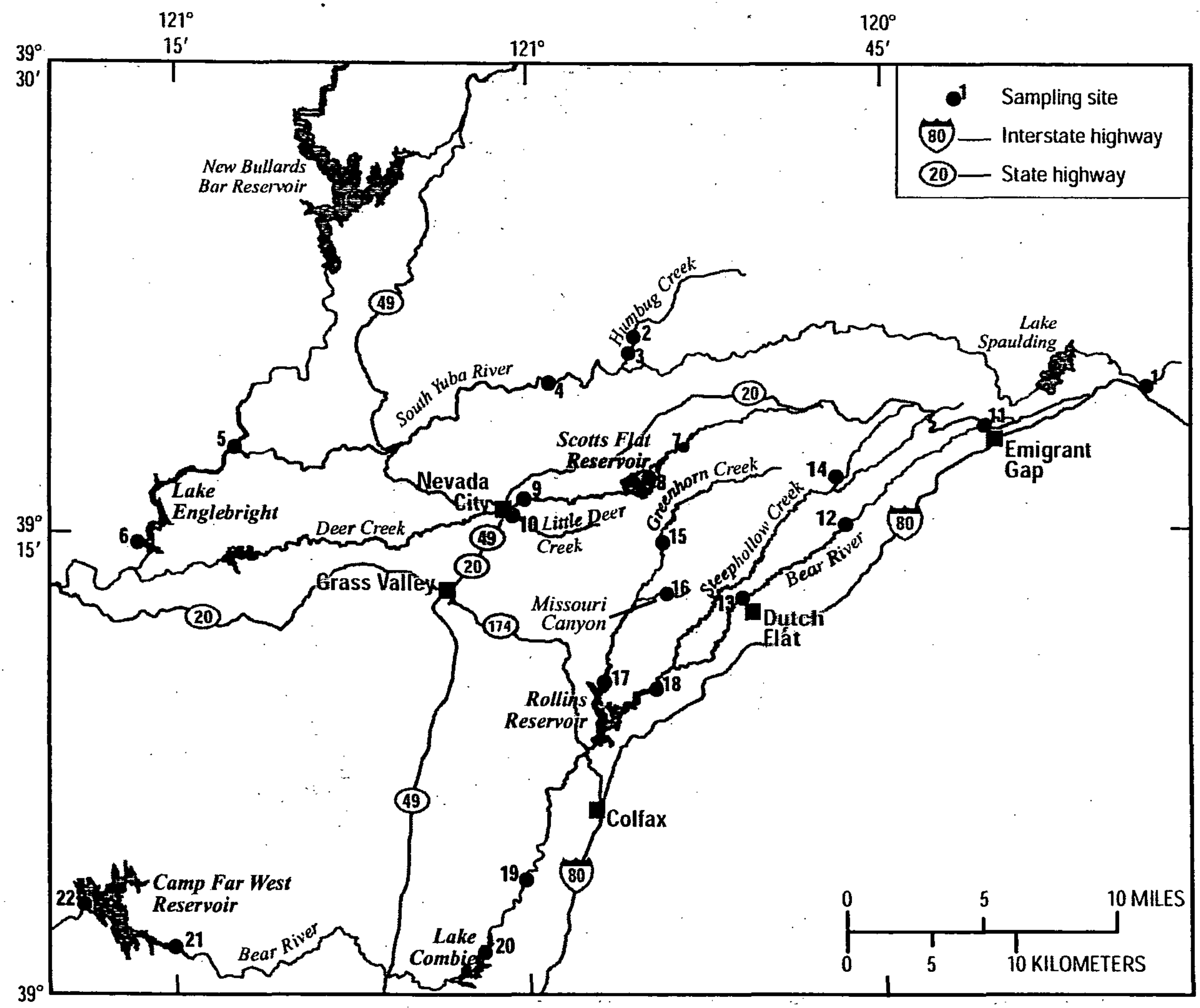


Figure 2. Fish sampling sites in the South Yuba River, Deer Creek, and Bear River watersheds, California, 1999.

rinsing the instruments with polished water before and after dissections of each fish specimen. Fish were thawed and scaled, or the skin was removed (on scaleless fish such as channel catfish) before dissection. Scales were removed for age determination (to be published separately). Boneless and skinless fillet portions were dissected from the upper medial-axial region of the fish in an approximately rectangular shape. Excised tissues were placed directly into labeled, chemically cleaned borosilicate glass jars on a pretared balance, the sample weight was recorded, and Teflon-lined lids were then screwed atop jars and sealed with Parafilm. Fish tissue samples were stored frozen in sealed sample jars until they were packed in coolers with dry ice and shipped to the analytical laboratory.

Muscle tissues were removed from both the left and right fillet of each fish processed during this study. Tissues dissected from the left fillet were labeled either with sample numbers beginning with "F" for individual samples or with "C" for composite samples. Composite samples were used for initial screening of mercury concentrations. The composite samples consisted of similarly sized tissue portions (within a tenth of a gram in most cases) from three fish of the same species that were within the same size class (that is, the smallest fish in the composite was at least 75 percent of the total weight and total length of the largest fish in the composite). Tissues removed from the right fillet were labeled with sample numbers beginning with "R." These samples served as archive samples that, in some cases, were later analyzed. Also, unless otherwise noted, "R" sample numbers that are listed in tables in this report indicate that a sample was initially analyzed as part of a composite and then later analyzed as an individual (from the archive tissue). In this situation, only the mercury concentrations for the individual samples are presented in this report.

Because multiple species of various sizes were collected in this study, there was a range in tissue sample weights collected. The ranges of sample weights submitted for analysis of each species were black crappie, 3 g; bluegill, 2–5 g; green sunfish, 3–5 g; rainbow trout, 2–10 g; brown trout, 5–15 g; smallmouth bass, 10 g; largemouth bass, 10–20 g; spotted bass, 10–20 g; and channel catfish 25–137 g. The actual sample weight excised from each fish fillet sample (or the average weight for composite samples) is listed in the data table for each sampling area, presented later in the report.

Fish samples were submitted to two analytical laboratories for total mercury analyses. The primary laboratory was the Trace Element Research Laboratory (TERL) at Texas A&M University in College Station, Texas. The U.S. Fish and Wildlife Service, through its Patuxent Analytical Control Facility in Patuxent, Maryland, has certified this laboratory for the analysis of trace elements in biological tissues. A second laboratory, Frontier Geosciences, Incorporated (FGS) in Seattle, Washington, was used for interlaboratory comparisons. The EPA, through their contractor Ecology & Environment, funded one group of analyses by FGS for this study; another group of analyses by FGS was contracted directly by the USGS.

Statistical Methods

Nonparametric statistical methods were used in this study because the data sets available for each collection area were relatively small, and a large portion of the data were not normally distributed. Nonparametric statistics, in general, are not sensitive to small sample sizes or to the potential bias of outlying values or nonnormally distributed data (Helsel and Hirsch, 1992). Geometric means were calculated for mercury concentrations because the geometric mean is less sensitive to nonnormally distributed data. The Wilcoxon paired-sample test was used to evaluate whether there were significant differences between the split sample values from the two independent laboratories. Spearman's rank correlation (Lehmann, 1975) was used to evaluate the correlations between mercury concentration and fish size (total length and total mass) within specific reservoirs. Statistical analyses were performed on mercury concentrations both on a wet and dry basis.

Laboratory Methods

Samples were packed in coolers on dry ice and shipped to the designated laboratories, with chain of custody documentation. All sample materials were received in good condition and recorded according to standard protocols by the receiving laboratories.

Trace Element Research Laboratory

Mercury concentrations were determined at TERL by cold-vapor atomic absorption spectroscopy (CVAAS) using EPA methods 245.5 and 245.6 (U.S.

Environmental Protection Agency, 1991). Prior to analysis by CVAAS, whole tissue samples were homogenized with a tissumizer in the original sample containers. After freeze-drying, samples were digested with nitric acid, sulfuric acid, potassium permanganate, and potassium persulfate in polypropylene tubes in a water bath at 90–95°C. Before analysis, hydroxylamine hydrochloride was added to reduce excess permanganate, and the samples were brought to volume with distilled, deionized water.

Tissue moisture content was determined by the weight loss upon freeze-drying and is expressed as weight percent of the original wet sample. Depending on sample size, either the whole sample or a representative aliquot was frozen, then dried under vacuum until a constant weight was attained. Sample size prior to freeze-drying was typically 5 g. Samples were prepared and dried using plastic materials to minimize potential contamination artifacts that might affect subsequent mercury analysis.

Frontier Geosciences Laboratory

Mercury analyses at FGS were performed using cold vapor atomic-fluorescence spectroscopy (CVAFS) using a modification of EPA method 1631 (U.S. Environmental Protection Agency, 1991). Prior to analysis by CVAFS, whole tissue samples were homogenized; for larger fish tissue samples, a food processor was used. For smaller fish tissue samples, homogenization was performed by chopping the fillet with a clean razor blade. Before and after homogenization, blanks were collected to confirm the absence of contamination. After homogenization, a subsample consisting of approximately 0.5 g of wet tissue was digested in a 40-mL borosilicate glass vial. Digestion was accomplished using a hot mixture of 70 percent nitric acid and 30 percent sulfuric acid for a period of approximately 2 hours, after which samples were diluted up to a final volume of 40 mL with a solution of 10 percent bromine chloride. Aliquots of each digestate were analyzed by tin-chloride reduction and dual gold-amalgamation CVAFS.

Quality Assurance and Quality Control

Both laboratories (TERL and FGS) performed internal quality assurance–quality control (QA–QC) measures. In addition, interlaboratory comparisons were made for numerous fish samples. Both laboratories conducted duplicate, blank, standard reference material (SRM), and spike recovery analyses.

Trace Element Research Laboratory

The analyses performed at TERL on samples from individual fish for this study were done in groups of 23, 42, and 66, for a total of 131. In addition, composite analyses were done with the first two groups of samples. Considering all three groups of analyses, 10 of each type of the QA–QC analyses were performed on duplicates, blanks, SRMs, and spike recoveries.

The variability of duplicate analyses was compared using the following formula for relative percent difference (RPD):

$$RPD = 100 \times \{(m_1 - m_2)/[(m_1 + m_2)/2]\} \quad (1)$$

where m_1 and m_2 are the two measurements being compared. The 10 duplicates had RPD values ranging from 0.27 to 15 percent, with 8 of the 10 values being less than 6 percent.

Procedural blanks were analyzed to assure that no analyte was added during the processing of the samples. All blanks analyzed by TERL were within an acceptable range.

The SRM used by TERL was dogfish (*Squalus sp.*) muscle, certified by the National Research Council of Canada (NRCC) as DORM-2, which has a certified reference value (CRV) of 4.64 ppm mercury (dry basis). Analyses of the SRM by TERL ranged from 4.17 to 4.88 ppm with an average value of 4.59 ppm mercury (dry basis), about 99 percent of the CRV.

Spike recoveries were done by adding mercury in the amount of about 4.00 to 5.40 ppm (dry basis) to samples in each group of analyses. The spike recoveries for ten such analyses ranged from 90.2 to 110 percent, all within acceptable limits.

Frontier Geosciences Laboratory

The analyses at the FGS laboratory were done in two groups, consisting of 31 and 11 individual fish samples. For each group, method blanks were analyzed to estimate the method detection limit (MDL). For the group of 31 samples, six method blanks were analyzed, from which an estimated MDL of 0.00051 ppm (wet basis) was determined. For the group of 11 samples, three method blanks were used to obtain an estimated MDL of 0.00025 ppm (wet basis).

A total of three replicate analyses of total mercury in fish tissue were done for the two groups of samples. The RPD values for these replicates ranged from 3.1 to 19.3 percent. Two analytical replicates also were done by FGS on moisture content analyses, giving RPD values of 0.5 and 1.4 percent. Additionally, three blind replicate samples were submitted to FGS as part of the first group of 31 analyses. The RPD values for the blind replicates ranged from 0 to 22 percent.

The SRM used by FGS was the same dogfish muscle standard (NRCC DORM-2) used by TERL, with a CRV of 4.64 ppm (dry basis). Three analyses by FGS ranged from 4.07 to 4.62 ppm (dry basis), with an average value of 4.31 ppm (dry basis), which is 92.8 percent of the CRV. The relatively low value for the SRM suggests that FGS results might have been biased toward the low side. Concerns regarding this possible bias, however, were mitigated on the basis of results of the interlaboratory comparisons, described later in this section.

FGS conducted spike recoveries on a total of six samples in the two groups of analyses. The spike levels ranged from 1.08 to 1.89 ppm (wet basis). The final reported recovery rates ranged from 98.3 to 111 percent. The initial analysis of one spiked sample gave a recovery of 128 percent, which exceeded the QC acceptance limit of FGS (125 percent). However, this sample was redone, and the rerun gave a spike recovery of 108 percent, which was within the acceptable range.

Interlaboratory Comparisons for Quality Control

Interlaboratory comparisons between TERL and FGS were performed on a total of 34 fish tissue samples (table 2). In some of the interlaboratory comparisons, one laboratory analyzed fish muscle tissue from the left fillet and the other laboratory analyzed tissue from the right fillet. Other comparisons were made in which both laboratories analyzed subsamples of tissue from the right fillet.

The Wilcoxon sign-rank test, used to compare mercury concentrations (wet basis) reported from the two laboratories, indicated no significant difference ($p = 0.34$, alpha = 0.001) in values reported between TERL and FGS. Statistical analysis also was performed on the dry basis analyses. There was no difference in the outcome of the statistical analysis, so the comparisons are reported on a wet basis only. In addition, RPD values were calculated as a second quality-control check on interlaboratory comparisons. RPD values of less than 30 percent were considered acceptable for these comparisons. Most interlaboratory comparisons yielded acceptable results; only 8 of 34 of the comparisons have RPD values greater than ±30 percent and 6 of 34 comparisons have RPD values greater than 20 percent (table 2). The arithmetic mean of RPD absolute values for the 34 comparisons is 15 percent, and the median absolute value is 11.6 percent. A correlation plot of the interlaboratory comparison data (fig. 3) indicates that there is no apparent bias toward higher mercury concentrations from one laboratory in relation to the other.

Results of both the individual laboratory QA–QC efforts and the interlaboratory comparisons (fig. 3, table 2) indicate that a high level of confidence is warranted in the accuracy of the data reported in this study for total mercury concentrations in fish tissue.

MERCURY CONCENTRATIONS IN FISH

Samples of 161 fish from 5 reservoirs and 14 stream sites in the South Yuba River, Deer Creek, and Bear River watersheds (fig. 2) were analyzed for total mercury in boneless and skinless upper-medial-axial muscle tissue. Analyses on 141 samples were done, with 131 as individual samples, and 10 as composite samples of three fish each. All results for total mercury concentrations in fish tissue are reported from the primary analytical laboratory, TERL, in parts per

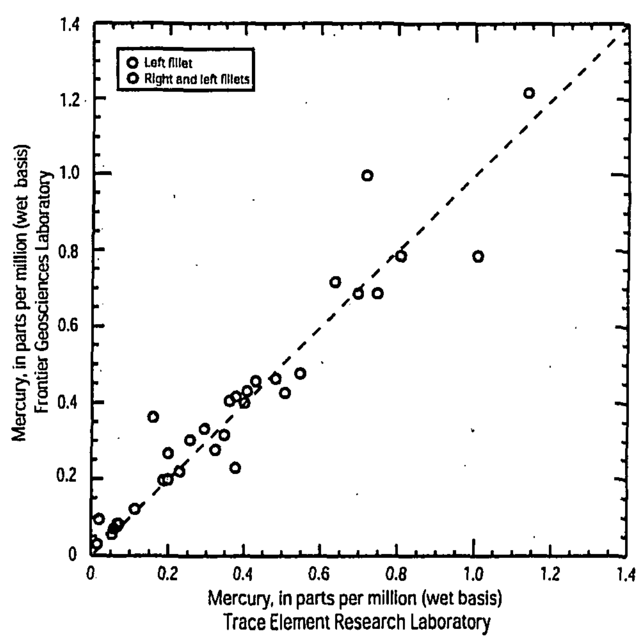


Figure 3. Correlation plot of interlaboratory comparisons for mercury concentrations in fish tissue. Orange circles represent comparison of right and left fillets, whereas white circles indicate analysis of right fillets. Dashed line represents theoretical line of perfect agreement. See table 2 for data.

million (ppm), wet basis, with two significant figures, unless noted otherwise.

Reservoirs

Lake Englebright

Twenty-one fish were collected for this study from Lake Englebright (table 3). Most samples (14) were collected from the South Yuba River arm of the reservoir near the Point Defiance campground (site 5, fig. 2), and the others were taken from the vicinity of Hogsback Ravine, a cove in the lower part of the lake near Englebright Dam (site 6, fig. 2). There were not enough data to test for differences of specific within-lake locations. Fourteen smallmouth bass were collected, including twelve from the South Yuba River arm. The smallmouth bass show a trend of increasing mercury concentration with increasing length and mass (fig. 4). Spearman's rank correlations for the 14 smallmouth bass samples (table 3) indicate significant (alpha = 0.05) relations between mercury concentration and total length ($p < 0.001$, rho = 0.88) and between mercury concentration and total mass ($p < 0.001$, rho = 0.94). Mercury concentrations in all 14 smallmouth bass, as well as the 3 spotted bass from Lake Englebright, were higher than OEHHA's screening value (SV) of 0.30 ppm. The geometric mean mercury concentration for the 14 smallmouth bass samples is 0.63 ppm. Mercury concentrations in the two largemouth bass collected for this study from Lake Englebright, however, were less than 0.30 ppm (fig. 4).

Slotton and others (1997) reported a smallmouth bass from Lake Englebright with a mercury concentration of 0.53 ppm, which fits the trend established by data from this study (fig. 4). The largemouth bass reported by Slotton and others (1997) had a mercury concentration of 0.64 ppm (fig. 4). Mercury concentrations reported by Slotton and others (1997) for species not sampled in the current study include 0.47 ppm in one sample of hardhead (*Mylopharodon conocephalus*), 0.88 ppm in one sample of common carp (*Cyprinus carpio*), and from 0.41 to 0.89 ppm in five samples of Sacramento sucker (*Catostomus occidentalis*).

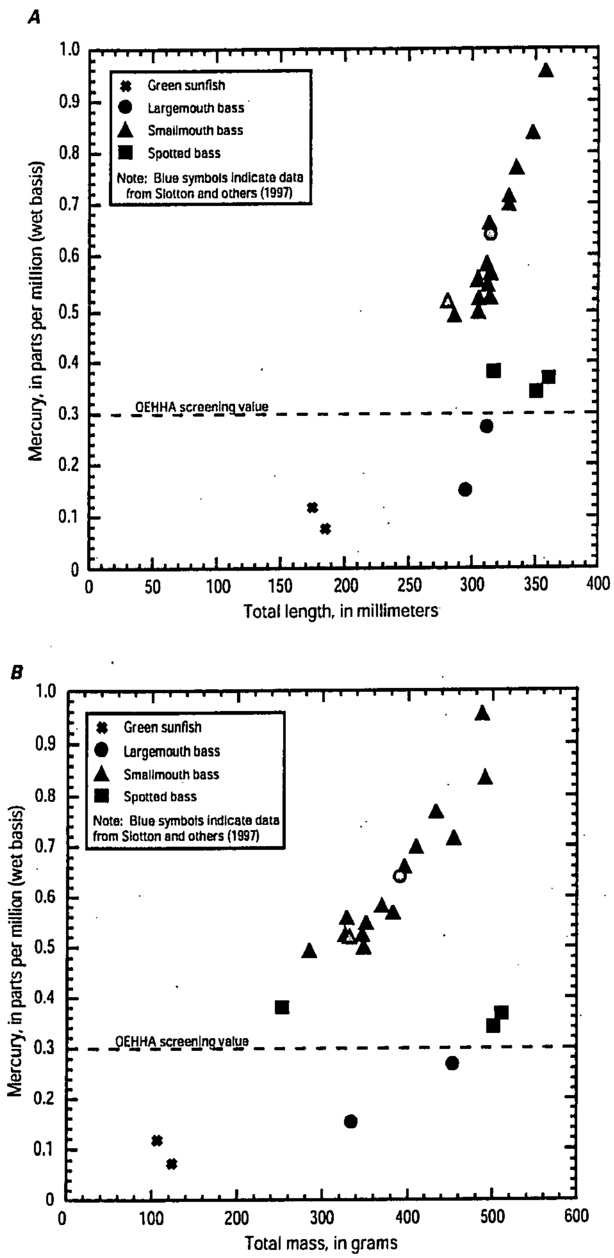


Figure 4. Mercury concentration for fish collected from Lake Englebright, California, 1999. *A*, In relation to total length. *B*, In relation to total mass. Dashed horizontal line at mercury concentration of 0.3 ppm represents a screening value provided by the Office of Environmental Health Hazard Assessment (Brodberg and Pollock, 1999). Blue symbols indicate data from Slotton and others (1997).

Scotts Flat Reservoir

Twelve fish analyses were determined for Scotts Flat Reservoir (site 8, fig. 2; table 4). Although none of these samples had mercury concentrations greater than 0.50 ppm, six of the seven largemouth bass had concentrations greater than 0.30 ppm. The geometric mean concentration for the seven largemouth bass samples is 0.36 ppm. There is no observable relation between mercury concentration and length or mass of these fish (fig. 5). In addition, Spearman's rank correlation of the seven largemouth bass samples indicate nonsignificant (alpha = 0.05) relations between mercury concentration and total length (p = 0.67, rho = –0.20) and mercury concentration and total mass (p = 1.00, rho = 0.00). Mercury concentrations in bluegill (two individual samples), green sunfish (one composite sample), and brown trout (two individual samples) from Scotts Flat Reservoir were all less than 0.20 ppm.

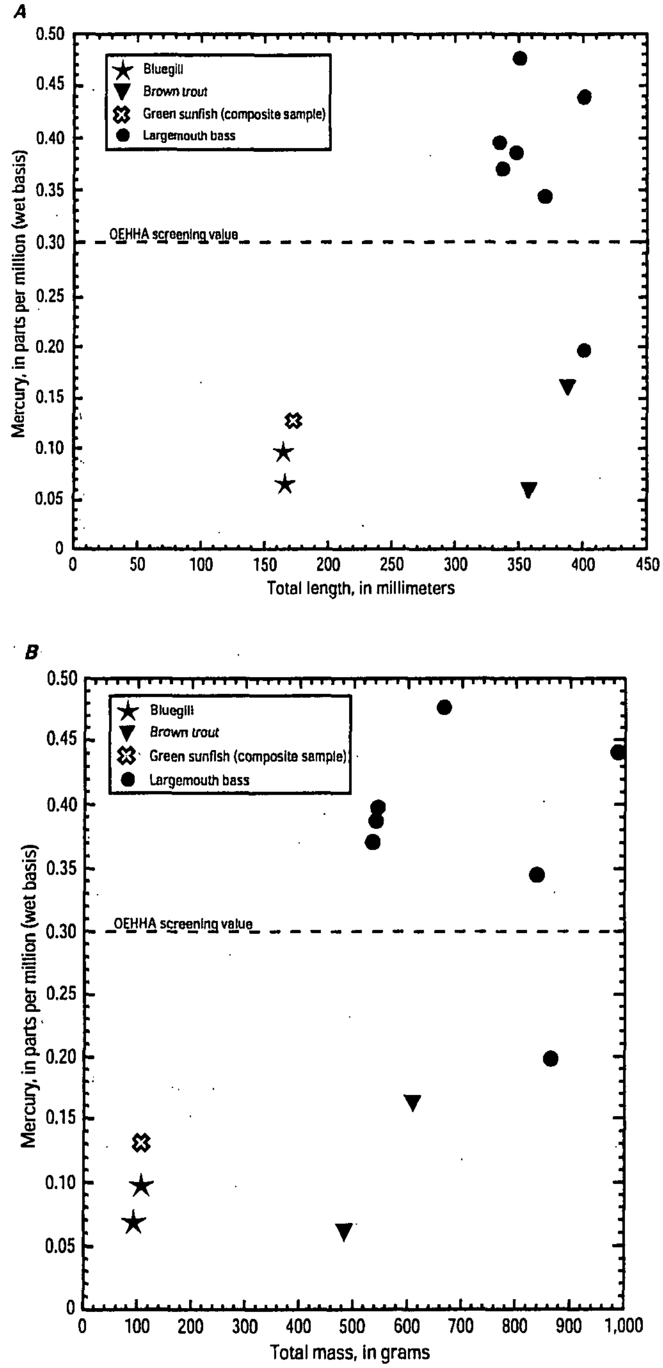


Figure 5. Mercury concentration for fish collected from Scotts Flat Reservoir, California, 1999. *A*, In relation to total length. *B*, In relation to total mass. *Dashed horizontal line at mercury concentration of 0.3 ppm represents a screening value provided by the Office of Environmental Health Hazard Assessment (Brodberg and Pollock, 1999). Green symbol indicates composite sample from this study.*

Rollins Reservoir

Twenty-eight fish analyses are reported for Rollins Reservoir; 18 samples were collected from the Bear River arm and 10 from the Greenhorn Creek arm (sites 18 and 17 respectively, fig. 2; table 5). There are not enough data to test for within-lake differences between these sampling sites. Fifteen of the 28 samples from Rollins Reservoir contained mercury concentrations greater than 0.30 ppm. Of the Rollins Reservoir samples analyzed for this study, channel catfish had the highest concentrations of mercury; the geometric mean for 13 catfish samples is 0.35 ppm. No clear relation is evident between fish length or mass and mercury concentration in the channel catfish (fig. 6). Spearman's rank correlations indicate nonsignificant (alpha = 0.05) relations between mercury concentration and total length (p = 0.94, rho = – 0.02) and between mercury concentration and total mass (p = 0.80, rho = 0.07). In contrast, the seven largemouth bass collected from Rollins Reservoir show a trend of increasing mercury concentration with increasing length and mass (fig. 6). Spearman's rank correlations of these seven bass samples indicate a significant (alpha = 0.05) relation between mercury concentration and total length (p = 0.04, rho = 0.79) and between mercury concentration and total mass (p = 0.01, rho = 0.86). Mercury concentrations in the seven largemouth bass samples ranged from 0.20 to 0.45 ppm with a geometric mean concentration of 0.33 ppm. Seven bluegill samples were analyzed as two composite samples of three fish each, plus one individual sample. The two composite samples of bluegill had mercury concentrations of 0.16 and 0.21 ppm, whereas the individual sample had an anomalously high concentration of 0.41 ppm. A composite sample of three black crappie had a mercury concentration of 0.31 ppm, and four individual brown trout samples had mercury concentrations less than 0.10 ppm.

Mercury data for four fish from Rollins Reservoir are reported in the California Toxic Substances Monitoring Program (TSMP) database (State Water Resources Control Board, accessed July 3, 2000). A largemouth bass collected in 1985, somewhat larger in size than the bass collected in this study from Rollins Reservoir, had 0.56 ppm mercury; this concentration is higher than all of the fish analyses for Rollins Reservoir from the current study, including bass and

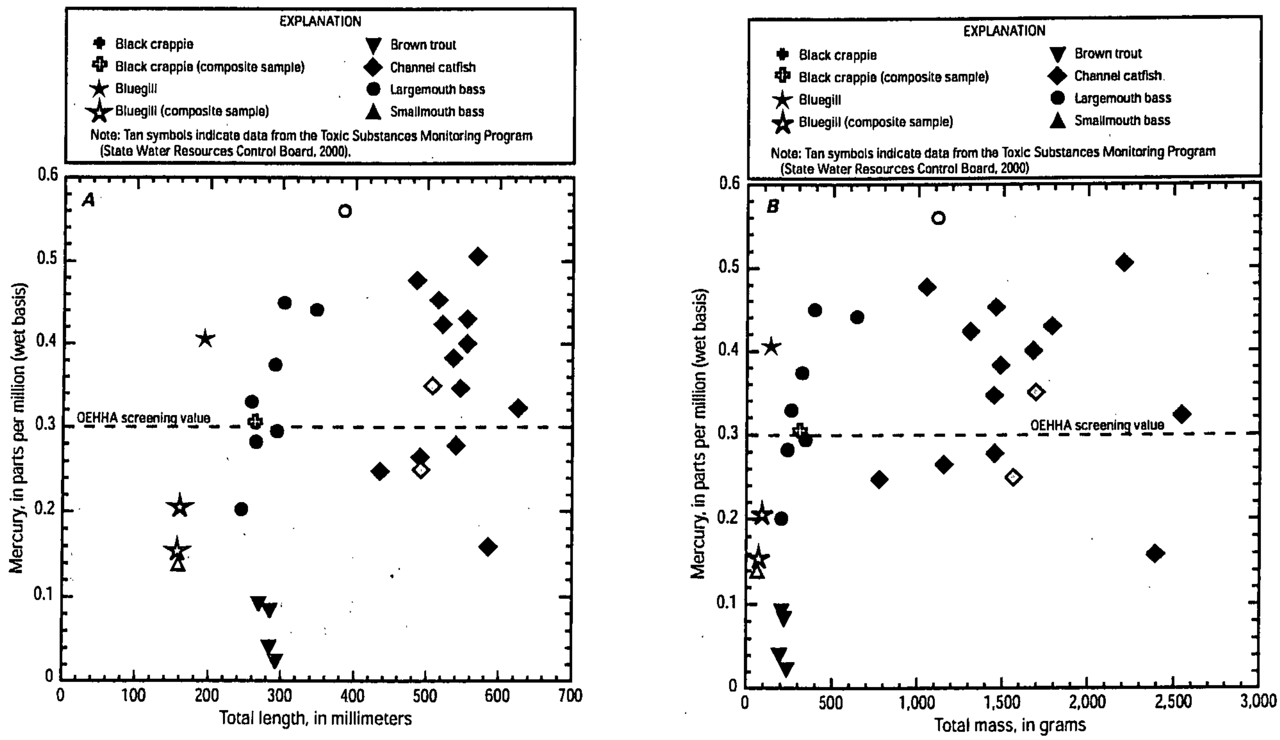


Figure 6. Mercury concentration for fish collected from Rollins Reservoir, California, 1999. *A*, In relation to total length. *B*, In relation to total mass. Dashed horizontal line at mercury concentration of 0.3 ppm represents a screening value provided by the Office of Environmental Health Hazard Assessment (Brodberg and Pollock, 1999). Tan symbols indicate data from the State of California's Toxic Substances Monitoring Program (State Water Resources Control Board, 2000); green symbols indicate composite samples from this study.

catfish. The TSMP database also includes a smallmouth bass from Rollins Reservoir, with a mercury concentration of 0.14 ppm. Two channel catfish samples reported in the TSMP database, collected during 1984 and 1985, had concentrations of 0.25 and 0.35 ppm, both within the range of the concentrations in catfish samples analyzed for this study (fig. 6, table 5).

Lake Combie

Thirteen fish were collected from Lake Combie, all from the northeastern part of the lake (site 20, fig. 2; table 6). The total mercury concentrations in largemouth bass (nine individual samples) range from 0.74 to 1.2 ppm. Five of the nine largemouth bass samples had mercury concentrations greater than 0.90 ppm; the geometric mean mercury concentration for the nine largemouth bass samples is 0.90 ppm. There is no significant trend for increasing mercury concentrations associated with length or mass in largemouth bass from Lake Combie (fig. 7). Spearman's rank correlations of the nine largemouth bass samples indicate nonsignificant (alpha = 0.05) relations between mercury concentration and total length (p = 0.73, rho = 0.13) and between mercury concentration and total mass (p = 0.46, rho = 0.28). Two individual rainbow trout samples and two individual bluegill samples from Lake Combie had mercury concentrations less than or equal to 0.20 ppm.

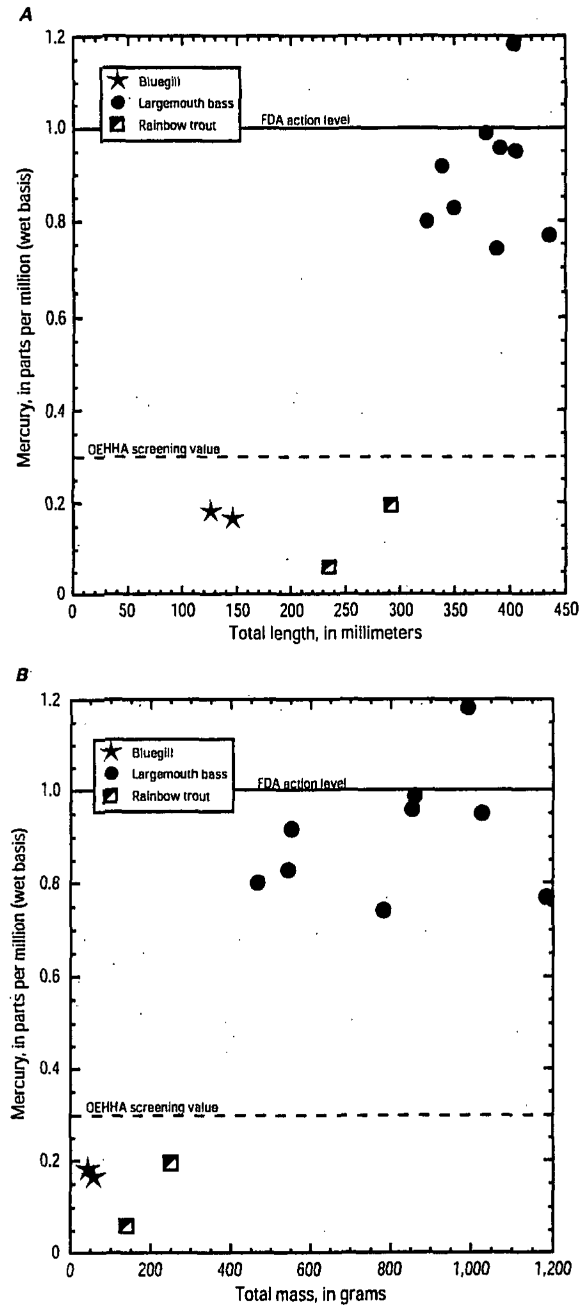


Figure 7. Mercury concentration for fish collected from Lake Combie, California, 1999. *A*, In relation to total length. *B*, In relation to total mass. Dashed horizontal line at mercury concentration of 0.3 ppm represents a screening value provided by the Office of Environmental Health Hazard Assessment (Brodberg and Pollock, 1999). Solid horizontal line at mercury concentration of 1.0 ppm indicates the Food and Drug Administration (FDA) action level for commercial fish.

Camp Far West Reservoir

Twenty-one fish analyses are reported from Camp Far West Reservoir; 14 samples were taken from the Bear River arm of the reservoir, and the remaining samples from near the dam (sites 21 and 22 respectively, fig. 2; table 7). There are not enough data to test for within-lake differences. Nineteen of the 21 samples collected from Camp Far West Reservoir had mercury concentrations greater than 0.30 ppm. Mercury concentrations for the 14 spotted bass samples range from 0.58 to 1.5 ppm, and the geometric mean concentration was calculated as 0.92 ppm; 7 of the 14 spotted bass had mercury concentrations greater than or equal to 1.0 ppm. The 14 spotted bass samples from Camp Far West Reservoir show weak, apparent positive relations for mercury concentration in relation to length and mass (fig. 8); however, Spearman's rank correlations for these samples indicate nonsignificant (alpha = 0.05) relations between mercury concentration and total length (p = 0.09, rho = 0.46) and between mercury concentration and total mass (p = 0.17, rho = 0.39). In addition, the three channel catfish collected from Camp Far West Reservoir had mercury concentrations between 0.51 and 0.75 ppm.

Data on two largemouth bass samples, one collected in 1987 and the other in 1990, are reported in the TSMP database (State Water Resources Control Board, accessed July 3, 2000). These samples had mercury concentrations of 0.40 and 0.65 ppm, respectively, and they were generally smaller than the largemouth and spotted bass samples collected for this study (fig. 8).

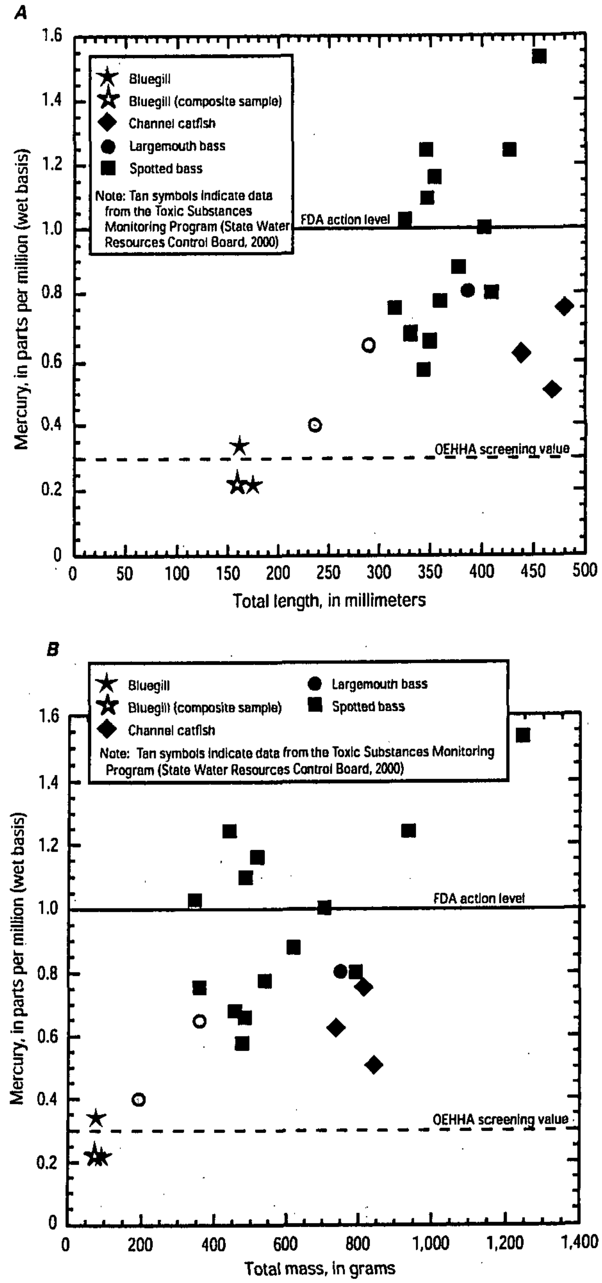


Figure 8. Mercury concentration for fish collected from Camp Far West Reservoir, California, 1999. *A*, In relation to total length. *B*, In relation to total mass. Dashed horizontal line at mercury concentration of 0.3 ppm represents a screening value provided by the Office of Environmental Health Hazard Assessment (Brodberg and Pollock, 1999). Solid horizontal line at mercury concentration of 1.0 ppm indicates the Food and Drug Administration (FDA) action level for commercial fish. Tan symbol indicates data from the State of California's Toxic Substances Monitoring Program (State Water Resources Control Board, 2000); green symbol indicates composite sample from this study.

Stream Habitats

Forty-six analyses are reported for brown and rainbow trout collected from stream habitats of the South Yuba River, Deer Creek, and Bear River watersheds (table 8). Mercury concentrations in trout samples from 14 of 14 sampling sites were less than 0.30 ppm (fig. 9; table 8). Two sites—South Yuba River near Emigrant Gap (site 1, fig. 2) and Bear River at Highway 20 (site 11, fig. 2)—were reference sites, relatively unaffected by historic gold mining activities. Ten of 11 trout samples from these two reference sites had mercury concentrations less than 0.10 ppm (fig. 9).

Three sampling sites—Bear River at Dog Bar Road (site 19, fig. 2), Little Deer Creek at Pioneer Park (site 10, fig. 2), and Deer Creek at Willow Valley Road (site 9, fig. 2)— had one or more individual trout samples with concentrations greater than 0.30 ppm (table 8). The Bear River at Dog Bar Road site had trout (two brown and one rainbow) with mercury concentrations that ranged from 0.38 to 0.43 ppm (fig. 9). The six brown trout collected from Little Deer Creek at Pioneer Park had mercury concentrations that ranged from 0.23 to 0.39 ppm with a geometric mean of 0.32 ppm (fig 9). Four brown trout taken from Deer Creek at Willow Valley Road had mercury concentrations that ranged from 0.11 to 0.32 ppm; a rainbow trout from this location had a concentration of 0.22 ppm (table 8).

Slotton and others (1997) presented data for 22 rainbow trout and 2 brown trout from stream habitats in the South Fork Yuba watershed, 9 rainbow trout collected below Englebright Dam in the lower Yuba River, and a single rainbow trout from the Bear River below Rollins Reservoir. Fourteen rainbow trout samples from the South Yuba River at Washington were used by Slotton and others (1997) to compute a normalized mercury concentration of 0.21 ppm, corresponding to a hypothetical rainbow trout with a mass of 250 g. The overall range in mercury concentration for the 32 rainbow trout from these watersheds reported by Slotton and others (1997) was 0.04 to 0.30 ppm, which is similar to the overall range for concentrations in rainbow trout in the present study (0.06 to 0.38 ppm). The number of brown trout analyzed by Slotton and others (1997) were too low for meaningful comparisons to be made with the present study.

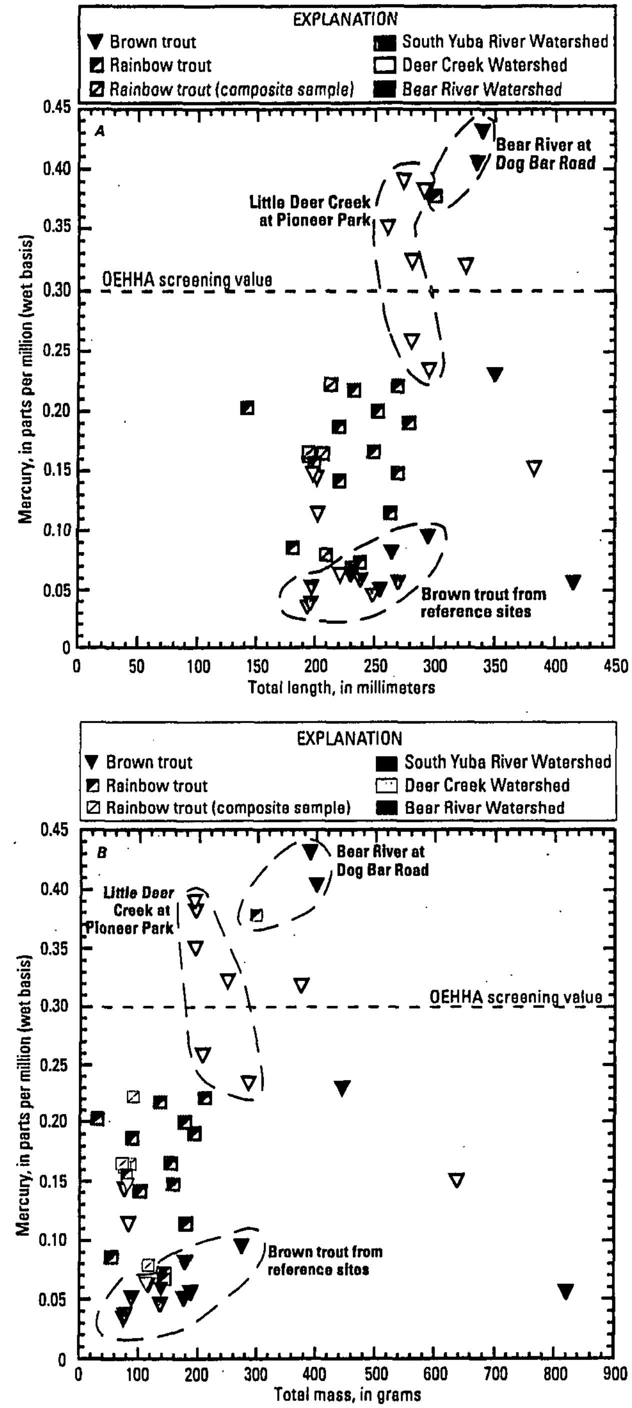


Figure 9. Mercury concentration for stream fish samples ollected from the South Yuba River, Deer Creek, and Bear River watersheds, California, 1999. *A*, In relation to total length. *B*, In relation to total mass. Dashed horizontal line at mercury concentration of 0.3 ppm represents a screening value provided by the Office of Environmental Health Hazard Assessment (Brodberg and Pollock, 1999).

DISCUSSION

Numerous studies indicate that mercury bioaccumulates in fish muscle tissue and that mercury concentrations typically increase with increasing fish size and age (Phillips and others, 1980; Lange and others, 1993; Driscoll and others, 1994; Munn and Short, 1997; Neumann and others, 1997; Stafford and Hayes, 1997; Neumann and Ward, 1999). Considering all reservoir fish collected in this study, the best correlation between increasing size and mercury concentration for an individual species from a specific waterbody was found in smallmouth bass from Lake Englebright (fig. 4). Rollins Reservoir (fig. 6) and Camp Far West Reservoir (fig. 8) were the other reservoirs with positive correlations for mercury concentration in relation to increasing size for specific species of bass (*Micropterus spp.*).

It is difficult to compare mercury concentrations among the three bass species from the different reservoirs sampled in this study because the total number of samples from each reservoir was relatively small, each species of bass was not represented in each reservoir, and the size range of bass was different in each reservoir. Nevertheless, some general characteristics are apparent when the mercury data for all bass (*Micropterus spp.*) are plotted as a function of fish length and mass (fig. 10). The highest mercury concentrations were found in spotted bass collected from Camp Far West Reservoir and in largemouth bass collected from Lake Combie (fig. 10; table 9). Considering all of the bass data together, Scotts Flat Reservoir is the only reservoir site for which the data do not follow a general trend of increasing mercury concentration with increasing size.

Slotton and others (1997) investigated many of the streams of the northwestern Sierra Nevada region and identified the Yuba River and Bear River watersheds as problematic areas for mercury bioaccumulation in the food chain. Their study primarily focused on invertebrates and fish from stream habitats, with relatively few fish samples collected from the reservoirs in these watersheds. The data from the present study adds to the knowledge of the distribution of mercury concentrations in fish in these watersheds, and supports the conclusions of Slotton and others (1997) that the South Yuba River, Deer Creek, and Bear River watersheds have elevated concentrations of bioavailable mercury.

The data presented in this report contribute to a better understanding of the occurrence and distribution of mercury and methylmercury in the South Yuba River, Deer Creek, and Bear River watersheds. Results from the current study suggest the need for investigations of reservoirs in other Sierra Nevada foothill watersheds that have had similar historic gold mining activities.

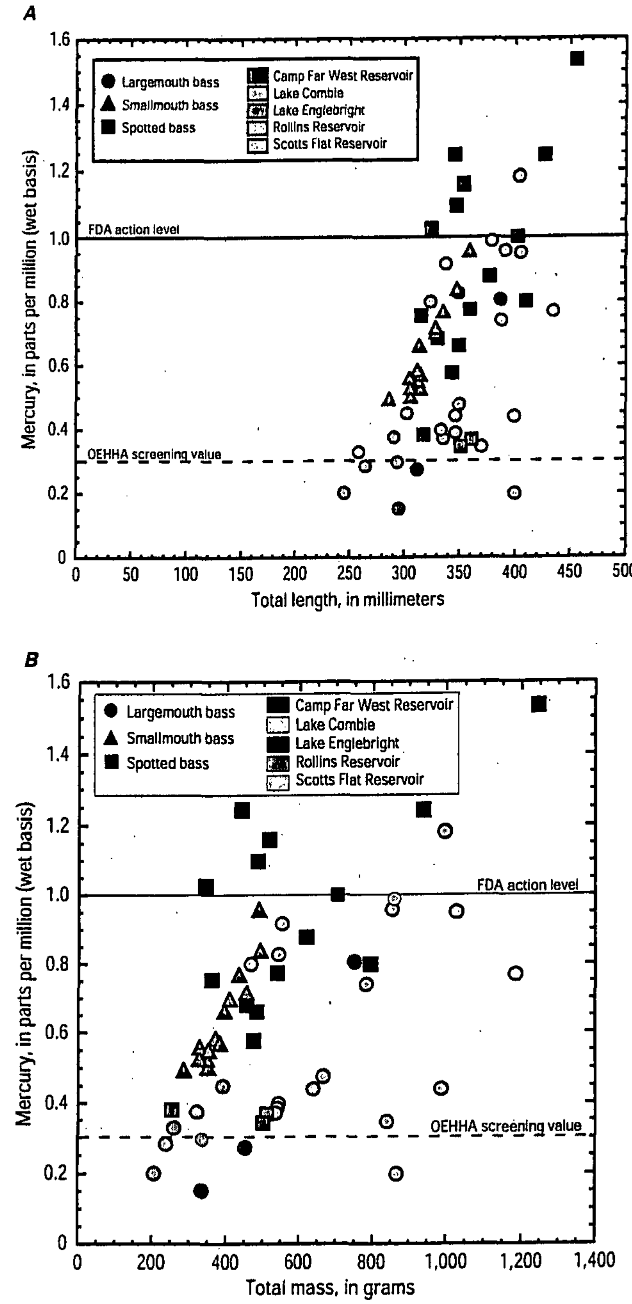


Figure 10. Mercury concentration for all bass (*Micropterus spp.*) samples collected from reservoirs in the South Yuba River, Deer Creek, and Bear River watersheds, California, 1999. *A*, In relation to total length. *B*, In relation to total mass. Dashed horizontal line at mercury concentration of 0.3 ppm represents a screening value provided by the Office of Environmental Health Hazard Assessment (Brodberg and Pollock, 1999). Solid horizontal line at mercury concentration of 1.0 ppm indicates the Food and Drug Administration (FDA) action level for commercial fish.

SUMMARY AND CONCLUSIONS

Mercury concentrations in fish collected from the South Yuba River, Deer Creek, and Bear River watersheds are summarized in table 9. The highest mercury concentrations were found in the upper-trophic-level predators—the largemouth, smallmouth, and spotted bass—from Camp Far West Reservoir and Lake Combie in the Bear River watershed, and Lake Englebright in the South Yuba River watershed.

Mercury concentrations exceeded 1.0 ppm, the FDA's action level for regulating mercury concentrations in commercial fish, in 14 percent (8 of 57) of the samples of bass (*Micropterus spp.*) analyzed for this study. Sixty-five percent of the black bass (*Micropterus spp.*) samples (37 of 57) had mercury concentrations greater than 0.50 ppm, and 88 percent (50 of 57) had mercury concentrations greater than 0.30 ppm, the level used by OEHHA as a screening value.

Mercury concentrations in benthic omnivores (channel catfish) and intermediate-trophic-level predators [sunfish (bluegill, green sunfish, and black crappie)] were generally lower than in black bass samples. Upper-level predators that feed on prey with more elevated mercury concentrations likely bioaccumulate mercury to a greater extent than the lower-trophic-level taxa.

Brown trout and rainbow trout collected from stream environments were found to have generally much lower mercury concentrations than the bass and catfish collected from the reservoirs. Trout are primarily insectivorous species and they were collected mostly from streams that are less likely to be mercury methylation sites than the reservoirs. Nevertheless, trout from three stream sites sampled in this study—Little Deer Creek at Pioneer Park (site10, fig. 2), Bear River at Dog Bar Road (site19, fig. 2), and Deer Creek at Willow Valley Road (site 9, fig. 2)—showed relatively elevated mercury concentrations greater than 0.30 ppm.

The data provided in this report may be useful to local, state, and federal agencies responsible for assessing potential risks associated with elevated concentrations of mercury in fish tissues in the South Yuba River, Deer Creek, and Bear River watersheds. Results from the present study suggest the need for investigation of mercury levels in fish from reservoirs and stream habitats in other watersheds that have been affected by historic gold-mining activities, especially hydraulic mining.

REFERENCES CITED

Alpers, C.N., and Hunerlach, M.P., 2000, Mercury contamination from historic gold mining in California: U.S. Geological Survey Fact Sheet FS-061-00.

Bloom, N.S., 1992, On the chemical form of mercury in edible fish and marine invertebrate tissue: Canadian Journal of Fisheries and Aquatic Sciences, v. 49, no. 5, p. 1010–1017.

Bowie, A.J., 1905, A practical treatise on hydraulic mining in California (10th ed.): New York, Van Nostrand, 313 *p.

Brodberg, R.K., and Pollock, G.A., 1999, Prevalence of selected target chemical contaminants in sport fish from two California lakes: Public health designed screening study, Final project report CX 825856-01-0, Office of Environmental Health Hazard Assessment, June 1999, 24 p. Available online at URL http://www.oehha.ca.gov/fish/nor_cal/CX825.html

Causey, J.D., 1998, MAS/MILS Arc/Info point coverage for the western U.S., excluding Hawaii: U.S. Geological Survey Open-File Report 98-512, 25 p.

Churchill, R., 1999, Insights into California mercury production and mercury availability for the gold mining industry from the historical record: Geological Society of America Abstracts with Program, v. 31, no. 6, p. 45.

Davidson, P.W., Myers, G.J., Cox, C., Axtell, C., Shamlaye, C., Sloane-Reeves, J., Cernichieri, E., Needham, L., Choi, A., Wang, Y., Berlin, M., and Clarkson, T.W., 1998, Effects of prenatal and postnatal methylmercury exposure from fish consumption on neurodevelopment: Outcome at 66 months of age in the Seychelles child development study: Journal of the American Medical Association, v. 280, no 8, p. 701–707.

Domagalski, J.L., 1998, Occurrence and transport of total mercury and methylmercury in the Sacramento River Basin, California: Journal of Geochemical Exploration, v. 64, p. 277–291.

Driscoll, C.T., Yan, C., Schofield, C.L., Munson, R., and Holsapple, J., 1994, The mercury cycle and fish in Adirondack lakes: Environmental Science & Technology, v. 28, no. 3, p. 136A–143A.

Foulke, J.E., 1994, Mercury in Fish: Cause for Concern? FDA Consumer, September 1994, Revised May 1995. Accessed July 3, 2000 at URL http://www.fda.gov/opacom/catalog/mercury.html

Helsel, D.R., and Hirsch, R.M., 1992, Statistical methods in water resources: Amersterdam, The Netherlands, Elsevier, Studies in Environmental Science 49, 522 p., software in pocket (5 1/4 diskette).

Hunerlach, M.P., Rytuba, J.J., and Alpers. C.N., 1999, Mercury contamination from hydraulic placer-gold mining in the Dutch Flat mining district, California *in* Morganwalp, D.W., and Buxton, H.T., eds., U.S.

Geological Survey Toxic Substances Hydrology Program — Proceedings of the Technical Meeting, Charleston, South Carolina, March 8-12, 1999: U.S. Geological Survey Water-Resources Investigations Report 99-4018B, v. 2, p. 179–190.

Lange, T.R., Royals, H.E., and Connor, L.L., 1993, Influence of water chemistry on mercury concentrations in largemouth bass from Florida lakes: Transactions of the American Fisheries Society, v. 122, no. 1, p. 74–84.

Lehman, E.L., 1975, Nonparametrics, statistical methods based on ranks: Oakland, Calif., 457 p.

Long, K.R., De Young, J.H., Jr., and Ludington, S.D., 1998, Database of significant deposits of gold, silver, copper, lead, zinc in the United States: U.S. Geological Survey Open-File Report 98-206A, 33 p.

Moyle, P.B., 1976, Inland fishes of California: Berkeley, Calif., University of California Press, 405 p.

Munn, M.D., and Short, T.M., 1997, Spatial heterogeneity of mercury bioaccumulation by walleye in Franklin D. Roosevelt Lake and the upper Columbia River, Washington: Transactions of the American Fisheries Society, v. 126, no. 3, p. 477–487.

Neumann, C.M., Kauffmann, K.W., and Gilroy, D.J., 1997, Methylmercury in fish from Owyhee Reservoir in southeast Oregon: Scientific uncertainty and fish advisories: The Science of the Total Environment, v. 204, no. 3, p. 205–214.

Neumann, R.M., and Ward, S.M., 1999, Bioaccumulation and biomagnification of mercury in two warmwater fish communities: Journal of Freshwater Ecology, v. 14, no. 4, p. 487–497.

Office of Environmental Health Hazard Assessment, 1999, California Sport Fish Consumption Advisories, 1999: Sacramento, California, 9 p, accessed September 7, 2000 at URL http://www .oehha.ca.gov/fish/nor_cal/index.html

Phillips, G.R., Lenhart, T.E., and Gregory, R.W., 1980, Relation between trophic position and mercury concentration accumulation among fishes from the Tongue River Reservoir, Montana: Environmental Research, v. 22, p. 73-80.

Slotton, D.G., Ayers, S.M., Reuter, J.E., and Goldman, C.R., 1997, Gold mining impacts on food chain mercury in northwestern Sierra Nevada streams: Appendix B *in* Larry Walker Associates, 1997, Sacramento River watershed mercury control planning project: report for the Sacramento Regional County Sanitation District, 74 p.

Stafford, C.P., and Hayes, T.A., 1997, Mercury concentrations in Maine sport fishes: Transactions of the American Fisheries Society, v. 126, no. 1, p. 144–152.

State Water Resources Control Board, Toxic Substances Monitoring Program data base for years 1978-1996, accessed July 3, 2000 at URL http://www.swrcb.ca.gov/programs/smw/index.html

Wolfe, M.F., Schwarzbach, S. and Sulaiman, R.A., 1998, Effects on mercury on wildlife–A comprehensive review: Environmental Toxicology and Chemistry, v. 17, no. 2, p. 146–160.

U.S. Environmental Protection Agency, 1991, Methods for the determination of metals in environmental samples: U.S. Environmental Protection Agency, Office of Research and Development, Environmental Monitoring Systems Laboratory, EPA- PA/600 4-91-010, 293 p.

———1995, Guidance for assessing chemical contaminant data for use in fish advisories. Volume 1, Fish sampling and analysis (2nd ed.): U.S. Environmental Protection Agency, office of Water, EPA823-R-95-007, variously paged.

———1997, Mercury study report to Congress: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards and Office of Research and Development, v. 1–8, EPA-452/R-97-009.

U.S. Geological Survey, 2000, Mercury data for water and sediment from the Dutch Flat Mining District, California, accessed July 3, 2000 at URL http://ca.water.usgs.gov/valley/dutch

Table 1. Fish sampling sites in the South Yuba River, Deer Creek, and Bear River watersheds, California, 1999, including report site number and collection dates

[Report site number refers to figure 2. Site name, abbreviated version of official USGS station name listed in the Appendix. mm/dd/yy, month/day/year]

Report site number	Site name	Collection date(s) (mm/dd/yy)
	South Yuba River Watershed	
1	South Yuba River near Emigrant Gap[1]	10/1/99
2	Humbug Creek above Falls	9/4/99
3	Humbug Creek below Falls	9/4/99
4	South Yuba River near Edwards Crossing	9/29/99
5	Lake Englebright (South Yuba arm)	9/16/99
6	Lake Englebright (Hogsback Ravine)	9/17/99
	Deer Creek Watershed	
7	Deer Creek above Scotts Flat Reservoir	10/6/99
8	Scotts Flat Reservoir	9/7–8/99
9	Deer Creek near Willow Valley Road	10/6/99
10	Little Deer Creek at Pioneer Park	10/6/99
	Bear River Watershed	
11	Bear River at Hwy 20[1]	8/26/99
12	Bear River above Dutch Flat	10/8/99
13	Bear River below Dutch Flat	10/8/99
14	North Fork of Steephollow Creek	8/26/99
15	Greenhorn Creek above Buckeye Drain	9/30/99
16	Missouri Canyon	9/1/99
17	Rollins Reservoir (Greenhorn Creek arm)	9/14/99
18	Rollins Reservoir (Bear River arm)	9/15/99
19	Bear River at Dog Bar Road	9/23/99
20	Lake Combie	9/10–11/99
21	Camp Far West Reservoir (Bear River arm)	9/22/99
22	Camp Far West Reservoir (at dam)	9/21/99

[1] Sampling sites upstream of known gold mining effects.

Table 2. Summary of interlaboratory comparison data for mercury concentration in fish fillet samples from the South Yuba River, Deer Creek, and Bear River watersheds, California, 1999

[ID, identification code; F, tissue sample from left fillet; R, tissue sample from right fillet; ppm, parts per million; Hg, mercury; TERL, Trace Element Research Laboratory, College Station, Texas; FGS, Frontier Geosciences, Incorporated, Seattle, Washington; RPD, relative percent difference, computed from the formula RPD = $100\times\{(m_1-m_2)/[(m_1+m_2)/2]\}$, where m_1 is the value from TERL and m_2 is the value from FGS; %, percent]

Sample ID[1]	TERL, total Hg in fish tissue (ppm wet)	FGS, total Hg in fish tissue (ppm wet)	RPD (%)
F-001/R-001[2]	0.02	0.09	–127
F-002/R-005[2]	0.30	0.33	–9.5
F-003/R-006[2]	0.20	0.27	–29.8
F-004/R-007[2]	0.16	0.36	–76.9
F-007/R-022[2]	0.06	0.06	0.0
F-008/R-023[2]	0.12	0.12	0.0
F-009/R-024[2]	0.20	0.20	0.0
F-010/R-025[2]	0.19	0.20	–5.1
F-011/R-026[2]	0.23	0.22	4.4
F-012/R-028[2]	0.07	0.08	–13.3
F-013/R-029[2]	0.07	0.08	–13.3
R-002	0.04	0.05	–22.2
R-003	0.08	0.10	–22.2
R-004	0.09	0.11	–20.0
R-008	0.43	0.45	–4.6
R-013	0.51	0.49	4.0
R-014	0.40	0.25	46.2
R-015	0.28	0.33	–16.4
R-016	0.35	0.30	15.4
R-017	0.38	0.43	–12.4
R-018	0.45	0.48	–6.5
R-019	0.42	0.42	0.0
R-020	0.27	0.24	11.8
R-086	0.40	0.44	–9.5
R-100	0.74	1.02	–31.8
R-105	0.83	0.81	2.4
R-114	0.37	0.34	8.5
R-123	0.53	0.45	16.3
R-127	0.57	0.50	13.1
R-129	0.72	0.71	1.4
R-131	0.77	0.71	8.1
R-144	1.03	0.81	23.9
R-148	1.16	1.24	–6.7
R-163	0.66	0.74	–11.4

[1] Multiple sample IDs indicate a comparison between samples of the left and right fillet, single sample IDs indicate a comparison between subsamples of the right fillet.

[2] Right fillet sample analysis (by FGS laboratory) provided by the U.S. Environmental Protection Agency.

Table 3. Data for fish collected from Lake Englebright, California, 1999, including common name, mercury concentrations, moisture content of fillet tissue, gender, total length, and total mass

[ID, identification code; Hg, mercury; ppm, parts per million; %, percent; Gender: F, female; M, male; mm, millimeter; g, gram]

Sampling location	Sample ID[1]	Common name	Tissue sample mass (g)	Total Hg (ppm dry)	Moisture (%)	Total Hg (ppm wet)	Gender	Total length (mm)	Total mass (g)
Lake Englebright (South Yuba River arm)	F-052	Green sunfish	5.10	0.36	79.0	0.08	M	185	123
Lake Englebright (South Yuba River arm)	F-053	Green sunfish	4.16	0.55	78.9	0.12	M	175	106
Lake Englebright (South Yuba River arm)	R-122	Smallmouth bass	10.70	2.3	75.5	0.56	F	304	327
Lake Englebright (South Yuba River arm)	R-123	Smallmouth bass	10.29	2.4	78.1	0.53	F	305	326
Lake Englebright (South Yuba River arm)	R-124	Smallmouth bass	10.41	3.1	81.0	0.58	M	311	369
Lake Englebright (South Yuba River arm)	R-125	Smallmouth bass	10.29	2.7	79.5	0.55	M	312	350
Lake Englebright (South Yuba River arm)	R-126	Smallmouth bass	10.16	3.2	79.5	0.66	F	313	394
Lake Englebright (South Yuba River arm)	R-127	Smallmouth bass	10.29	2.5	77.3	0.57	F	314	381
Lake Englebright (South Yuba River arm)	R-128	Smallmouth bass	10.47	2.3	77.1	0.53	F	314	345
Lake Englebright (South Yuba River arm)	R-129	Smallmouth bass	10.66	3.2	77.4	0.72	M	328	453
Lake Englebright (South Yuba River arm)	R-130	Smallmouth bass	10.70	3.3	78.5	0.70	M	328	408
Lake Englebright (South Yuba River arm)	R-131	Smallmouth bass	10.54	3.3	76.5	0.77	M	335	432
Lake Englebright (South Yuba River arm)	R-132	Smallmouth bass	10.67	3.9	78.4	0.84	M	347	490
Lake Englebright (South Yuba River arm)	R-133	Smallmouth bass	10.66	4.0	76.3	0.96	F	358	487
Lake Englebright (Hogsback Ravine)	F-059	Smallmouth bass	10.29	2.3	78.2	0.50	M	285	283
Lake Englebright (Hogsback Ravine)	F-060	Smallmouth bass	16.43	2.4	79.1	0.50	M	305	347
Lake Englebright (Hogsback Ravine)	F-054	Largemouth bass	15.41	0.74	79.4	0.15	M	295	334
Lake Englebright (Hogsback Ravine)	F-055	Largemouth bass	15.30	1.3	78.7	0.27	F	312	453
Lake Englebright (Hogsback Ravine)	F-056	Spotted bass	10.01	1.7	78.6	0.37	F	360	510
Lake Englebright (Hogsback Ravine)	F-057	Spotted bass	10.07	1.5	77.8	0.34	F	351	500
Lake Englebright (Hogsback Ravine)	F-061	Spotted bass	10.16	1.8	78.6	0.38	F	317	252

[1]Sample IDs beginning with "F" represent individual samples from the left fillet of the fish; IDs with "R" represent individual samples from right fillet of the fish.

Table 4. Data for fish collected from Scotts Flat Reservoir, California, 1999, including common name, mercury concentrations, moisture content in fish tissue, gender, total length, and total mass

[ID, identification code; Hg, mercury; ppm, parts per million; %, percent; Gender: F, female; M, male; —, undetermined; mm, millimeter; g, gram]

Sampling Location	Sample ID	Common name	Tissue sample mass (g)	Total Hg (ppm dry)	Moisture (%)	Total Hg (ppm wet)	Gender	Total length (mm)	Total mass (g)
Scotts Flat Reservoir	C-017	Green sunfish	3.34	0.67	80.5	0.13	—	171	106
Scotts Flat Reservoir	F-030	Brown trout	15.79	0.26	76.3	0.06	F	357	484
Scotts Flat Reservoir	F-031	Brown trout	15.74	0.69	76.2	0.16	M	387	608
Scotts Flat Reservoir	F-032	Bluegill	4.43	0.33	79.3	0.07	M	165	93
Scotts Flat Reservoir	F-033	Bluegill	4.56	0.51	80.9	0.10	M	164	107
Scotts Flat Reservoir	F-034	Largemouth bass	20.82	1.6	78.7	0.35	F	370	839
Scotts Flat Reservoir	F-035	Largemouth bass	20.83	0.93	78.7	0.20	F	400	867
Scotts Flat Reservoir	F-036	Largemouth bass	20.85	2.1	78.6	0.44	M	400	988
Scotts Flat Reservoir	F-039	Largemouth bass	20.81	2.2	78.5	0.48	F	350	666
Scotts Flat Reservoir	R-086	Largemouth bass	20.04	1.9	78.5	0.40	M	334	544
Scotts Flat Reservoir	R-087	Largemouth bass	20.22	1.8	79.4	0.37	M	336	537
Scotts Flat Reservoir	R-088	Largemouth bass	20.06	1.9	79.4	0.39	M	347	541

[1]Sample IDs beginning with "C" represent composite samples of three fish; corresponding tissue sample mass, total length, and weight values for composites represent arithmetic means; IDs with "F" represent individual samples from the left fillet of the fish; IDs with "R" represents individual samples from right fillet of the fish.

Table 5. Data for fish collected from Rollins Reservoir, California, 1999, including common name, mercury concentrations, moisture content in fish tissue, gender, total length, and total mass

[ID, identification code; Hg, mercury; ppm, parts per million; %, percent; Gender: F, female; M, male; —, undetermined; mm, millimeters; g, grams]

Sampling location	Sample ID[1]	Common name	Tissue sample mass (g)	Total Hg (ppm dry)	Moisture (%)	Total Hg (ppm wet)	Gender	Total length (mm)	Total mass (g)
Rollins Reservoir (Bear River arm)	R-002	Brown trout	25.29	0.19	78.7	0.04	—	284	191
Rollins Reservoir (Bear River arm)	R-003	Brown trout	23.80	0.42	80.5	0.08	—	284	221
Rollins Reservoir (Bear River arm)	R-004	Brown trout	25.55	0.43	78.8	0.09	—	269	203
Rollins Reservoir (Bear River arm)	F-001	Brown trout	15.57	0.11	79.2	0.02	—	292	239
Rollins Reservoir (Bear River arm)	R-008	Channel catfish	137.04	1.6	73.3	0.43	—	555	1,786
Rollins Reservoir (Bear River arm)	R-013	Channel catfish	113.93	2.2	77.4	0.51	—	569	2,202
Rollins Reservoir (Bear River arm)	R-014	Channel catfish	115.27	1.7	76.6	0.40	—	555	1,673
Rollins Reservoir (Bear River arm)	R-015	Channel catfish	103.58	1.1	74.4	0.28	—	540	1,446
Rollins Reservoir (Bear River arm)	R-016	Channel catfish	82.71	1.3	74.1	0.35	F	545	1,446
Rollins Reservoir (Bear River arm)	R-017	Channel catfish	102.16	1.7	76.9	0.38	M	535	1,485
Rollins Reservoir (Bear River arm)	R-018	Channel catfish	81.75	2.3	80.3	0.45	—	515	1,456
Rollins Reservoir (Bear River arm)	R-019	Channel catfish	90.53	1.4	70.6	0.42	M	521	1,304
Rollins Reservoir (Bear River arm)	R-020	Channel catfish	87.75	1.1	75.9	0.27	M	490	1,153
Rollins Reservoir (Bear River arm)	F-004	Channel catfish	40.02	0.56	71.3	0.16	—	585	2,389
Rollins Reservoir (Bear River arm)	F-005	Bluegill	5.14	2.0	79.7	0.41	—	193	138
Rollins Reservoir (Bear River arm)	C-003	Bluegill	5.04	0.99	79.1	0.21	—	161	94
Rollins Reservoir (Bear River arm)	F-002	Largemouth bass	20.07	1.4	78.5	0.30	M	294	336
Rollins Reservoir (Bear River arm)	F-003	Largemouth bass	20.16	0.93	78.4	0.20	F	245	206
Rollins Reservoir (Greenhorn Creek arm)	C-021	Black crappie	10.46	1.4	78.6	0.31	—	263	304
Rollins Reservoir (Greenhorn Creek arm)	C-022	Bluegill	3.05	0.77	79.9	0.16	—	157	75
Rollins Reservoir (Greenhorn Creek arm)	F-047	Largemouth bass	12.80	2.2	79.1	0.45	F	303	391
Rollins Reservoir (Greenhorn Creek arm)	F-048	Largemouth bass	20.13	2.1	78.5	0.44	F	347	640
Rollins Reservoir (Greenhorn Creek arm)	R-112	Largemouth bass	10.23	1.6	79.8	0.33	F	259	259
Rollins Reservoir (Greenhorn Creek arm)	R-113	Largemouth bass	10.08	1.3	78.9	0.28	M	265	239
Rollins Reservoir (Greenhorn Creek arm)	R-114	Largemouth bass	10.08	1.7	78.1	0.37	M	291	321
Rollins Reservoir (Greenhorn Creek arm)	F-049	Channel catfish	28.39	1.2	78.6	0.25	M	434	772
Rollins Reservoir (Greenhorn Creek arm)	F-050	Channel catfish	35.12	1.8	73.6	0.48	M	485	1,047
Rollins Reservoir (Greenhorn Creek arm)	F-051	Channel catfish	40.37	1.2	74.0	0.32	M	625	2,544

[1]Sample IDs beginning with "C" represent composite samples of three fish; corresponding tissue sample weight, total length, and mass values for composites represent arithmetic means; IDs with "F" represent individual samples from the left fillet of the fish; IDs with "R" represent individual samples from right fillet of the fish.

Table 6. Data for fish collected from Lake Combie, California, 1999, including common name, mercury concentrations, moisture content in fish tissue, gender, total length, and total mass

[ID, identification code; Hg, mercury; ppm, parts per million; %, percent; Gender: F, female; M, male; —, undetermined; mm, millimeter; g, gram]

Sampling location	Sample ID[1]	Common name	Tissue sample mass (g)	Total Hg (ppm dry)	Moisture (%)	Total Hg (ppm wet)	Gender	Total length (mm)	Total mass (g)
Lake Combie	F-040	Bluegill	2.49	0.84	80	0.17	F	145	57
Lake Combie	F-041	Bluegill	2.21	0.98	81.2	0.18	F	125	42
Lake Combie	F-042	Rainbow trout	8.69	0.75	74.1	0.20	F	291	250
Lake Combie	F-043	Rainbow trout	6.30	0.26	76.3	0.06	—	234	140
Lake Combie	F-044	Largemouth bass	20.79	3.6	78.5	0.77	F	435	1,186
Lake Combie	F-045	Largemouth bass	20.83	4.5	79	0.95	F	405	1,027
Lake Combie	F-046	Largemouth bass	20.89	5.3	77.6	1.2	F	404	994
Lake Combie	R-100	Largemouth bass	20.29	3.5	78.7	0.74	F	388	783
Lake Combie	R-101	Largemouth bass	20.40	4.8	79.9	0.96	F	391	854
Lake Combie	R-102	Largemouth bass	20.35	4.8	79.5	0.99	F	379	860
Lake Combie	R-103	Largemouth bass	15.26	3.8	79.1	0.80	M	324	467
Lake Combie	R-104	Largemouth bass	15.31	4.5	79.6	0.92	F	338	552
Lake Combie	R-105	Largemouth bass	15.29	3.6	77.5	0.83	F	349	543

[1]Sample IDs beginning with "F" represent individual samples from the left fillet of the fish; IDs with "R" represent individual samples from right fillet of the fish.

Table 7. Data for fish collected from Camp Far West Reservoir, California, 1999, including common name, mercury concentrations, moisture content in fish tissue, gender, total length, and total mass

[ID, identification code; Hg, mercury; ppm, parts per million; %, percent; Gender: F, female; M, male; —, undetermined; mm, millimeter; g, gram]

Sampling location	Sample ID[1]	Common name	Tissue sample mass (g)	Total Hg (ppm dry)	Moisture (%)	Total Hg (ppm wet)	Gender	Total length (mm)	Total mass (g)
Camp Far West Reservoir (at dam)	C-031	Bluegill	3.23	1.2	80.8	0.22	—	175	92
Camp Far West Reservoir (at dam)	F-067	Largemouth bass	20.29	3.8	78.9	0.81	F	387	751
Camp Far West Reservoir (at dam)	F-068	Spotted bass	20.57	3.7	78.1	0.80	M	409	792
Camp Far West Reservoir (at dam)	F-069	Spotted bass	20.60	3.9	77.6	0.88	M	377	617
Camp Far West Reservoir (at dam)	R-161	Spotted bass	15.26	3.5	78.5	0.76	M	315	356
Camp Far West Reservoir (at dam)	R-162	Spotted bass	15.46	6.0	79.1	1.2	F	345	439
Camp Far West Reservoir (at dam)	R-163	Spotted bass	15.42	3.3	79.7	0.66	F	349	482
Camp Far West Reservoir (Bear River arm)	F-062	Spotted bass	20.75	4.5	77.6	1.0	M	401	702
Camp Far West Reservoir (Bear River arm)	F-063	Spotted bass	20.68	5.7	78.0	1.2	M	426	935
Camp Far West Reservoir (Bear River arm)	F-064	Spotted bass	20.79	6.5	76.3	1.5	M	455	1,244
Camp Far West Reservoir (Bear River arm)	R-144	Spotted bass	13.17	4.8	78.5	1.0	F	324	341
Camp Far West Reservoir (Bear River arm)	R-145	Spotted bass	13.13	3.2	78.7	0.68	F	330	453
Camp Far West Reservoir (Bear River arm)	R-146	Spotted bass	13.13	2.8	79.7	0.58	F	343	472
Camp Far West Reservoir (Bear River arm)	R-147	Spotted bass	15.50	5.0	78.1	1.1	F	346	483
Camp Far West Reservoir (Bear River arm)	R-148	Spotted bass	15.60	5.4	78.3	1.2	—	353	516
Camp Far West Reservoir (Bear River arm)	R-149	Spotted bass	15.63	4.2	81.5	0.77	F	359	536
Camp Far West Reservoir (Bear River arm)	F-065	Bluegill	2.73	1.1	79.2	0.23	M	159	72
Camp Far West Reservoir (Bear River arm)	F-066	Bluegill	2.83	1.8	80.8	0.34	M	161	76
Camp Far West Reservoir (Bear River arm)	R-141	Channel catfish	25.20	3.2	80.5	0.62	M	437	737
Camp Far West Reservoir (Bear River arm)	R-142	Channel catfish	25.21	2.7	81.2	0.51	M	468	840
Camp Far West Reservoir (Bear River arm)	R-143	Channel catfish	25.22	3.6	79.2	0.75	M	479	812

[1]Sample IDs beginning with "C" represent composite samples of three fish; corresponding tissue sample mass, total length, and mass values for composites represent arithmetic means ; IDs with "F" represents individual samples from the left fillet of the fish; IDs with "R" represents individual samples from right fillet of the fish.

Table 8. Data for stream fish collected from South Yuba River, Deer Creek, and Bear River watersheds, California, 1999, including common name, mercury concentration, moisture content in fish tissue, gender, total length, and total mass

[ID, identification code; Hg, mercury; ppm, parts per million; %, percent; Gender: F, female; M, male; —, undetermined; mm, millimeter; g, gram; NF, North Fork]

Sampling location	Sample ID[1]	Common name	Tissue sample mass (g)	Total Hg (ppm dry)	Moisture (%)	Total Hg (ppm wet)	Gender	Total length (mm)	Total mass (g)
South Yuba River Watershed									
South Yuba River near Emigrant Gap[2]	R-041	Brown trout	5.33	0.28	78.9	0.06	F	238	141
South Yuba River near Emigrant Gap[2]	R-042	Brown trout	5.36	0.21	78.0	0.05	F	247	138
South Yuba River near Emigrant Gap[2]	R-043	Brown trout	5.32	0.29	80.5	0.06	F	270	189
South Yuba River near Emigrant Gap[2]	R-044	Brown trout	4.12	0.19	80.2	0.04	M	195	77
South Yuba River near Emigrant Gap[2]	R-045	Brown trout	4.25	0.18	72.4	0.05	M	196	89
South Yuba River near Emigrant Gap[2]	R-046	Brown trout	4.24	0.19	81.0	0.04	M	193	76
Humbug Creek above Falls	C-014	Rainbow trout	3.29	0.72	77.2	0.16	—	195	77
Humbug Creek above Falls	C-015	Rainbow trout	3.59	0.73	77.3	0.17	—	207	87
Humbug Creek above Falls	F-028	Rainbow trout	5.77	0.96	77.3	0.22	F	233	138
Humbug Creek below Falls	C-013	Rainbow trout	3.55	0.69	76.0	0.17	—	195	75
Humbug Creek below Falls	F-026	Rainbow trout	5.29	0.69	77.3	0.16	M	200	82
Humbug Creek below Falls	F-027	Rainbow trout	7.09	0.69	76.1	0.17	F	249	156
South Yuba River near Edwards Crossing	F-014	Rainbow trout	10.04	0.66	77.6	0.15	F	270	161
South Yuba River near Edwards Crossing	F-015	Rainbow trout	4.34	0.40	78.6	0.09	—	182	58
Deer Creek Watershed									
Deer Creek above Scotts Flat Reservoir	F-019	Brown trout	15.43	0.67	77.3	0.15	M	383	638
Deer Creek above Scotts Flat Reservoir	F-020	Brown trout	5.15	0.29	78.2	0.06	—	221	118
Deer Creek near Willow Valley Road	F-021	Brown trout	15.07	1.5	78.9	0.32	F	325	374
Deer Creek near Willow Valley Road	F-022	Rainbow trout	10.07	0.94	76.4	0.22	F	270	213
Deer Creek near Willow Valley Road	R-051	Brown trout	4.20	0.68	78.8	0.14	F	199	77
Deer Creek near Willow Valley Road	R-052	Brown trout	4.22	0.68	78.5	0.15	F	197	82
Deer Creek near Willow Valley Road	R-053	Brown trout	4.28	0.55	79.4	0.11	F	202	85
Little Deer Creek at Pioneer Park	R-054	Brown trout	7.74	2.0	81.1	0.38	F	291	196
Little Deer Creek at Pioneer Park	R-055	Brown trout	7.73	1.7	81.1	0.32	F	280	248
Little Deer Creek at Pioneer Park	R-056	Brown trout	7.64	0.95	75.3	0.23	M	295	284
Little Deer Creek at Pioneer Park	R-057	Brown trout	5.50	2.0	80.9	0.39	M	274	194
Little Deer Creek at Pioneer Park	R-058	Brown trout	5.45	1.6	77.5	0.35	F	260	195
Little Deer Creek at Pioneer Park	R-059	Brown trout	5.33	1.4	81.1	0.26	F	280	207
Bear River Watershed									
Bear River at Hwy 20[2]	F-029	Brown trout	10.11	0.43	77.8	0.10	F	295	275
Bear River at Hwy 20[2]	R-075	Brown trout	5.26	0.32	80.2	0.06	F	230	118
Bear River at Hwy 20[2]	R-076	Brown trout	5.39	0.20	75.4	0.05	F	255	177

Table 8. Data for stream fish collected from South Yuba River, Deer Creek, and Bear River watersheds, California, 1999, including common name, mercury concentration, moisture content in fish tissue, gender, total length, and total mass—*Continued*

Sampling Location	Sample ID[1]	Common name	Tissue sample mass (g)	Total Hg (ppm dry)	Moisture (%)	Total Hg (ppm wet)	Gender	Total length (mm)	Total mass (g)
Bear River at Hwy 20[2]	R-077	Brown trout	5.36	0.34	76.3	0.08	M	265	180
Bear River above Dutch Flat	F-007	Brown trout	15.35	0.26	78.2	0.06	M	416	821
Bear River above Dutch Flat	F-008	Rainbow trout	10.17	0.52	77.8	0.12	F	263	183
Bear River above Dutch Flat	F-009	Rainbow trout	9.20	0.99	79.8	0.20	M	253	180
Bear River above Dutch Flat	F-010	Rainbow trout	4.27	0.92	79.7	0.19	—	220	92
Bear River below Dutch Flat	C-006	Rainbow trout	5.10	0.36	77.9	0.08	—	210	119
Bear River below Dutch Flat	F-011	Brown trout	15.36	0.97	76.2	0.23	M	350	445
Bear River below Dutch Flat	F-012	Rainbow trout	5.10	0.30	77.2	0.07	M	231	148
Bear River below Dutch Flat	F-013	Rainbow trout	5.33	0.33	77.7	0.07	M	238	148
North Fork of Steephollow Creek	F-024	Rainbow trout	5.14	0.61	76.9	0.14	M	220	105
North Fork of Steephollow Creek	F-025	Rainbow trout	5.57	0.89	78.4	0.19	F	280	197
Greenhorn Creek above Buckeye Hill	C-007	Rainbow trout	4.25	1.1	78.9	0.22	—	213	92
Missouri Canyon	F-023	Rainbow trout	2.00	0.96	78.9	0.20	M	142	33
Bear River at Dog Bar Road	F-016	Rainbow trout	10.63	1.8	78.4	0.38	F	301	301
Bear River at Dog Bar Road	F-017	Brown trout	15.09	1.8	76.2	0.43	F	339	390
Bear River at Dog Bar Road	F-018	Brown trout	15.15	1.8	77.2	0.40	F	335	401

[1]Sample IDs beginning with "C" represent composite samples of three fish; corresponding tissue sample mass, total length, and mass values for composites represent arithmetic means; IDs with "F" represents individual samples from the left fillet of the fish; IDs with "R" represents individual samples from right fillet of the fish.

[2] Reference sites upstream from known historic gold mines.

Table 9. Range and mean values of mercury concentrations and length for selected fish species and locations within the South Yuba River, Deer Creek, and Bear River watersheds, California, 1999

[N, number of samples; Hg, mercury; ppm, parts per million; mean, geometric mean]

Common name	Sampling location	N	Total Hg (ppm wet) minimum	Total Hg (ppm wet) mean	Total Hg (ppm wet) maximum	Total length (mm) minimum	Total length (mm) mean	Total length (mm) maximum
Smallmouth bass	Lake Englebright	14	0.50	0.63	0.96	285	317	358
Largemouth bass	Scotts Flat Reservoir	7	0.20	0.36	0.48	334	361	400
Largemouth bass	Rollins Reservoir	7	0.20	0.33	0.45	245	284	347
Largemouth bass	Lake Combie	9	0.74	0.90	1.2	324	377	435
Spotted bass	Camp Far West Reservoir	14	0.58	0.92	1.5	324	364	455
Channel catfish	Rollins Reservoir	13	0.16	0.35	0.51	434	532	625
Channel catfish	Camp Far West Reservoir	3	0.51	0.62	0.75	437	460	479
Brown trout	South Yuba River near Emigrant Gap[1]	6	0.04	0.05	0.06	193	221	270
Brown trout	Deer Creek near Willow Valley Road	4	0.11	0.17	0.32	197	225	325
Brown trout	Little Deer Creek at Pioneer Park	6	0.23	0.32	0.39	260	279	295
Brown trout	Rollins Reservoir	4	0.02	0.05	0.09	269	282	292

[1] Sampling site upsream of known gold mining effects.

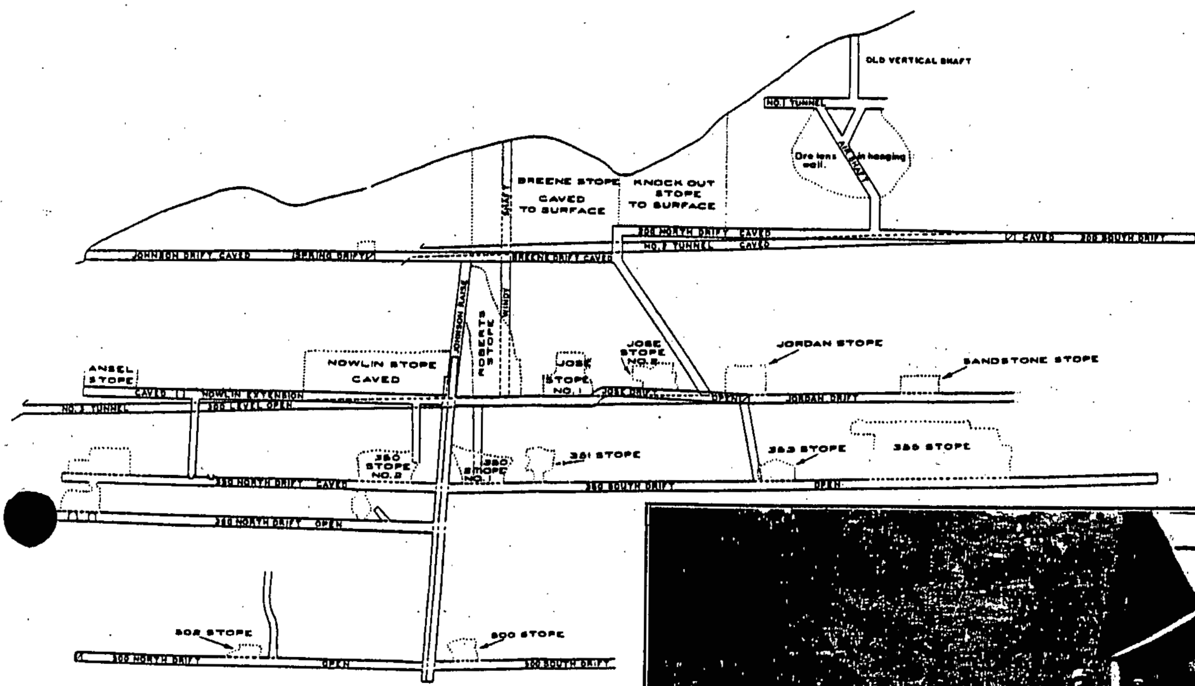
Appendix. Sampling site numbers, station names, station numbers, and locations in the South Yuba River, Deer Creek, and Bear River watersheds, California, 1999

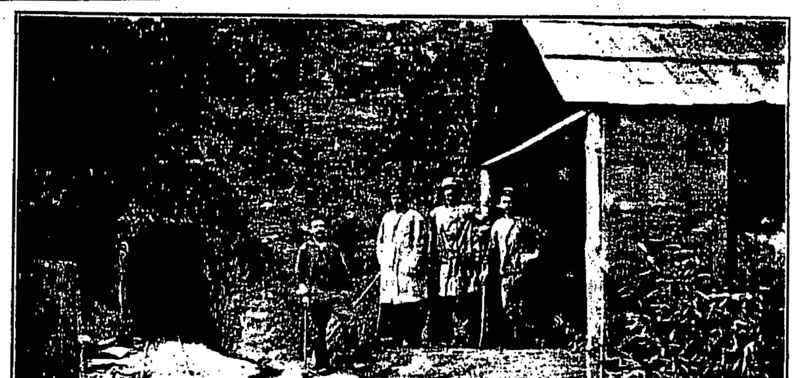
[Report site number refer numbers to figure 2 and table 1; deg, degrees; min, minutes; sec, seconds; latitude and longitude referenced to NAD 83; NAD 83, North American Datum 1983; USGS, U.S. Geological Survey. All latitude values are north of the equator all longitude values are west of the central meridian]

Report site number	USGS station name	USGS station number	Site latitude (deg min sec)	Site longitude (deg min sec)
	South Yuba River Watershed			
1	South Yuba River at Eagle Lakes Road near Emigrant Gap, California	391948120342201	39°19′52″	120°33″54″
2	Humbug Creek above Falls near Nevada City, California	392057120552901	39°21′17″	120°55′24″
3	Humbug Creek below Falls near Nevada City, California	392040120553701	39°20′47″	120°55′37″
4	South Yuba River near Edwards Crossing near Nevada City, California	391949120585001	39°19′49″	120°59′02″
5	Lake Englebright, South Yuba Arm at Point Defiance Campground near Bridgeport, California	391743121122401	39°17′47″	121°12′27″
6	Lake Englebright at Hogsback Ravine near Smartville, California	391442121163001	39°14′43″	121°16′36″
	Deer Creek Watershed			
7	Deer Creek Upstream of Scotts Flat Reservoir at Sawmill near Nevada City, California	391745120531201	39°17′44″	120°53′11″
8	Scotts Flat Reservoir Inlet South Shore near Nevada City, California	391716120540701	39°17′24″	120°54′00″
9	Deer Creek near Willow Valley Road near Nevada City, California	391602121000901	39°16′04″	121°00′06″
10	Little Deer Creek at Pioneer Park near Nevada City, California	391534121003101	39°15′34″	121°00′37″
	Bear River Watershed			
11	Bear River at Highway 20 near Emigrant Gap, California	391823120404101	39°18′23″	120°40′46″
12	Bear River below Drum Afterbay near Dutch Flat, California	391513120463101	39°15′12″	120°46′33″
13	Bear River below Dutch Flat Afterbay near Dutch Flat, California	11421790	39°12′49″	120°50′45″
14	North Fork of Steephollow Creek near Blue Canyon, California	391642120464701	39°16′45″	120°46′54″
15	Greenhorn Creek above Buckeye Drain near Nevada City, California	391437120541201	39°14′40″	120°54′12″
16	Missouri Canyon near Dutch Flat, California	391259120535801	39°12′59″	120°53′59″
17	Rollins Reservoir First Cove Greenhorn Creek arm near Chicago Park, California	391000120564301	39°10′05 ″	120°56′43″
18	Rollins Reservoir Bear arm near Chicago Park, California	390956120542501	39°10'06″	120°54′30″
19	Bear River at Dog Bar Road near Weimar, California	390346121000701	39°03'46″	121°00′09″
20	Lake Combie upper cove by Gravel Mine near Higgins Corner, California	390148121014701	39°00′38″	121°03′31″
21	Camp Far West Reservoir upper Bear River arm near Wheatland. California	390203121162701	39°01′41″	121°15′05″
22	Camp Far West Reservoir at dam near Wheatland, California	390304121184801	39°03′03″	121°18′57″

JAB

INACTIVE MINE DRAINAGE IN THE SACRAMENTO VALLEY, CALIFORNIA





Staff Report of the

California Regional Water Quality Control Board, Central Valley Region
Standards, Policies, and Special Studies Unit
3443 Routier Road, Suite A
Sacramento, California 95827

I. SUMMARY

A water quality survey was conducted between 1989 and 1991 to assess the pollutant contributions made by inactive mines in the Sacramento Valley. The goals included estimating pollutant loads and assessing impacts without assuming all mines in the watershed had been previously identified. The number of mines chosen for this study (94) were limited to those that were known or suspected water quality threats. Perennial adit drainage, waste rock, and upstream/downstream receiving waters were sampled and analyzed for several heavy metals, arsenic, and conventional parameters (flow, Eh, pH, EC). Dry weather loads were calculated with perennial adit drainage data collected largely during drought conditions (1987-1991).

Inactive mines were pervasive throughout the Valley outside the central basin and into the surrounding hills and mountains. Although not all mines had perennial adit drainage, waste rock material was observed at every site visited. Further, historical accounts and site observations indicate that ore processing operations were conducted at most of the mines, increasing the potential for water quality degradation. Minerals containing copper, lead, cadmium, and zinc were mined beginning around the mid-1800s. Other products directly or indirectly mined in the Valley included arsenic, gold, silver, mercury, and sulfur compounds. Adit drainage quality varied from unpolluted spring water to highly acidic outflow containing metals in the ppm range.

Adit releases in the Shasta Mining District exhibit characteristics typical of acid mine drainage - low pH and high metals content. Iron Mt. Mine (IMM) was the single largest loader, contributing between 57-85 percent of the estimated copper, cadmium, and zinc loads. Iron Mt. Mine loads were estimated from Spring Creek Debris Dam (SCDD) which collects water from the entire Spring Creek watershed including adit releases, waste rock erosion and seepage, and background stream flow. Unlike loads from the other mines, which were calculated using data on perennial adit drainage alone, loads from SCDD reflect the sum of year-round discharges coming from the IMM complex. The combined loads from all West Shasta District mines (Iron Mt., Mammoth, Balaklala, etc.) accounted for over 95 percent of the total copper, cadmium, and zinc inactive mine contributions to the Sacramento Valley.

Perennial mine drainage in the Sierra-Nevada mountain range was highly variable in quality. Drainage from gold mines in the Allegheny-Downieville area (Yuba River watershed) was characterized by near-neutral outflow and elevated arsenic. Positive Eh measurements indicate that the arsenic is discharged largely in the less toxic +5 state according to pH-Eh graphs. Mines in the Foothill Copper Belt (Spenceville, Valley View) exhibited typical acidic drainage but were not major loaders due to relatively small outflows.

Mercury mines are located in the Cache and Putah Creek watersheds. Although most sites were dry, a small number of western foothill mines discharged slightly acidic water characterized by high levels of iron, nickel, and carbonate compounds. Most waste rock samples contained relatively high levels of mercury.

Twenty-one of 31 receiving streams monitored during dry periods were impacted by one or more metals exceeding Inland Surface Water Plan chronic objectives. In general, the copper objective was most frequently exceeded followed by zinc and cadmium. Fewer than 9 streams exceeded the lead, nickel, and arsenic objectives and none were measured for chromium, and silver. Stream impact length appeared to depend on a variety of factors including compound-specific behavior, dilution capacity of the stream, mine loads, storm events, and the presence of complexing agents. Receiving water pollutant surges are expected during wet periods from increased adit outflows, waste rock runoff, and instream resuspension. Copper measured in Dry Creek below Spenceville Mine during a 3 inch storm event exceeded the 1-hour EPA hardness factored objective (15 ppb) by up to 8 times during a 10-hour period. Other mine influenced receiving waters are expected to experience similar impacts because of the prevalence of polluted waste rock piles at most mine sites. Waste rock runoff during the rainy season was estimated to account for 5-18 percent of the total annual copper, cadmium, and zinc loads coming from Spenceville Mine. This percentage will vary from site to site based on the magnitude of perennial loads - values range from insignificant for high volume acid mine drainage to 100 percent for dry mines. It is difficult to estimate runoff induced loads because of the variety of influencing factors including permeability, varying metals content and acidity, slope, porosity, rainfall characteristics, etc.

Almost all streams influenced by mine drainage eventually pass through one or more major reservoirs. The fraction of metals transported through a reservoir appears to depend largely on dam characteristics and the quality of upstream inputs. The concentration of several metals remained essentially unchanged between summer input-output flows at a Sierra-Nevada reservoir. The majority of the annual copper loads into Shasta Reservoir came from inactive mines which likely influenced Dam release levels - copper was approximately an order of magnitude greater than what was present in the major feeder streams not influenced by mine drainage.

II. INTRODUCTION

Mines once active in the extraction of heavy metals (e.g., mercury, gold, copper, zinc) have exposed sub-surface mineral deposits to the weathering attributes of water and air. Orebodies were mined largely around the turn of the century using underground and open pit techniques that increased the surface area of minerals highly prone to breakdown in the presence of water, oxygen, and acidophilic bacteria. Metals are leached from the minerals and transported downstream via rainfall runoff or adit discharges. These discharges can cause fish kills that have been documented as far back as 1940 (Nordstrom et al., 1977). Runoff from discarded mine soils has resulted in the issuance of health warnings against eating mercury tainted fish in Clear Lake and Marsh Creek Reservoir.

Prior to 1972, regulatory action by the regional board to abate inactive mine discharges was hindered by ineffective legislation (Miller et al., 1979). The board had limited legal means to force a mine property owner to comply. Because operations ceased altogether, the present mine/land owner was usually unwilling or economically unable to remediate the site. Further complications arose when the mine site had been sold by the original mining company. Typically, unresolved compliance was referred to the California court system because of the high costs inevitably involved. Many referrals to the District Attorney or Attorney General were not pursued, referred elsewhere, or decided in favor of the mine owner (e.g., Penn Mine in 1963; CVRWQCB, 1988). Several major mines in the Central Valley have extensive histories of regional board activity that, in some cases, exceed 30 years. Conversely, active mines permitted by the board are required to comply with the conditions of their permit as a requisite for continued operations. Regulatory options have increased since the passage of the federal Clean Water and state Porter-Cologne acts, although, some of the same cleanup impediments still remain. In many instances, government funds have been used to install control measures. Several control projects have resulted in reduced mine loads (e.g., Walker, Balaklala mines) but most attempts have not always been so successful primarily due to ineffective technology.

A water quality survey of inactive mines was conducted as part of the regional board's Basin Planning process to obtain information on pollutant loads contributed by Valley-wide sources (which also include permitted, agricultural, and urban runoff discharges). A water quality assessment using load estimates will allow us to prioritize sources of downstream impairments and help to focus control efforts on the major contributors. The cumulative input of pollutants from point and non-point sources has resulted in periodic objective exceedances for copper, zinc, cadmium, and lead in the Sacramento-San Joaquin Delta/Estuary (CVRWQCB, 1991). The regional board is responsible for developing programs to reduce overall metal loads to the Sacramento River and Delta. Although inactive mines contribute substantially to downstream concentrations, several questions remain regarding previously unsurveyed mines, waste rock runoff, and reservoir mass balance information.

This study attempted to assess the regional water quality impacts caused by inactive mines in the Sacramento Valley. In general the objectives were:

1. Estimate and compare the metals loading from known and previously unsurveyed major inactive mines.
2. Determine the pollutant contributions from waste rock runoff.
3. Assess the mass balance of metals coming into and leaving major reservoirs.

The results of this study show that most of the major mines with perennial drainage had been previously surveyed. The largest loads of copper, zinc, and cadmium came from mines located in the Shasta Mining District. The largest single loader for almost all metals was Iron Mt. Mine. Twenty-one of 31 inactive mines with perennial drainage caused impacts to downstream receiving waters using water quality objectives. Impacts are also expected at mines without perennial drainage due to runoff and seepage from waste rock piles during the wet season. Waste rock runoff caused by a 3 inch storm event significantly increased the receiving stream concentrations of suspended solids, copper, and zinc. Waste rock material was prevalent at all mines surveyed. Dam release water quality is probably influenced to some extent by upstream mine inputs.

III. MINE DRAINAGE FORMATION

Mine drainage forms as a result of past mining activities that exposed geological deposits to the natural weathering attributes of water and air. Air can enter an underground complex as advective drafts and barometric "breathing" through natural and manmade openings (e.g., shafts, vents, fractures; Shumate et al., 1971). Water entering the tunnel system originates as rainfall seepage and ground water accretion (CH2M Hill, 1984). Ground water flows intercept tunnel passageways following the path of least resistance and eventually become surface discharges when the interior floods to the level of the lowermost adit. Water participates in the weathering process as a reactant, reaction medium, and a vehicle transporting solubilized minerals out of the complex. The high humidity within a mine and large surface area of minerals exposed to oxidants are ideal conditions for reactive orebodies to degrade (Shumate et al., 1971). The volume of water discharged varies between seasons and years and outflow loads are strongly correlated with annual precipitation (Heiman, unpub. data). Drainage also originates at the surface of a mine complex where waste rock piles, composed of extracted mineral deposits, have been dumped and exposed to the same weathering forces. The off-site movement of pollutants released from waste rock material is largely limited by contact with water from sources such as precipitation, streams, and springs. The products of waste rock weathering can degrade water quality in the same manner as adit releases - elevated metals, turbidity, or acidity.

A. Acidic Drainage

Acid mine drainage is generated primarily from the oxidation of pyrite. Pyrite (FeS_2), the most common iron disulfide in California (CDMG, 1966), is susceptible to breakdown because of its high oxidation potential (Doyle and Mirza, 1989). When exposed to an oxidizing environment, the ferrous-disulfide bond is cleaved to form sulfuric acid and free iron. The generally accepted mechanism for acid formation is represented by the following pathways (from Singer and Stumm, 1970):

$$FeS_2(s) + 7/2\,O_2 + H_2O => Fe^{2+} + 2\,SO_4^{2-} + 2\,H^+ \quad (1)$$
$$Fe^{2+} + 1/4\,O_2 + H^{2+} => Fe^{3+} + 1/2\,H_2O \quad (2)$$
$$FeS_2(s) + 14\,Fe^{3+} + 8\,H_2O => 15\,Fe^{2+} + 2\,SO_4^{2-} + 16\,H^+ \quad (3)$$

Reaction pathways 1 and 3 have been proposed to describe the overall kinetics involved in the breakdown of pyrite. The direct pathway (1) involves oxygen acting directly on the pyrite crystals, whereas, the indirect pathway (3) goes forward only when the iron product of pathway 1 has oxidized to sufficient quantities via 2 (Onyesko, 1985). Oxygen serves as the oxidant in 1, producing acid at rates typically observed and can proceed only when an abundant supply of both water and oxygen are available (Taylor et al., 1984; Sullivan et al., 1988a-b). Oxygen serves as the ultimate electron acceptor that cleaves the iron-sulfide bond setting into motion a series of hydrolytic reactions that lead to the formation of sulfuric acid (Nordstrom, 1982). There are many chemical, physical, and biological factors that can affect the rate of pathway 1 including temperature, residence time of the water, pH of the medium, and the presence of microbes. However, the grain size of pyrite is thought to be a major factor controlling it's rate. Framboidal pyrite crystals less than 0.25 micron are much more prone to breakdown than larger, cubic forms (Caruccio, 1975).

Equation 3 is called the indirect pathway because ferric iron (Fe^{3+}) acts as the oxidant which is produced via conversion from the reduced form largely by a bacterially catalyzed reaction (pathway 2). The reduced species of iron (Fe^{2+} - ferrous) is initially present as a product of reactions 1 and 3. The oxidation of the ferrous ion proposed by pathway 2 is strongly facilitated by a resident microbial community tolerant of low pH waters (Drever, 1988; Singer and Stumm; 1970, Erlich, 1964; Malouf and Prater, 1961; Noike et al., 1983; Sullivan et al., 1988a). Reaction pathway 2 can proceed inorganically but the amount of dissolved oxygen present in water is insufficient in itself to perpetuate the conversion at observed rates. In the presence of acidophilic bacteria, the rate of 2 can be accelerated by up to 6 orders of magnitude over the inorganic or direct pathway and is governed by the concentration of reduced iron and size of the microbial population. The ferric ion can be generated to levels in water that strongly favor the forward direction of reaction pathway 3. Therefore, in an aqueous environment, pathway 2 is considered to be the rate determining step in the production of acid.

Mine drainage is known to support a diverse microbial community including both heterotrophic (using organic carbon) and autotrophic (using inorganic carbon) strains (Wichlacz and Unz, 1981). Chemoautotrophic bacteria have been isolated as the type catalyzing ferrous oxidation and hence the facilitation of acid mine drainage formation. Carbon dioxide is used as a food source which is metabolically incorporated via energy derived from the oxidation of divalent iron. Thiobacillus ferrooxidans and T. thiooxidans have been identified as the principal strains involved and were speciated based on their affinity for particular reduced compounds and the rate at which the compounds were oxidized (Bounds and Colmer, 1972). Optimum metabolic efficiency is generally attained within a pH range of 2.0-3.5 (Malouf and Prater, 1961) but can vary with temperature extremes (Macdonald and Clark, 1970). Although nutrients could be substituted as an energy source (Noike et al., 1983), their survival in waters above pH 6 are limited by inter-strain competition. Acidophilic microbes are generalists with a wide range of abilities enabling them to survive in extreme environments but are displaced by specialists better equipped to compete under conditions that are more favorable (i.e., in neutral streams; Mills and Mallory, 1987). The aquatic microbes become attached to stationary objects in the streambed and propagate in layers (Macdonald and Clark, 1970) which were found to be more metabolically active than their planktonic counterparts (Mills and Mallory, 1987). The oxidation of ferrous sulfate is thought to occur at the cell wall or membrane (McDonald and Clark, 1970).

The products of pyrite oxidation, as well as the dissolution products of other sulfides (e.g., CdS, CuS, ZnS) oxidized in similar fashion, concentrate to high levels in the acidic solution and are transported out of the mine complex in a singly complexed or ionic state ("dissolved"; Sullivan et al., 1988a). Minor amounts of dissolved compounds (metals, sulfate, other ions) crystallize as secondary minerals in the form of basic iron sulfates (e.g., copiapite, jarosite) and can be seen as red to yellow staining in the impacted streams (Ivarson, 1973; Fillpek et al., 1987).

As pH increases upon mixing with nearby receiving waters, the dissolved compounds become less soluble and precipitate out at a rate that is largely controlled by the formation of iron hydroxides. Between a pH of 2.5 and 4, iron instantaneously forms large masses of colloidal floc according to standard thermodynamic predictions (pathway 4; Jenke et al., 1983).

$$Fe^{2\text{-}3+} + 2\text{-}3\ H_2O \Rightarrow Fe(OH)_{2\text{-}3}(p) + 2\text{-}3\ H^+ \qquad (4)$$

Iron hydroxides are amorphous in nature (as opposed to crystalline) and are visible as thick, orange, streambed deposits. Other metals also precipitate as hydroxides when their individual supersaturation points are reached. However, elements such as copper, arsenic, and zinc are thought to be removed from solution primarily by co-precipitation and adsorption processes that accompany the formation of ferric and ferrous hydroxides. Metals can adsorb to the surfaces of forming colloids via electro-static attraction (Johnson, 1986). Co-precipitation can also scavenge metals when they are occluded within the forming colloids or are incorporated as part of the matrix (Harris, 1982). Arsenic, present as an oxyanion, directly integrates with iron by out-competing and replacing two hydroxides, resulting in a coordinated complex (Harrison and Berkheiser, 1982). The resultant removal rate of arsenic from solution by co-precipitation is in direct proportion to the amount of solid formed (Chapman et al., 1983), and therefore, very little arsenic remains in solution after acid mine drainage undergoes a pH shift. Alternately, copper and zinc are removed from solution mainly by electrostatic attraction forces that are weaker than the complexing forces involved in arsenic removal. Copper and zinc are largely present as aquo or anion (e.g., sulfate) pairs (Johnson and Thornton, 1987) and are attracted to, not incorporated into, the forming hydroxide material. The degree of metals sorption increases with pH (Johnson, 1986; Moore and Sutherland, 1981). As impacted water approaches neutrality, most of the metals have become components of the flocculated hydroxides. The metals remaining in solution continue to exchange with hydroxides (Windom et al., 1991) as well as other stream features such as the bed substrate, organic material, and suspended particulates (Chapman et al., 1983).

B. Arsenic Drainage

Mine drainage with high arsenic levels is associated with Sierra-Nevada mines located in the Allegheny-Downieville area. Miners were after underground gold deposits that formed with arsenopyrite (AsFeS) and calcareous minerals (mainly $CaCO_3$; Carlson and Clark, 1956). Drainage from this area is dissimilar to typical acid mine drainage in that it is clear, neutral to alkaline in pH, and produces no objectionable iron precipitates or staining. Disproportionately higher amounts of arsenic are released from arsenopyrite undergoing oxidation (Ehrlich, 1964), partially explaining the low iron content in the drainage. Arsenic in neutral waters is largely present as an oxyanion (AsO_4^{3-}; Burau et al., 1988) and has been measured as the +5 valence species in mine drainage based on pH-Eh diagrams. Arsenate is 1 to 2 orders of magnitude less toxic than the reduced valence species - arsenite (+3) - which is present only in reducing waters of less than -0.4 mV (Moore and Ramamoorthy, 1984; Hem, 1975). In waters not affected by acid mine drainage (low iron content), 50-90 percent of the arsenic is expected to be dissolved (Johnson and Thornton, 1987).

C. Waste Rock Drainage

Waste rock material deposited above ground also undergoes oxidative weathering when in contact with water. Waste rock was present at nearly all mine sites visited in this study and can be composed of overburden, gangue material (less valuable surrounding minerals), and leftover tailings from processed ore (U.S.EPA, 1986). Mineral oxidation and off-site transport is limited to periods of precipitation when no other water sources (e.g., springs, creeks) are in contact with the waste rock. In pyritic soils, the potential to generate acid is largely controlled by the availability of water, the presence of calcareous minerals (mainly $CaCO_3$; U.S.EPA, 1986), and crystal size (Caruccio, 1975). The top 6-14 inches of material is adequately aerated to provide oxygen at levels sufficient for direct oxidation (Good, 1970). During dry periods, soluble products of mineral weathering (acid and metals) are transported to the surface via capillary action where they build up between storm events (Potter, 1976). As a result, analyte levels are higher during the initial stages of a storm event (Harries and Richie, 1983; see Appendix B). The total pollutant content does not exhibit similar first flush effects because of erosional transport. Measured rainfall runoff coefficients range between 11 and 38 percent and vary with material morphology (Harries and Richie, 1983) and rainfall characteristics such as intensity and duration (see Appendix B). Infiltrated water passing through waste rock material usually emanates with a higher pollutant level compared to surface runoff due to the increased residence time of water allowed to approach equilibration with leachable acid and metals (Harries and Richie, 1983). Simple erosional forces can transport particulates and their associated metals off-site regardless of the pH of the material.

IV. CHARACTERISTICS OF SACRAMENTO VALLEY INACTIVE MINES

A water quality survey was conducted between 1989 and 1991 to assess the pollutant contributions made by inactive mines in the Sacramento Valley. There are hundreds of mine sites in the Valley, some of which are claims or prospects with little potential for significant water quality degradation. For instance, there are 55 known mine claims in El Dorado County alone (SWRCB, 1972) and 161 historical mine sites in Sierra County (CVRWQCB, unpub. data). The number of mines included in this study (94) were limited to those that were known or suspected water quality threats (see Appendix A for selection criteria). The goals included estimating pollutant loads and assessing the impacts of inactive mines without assuming all individual contributors had been identified and characterized. To achieve this, the mines selected were those with a history of heavy activity and/or high ore production.

At mines with perennial drainage, water samples were collected and later analyzed for several heavy metals and arsenic. Conventional parameters were measured on-site at the time of sampling (flow, EC, Eh, pH). Sediment samples were collected at all mine sites visited and a limited number were analyzed for similar parameters (see Appendix A for a complete description of the methods). Mines not well characterized during previous inspections were monitored several times over a 2 year period to account for any seasonal fluctuation in flow-volumes or pollutant levels. Those mines with abundant characterization data were not sampled because load calculations and impact assessment could be made using existing information (largely mines in the Shasta Mining District). Several mines included in the survey were inaccessible or could not be located. Data from past monitoring programs and the results of this survey are reported in Appendix C. A narrative description of each mine site with respect to water quality degradation potential is presented in Appendix D.

A. Drainage Characteristics

Mine locations areally graphed in Figure IV-1 show that mining was not limited to any one area of the Sacramento Valley. Table IV-1 summarizes the physical characteristics and historical background of mines in this survey. Inactive mines were pervasive throughout the Valley outside the central basin and into the surrounding hills and mountains. There are six broadly defined mining zones in the Valley (refer to Figure IV-1 and Table IV-1 for map identification numbers [map I.D. #s]): 1) Foothill Copper Belt (map I.D. #s 2, 9, 10, 11), 2) Sierra-Nevada lode gold, 3) Alleghany-Downieville area (map I.D. #s 20, 21, 22, 24 [Kanaka Creek mines]), 4) Plumas Copper Belt (map I.D. #s 32-39), 5) Shasta Mining District (map I.D. #s 44-57), and 6) western foothill mercury mines (Plates 10-12). Although not all mines had perennial adit discharges (Table IV-1), waste rock material was observed at almost all mines visited. Further, historical accounts and site observations indicate that ore processing and/or beneficiating operations were conducted on-site at a majority of the mines in the Valley (Table IV-1). This is significant because the mechanical/chemical breakdown of extracted minerals increases the surface area exposed to weathering and results in a greater potential for water quality impacts. This potential is manifested when waste rock pollutants are transported off-site into receiving waters during storm events or from intersecting flows.

The general attributes (e.g., products, mineralogy) of Sacramento Valley mines and their drainage quality were highly variable. Valuable orebodies containing copper, cadmium, zinc, and chromium minerals were most intensively mined from the mid-1800's to mid-1900s. Other products directly or indirectly mined in the Valley included mercury, arsenic, gold, silver, sulfur compounds, and paint pigments. Drainage quality ranged from unpolluted spring water (e.g., Silver Falls Mine) to highly acidic outflow containing metals in the ppm range (e.g., West Shasta District mines; Table IV-2). Previous studies generally agree that dramatic differences in water quality and outflow are mainly related to the geological makeup of underlying minerals and depth to ground water. Underground minerals may have the potential to easily degrade, but surface releases would be absent if the water table is below the lower-most opening. Variability in discharge quality from closely located adits may be more related to differences in the residence time of water passing through a complex (Potter, 1976). Water moving slowly through underground workings solubilize pollutants to a higher level given a longer time to approach their individual saturation points. At mines with no perennial adit releases, drainage is limited to rainfall and snowmelt runoff from waste rock material.

Mines in the Foothill Copper Belt of the Sierra-Nevada range exhibited typical acid drainage characteristics, although, not all had perennial outflow (Dairy Farm and Big Buzzard were dry). Spenceville and Valley View mines drained acidic water containing high levels of most compounds such as copper, zinc, cadmium, or lead (Table IV-2). The Foothill Copper Belt identifies a series of mines situated on a geological formation of, in part, massive pyrite deposits located at the western edge of the Sierra-Nevada foothill range between an elevation of 300 and 500 feet MSL. Four mines in this belt were visited but the polymetallic lens extends down the Sierra-Nevada range, well outside the Sacramento Valley. There are other significant acid mine drainage producers in the Foothill Copper Belt not included in this study (e.g., Penn Mine, Calaverous County).

Drainage from gold mines in the Allegheny-Downieville area (located in the Yuba River Watershed) was characterized by near neutral outflow and elevated arsenic levels (Table IV-2). The mineralogy of the area has been extensively studied because of the lode-grade gold deposits. Mining journals describe gold veins that were deposited in close association with carbonate minerals and arsenopyrite (AsFeS; Carlson and Clark, 1956), which partially explains the drainage makeup. Notable arsenic sources in the area include the Plumbago and Brush Creek mines and those situated in the Kanaka Creek watershed. United States Forest Service personnel have counted over 140 mines in this watershed including 16 to 1, Kenton, and Oriental (Daniels, pers. comm.). There are also a number of smaller mines discharging in the Yuba River watershed that were not included in this survey (Higgens, pers. comm.). Arsenic from these mines remains largely in solution in the downstream receiving waters because of the low iron content and near neutral pH of the drainage - arsenic is known to be effectively removed from solution by hydroxide precipitates. Positive Eh measurements of the drainage

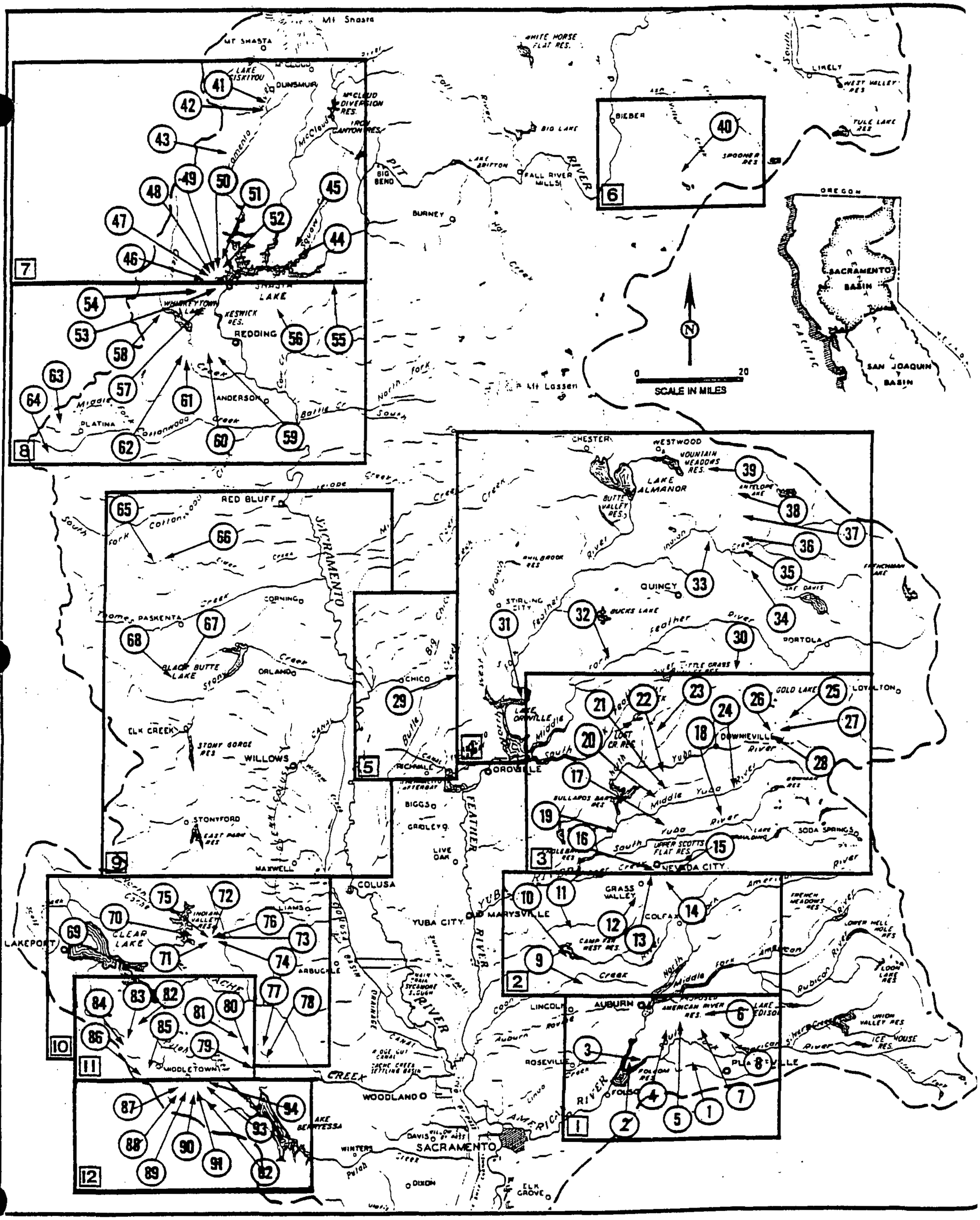


Figure IV-1. MAJOR INACTIVE MINES IN THE SACRAMENTO VALLEY. MAP I.D. NUMBERS (IN CIRCLES) ARE DEFINED IN TABLE IV-1. DETAILED WATERSHED LOCATIONS ARE PRESENTED IN PLATES 1-12 (IN SQUARES).

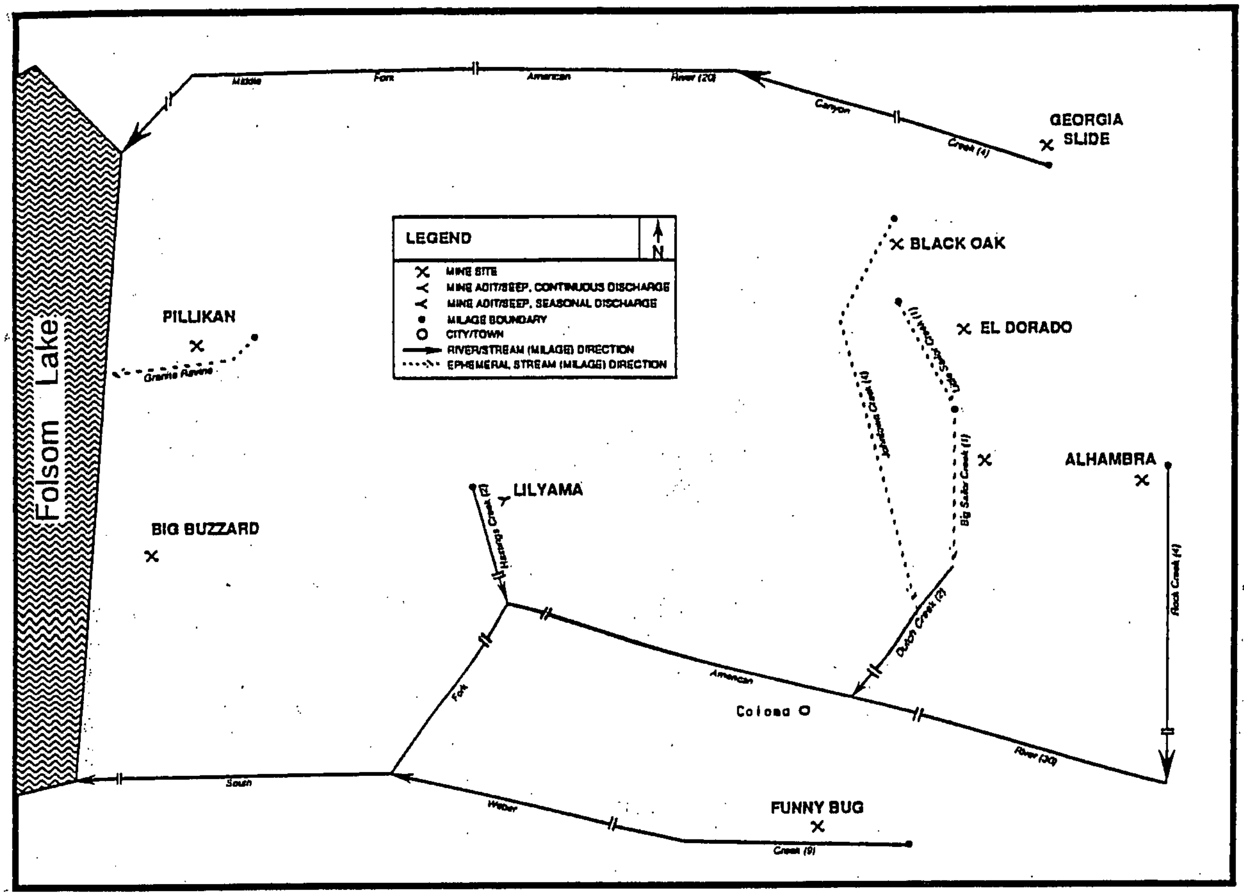


PLATE 1. Inactive mines of the Folsom Lake watershed.

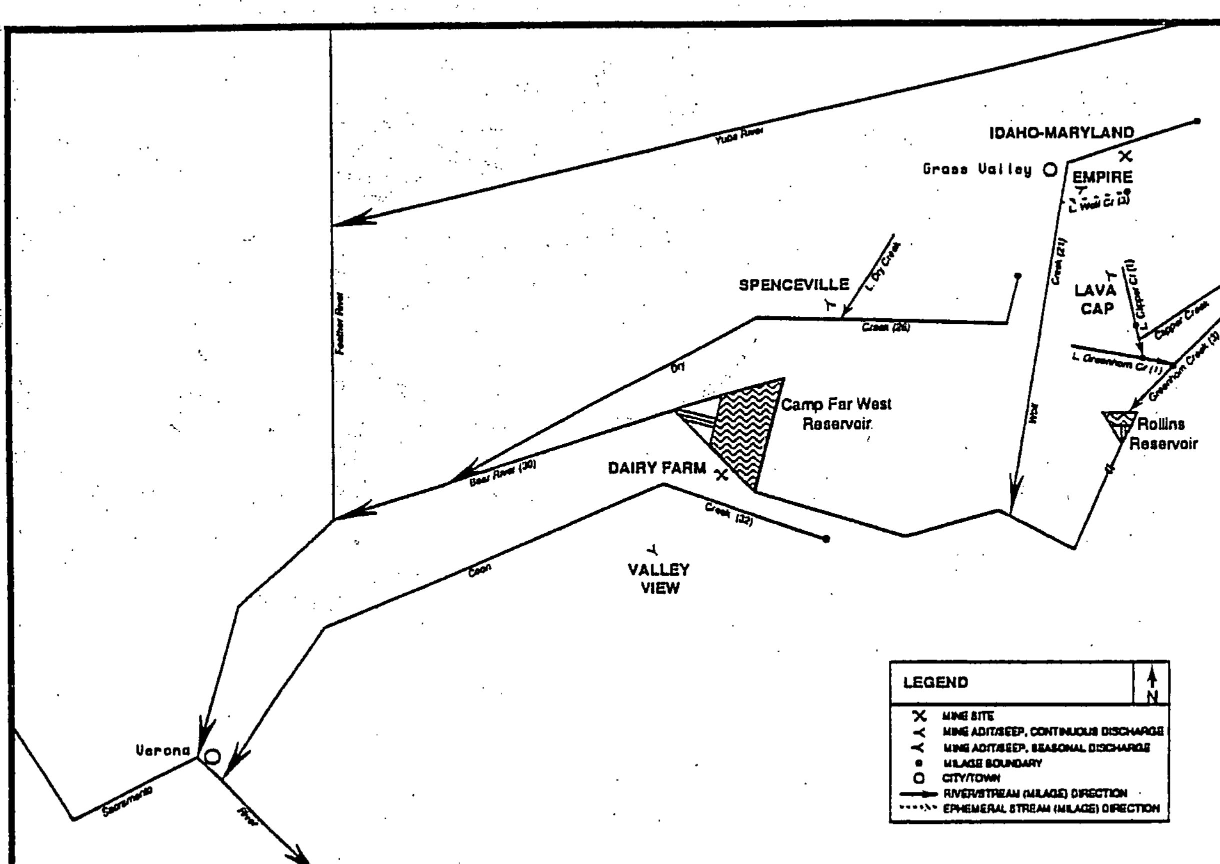


PLATE 2. Inactive mines of the Bear River / Dry Creek watershed.

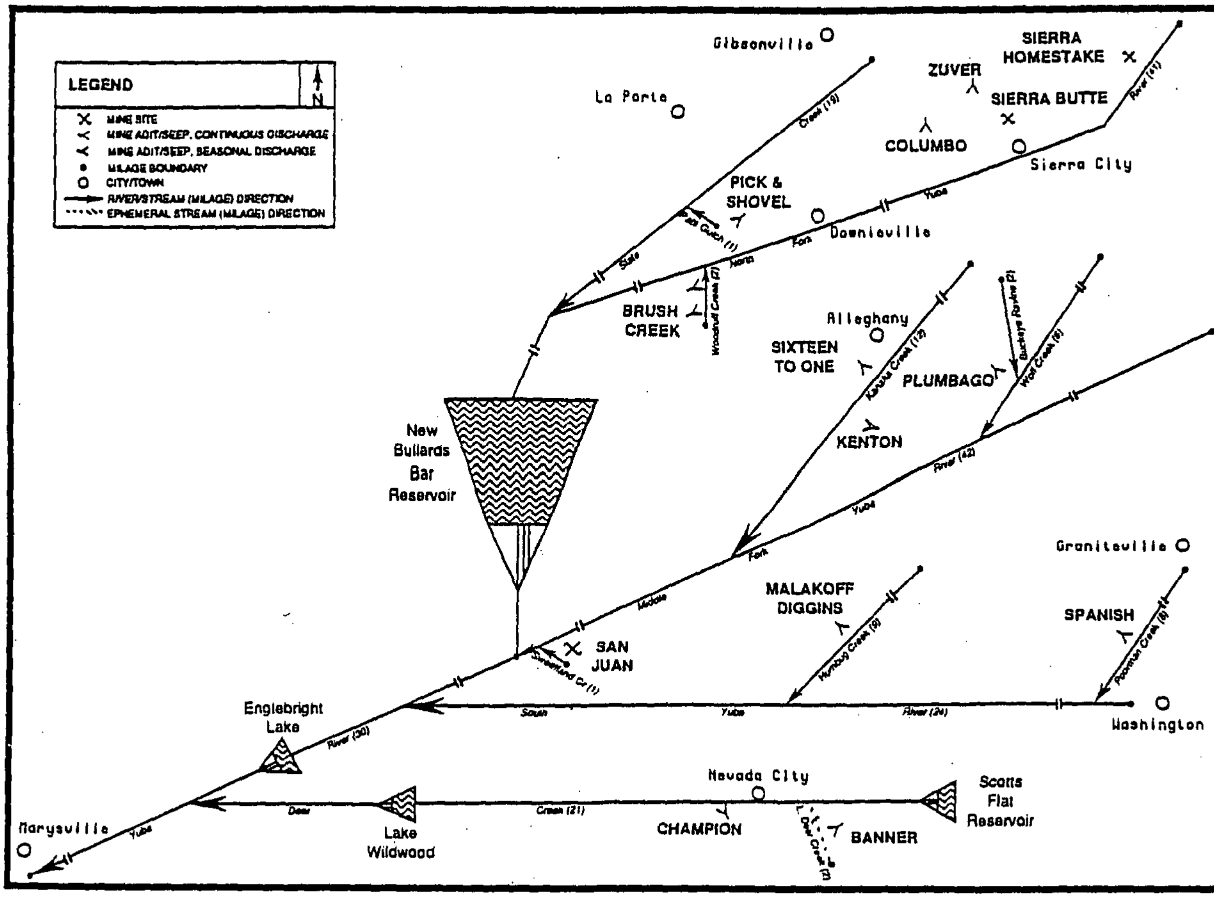


PLATE 3. Inactive mines of the Middle Fork, Yuba River Watershed

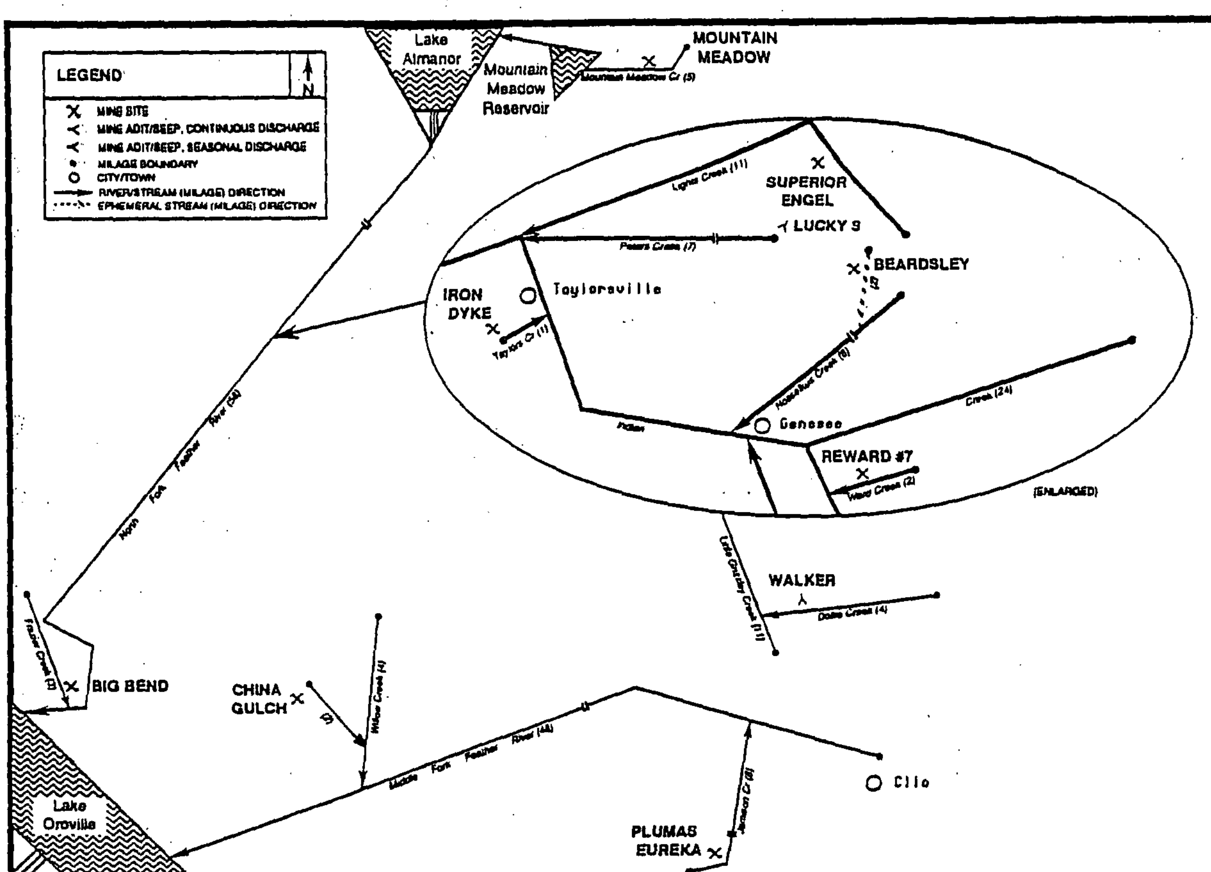


PLATE 4. Inactive mines of the Feather River watershed.

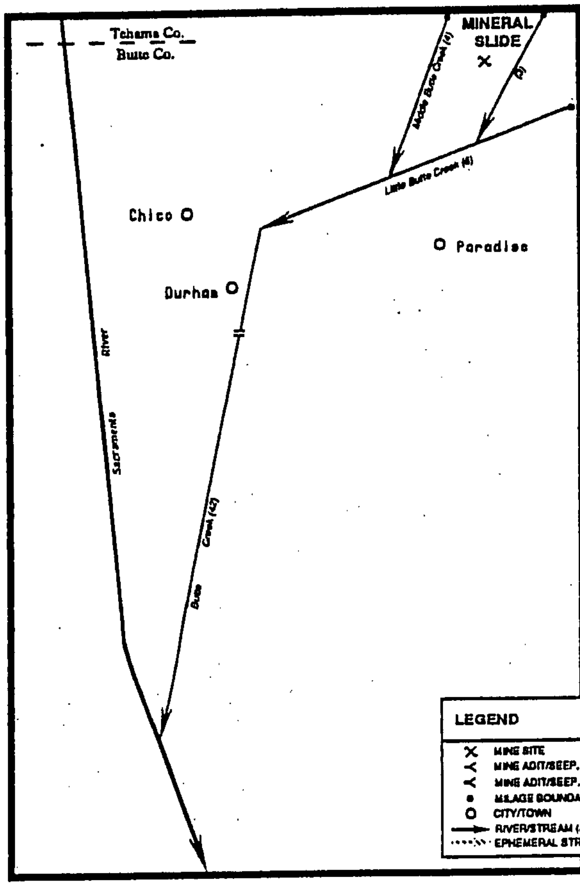


PLATE 5. Inactive mines of the Butte Creek watershed.

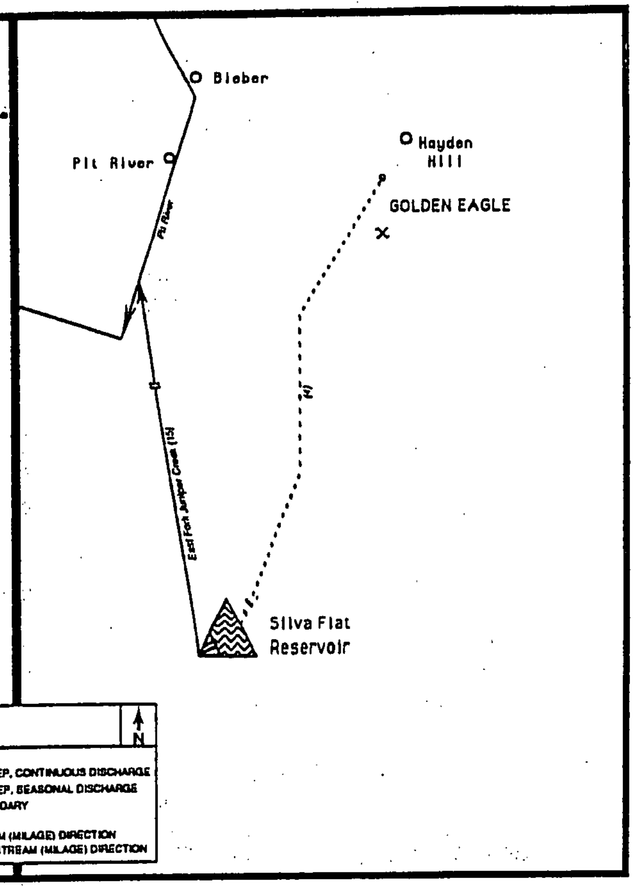


PLATE 6. Inactive mines of the Pit River watershed.

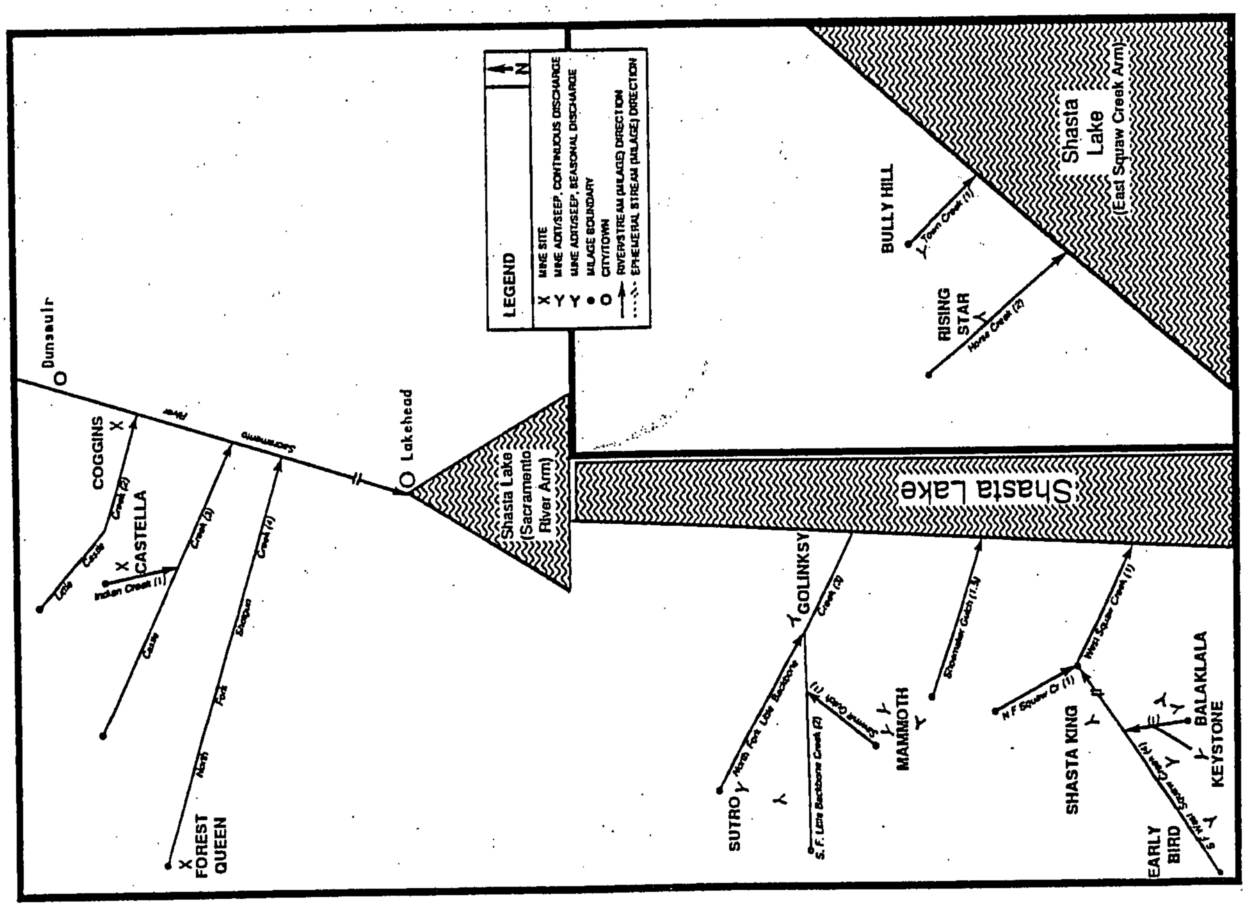


PLATE 7. Inactive mines of the Shasta Lake watershed.

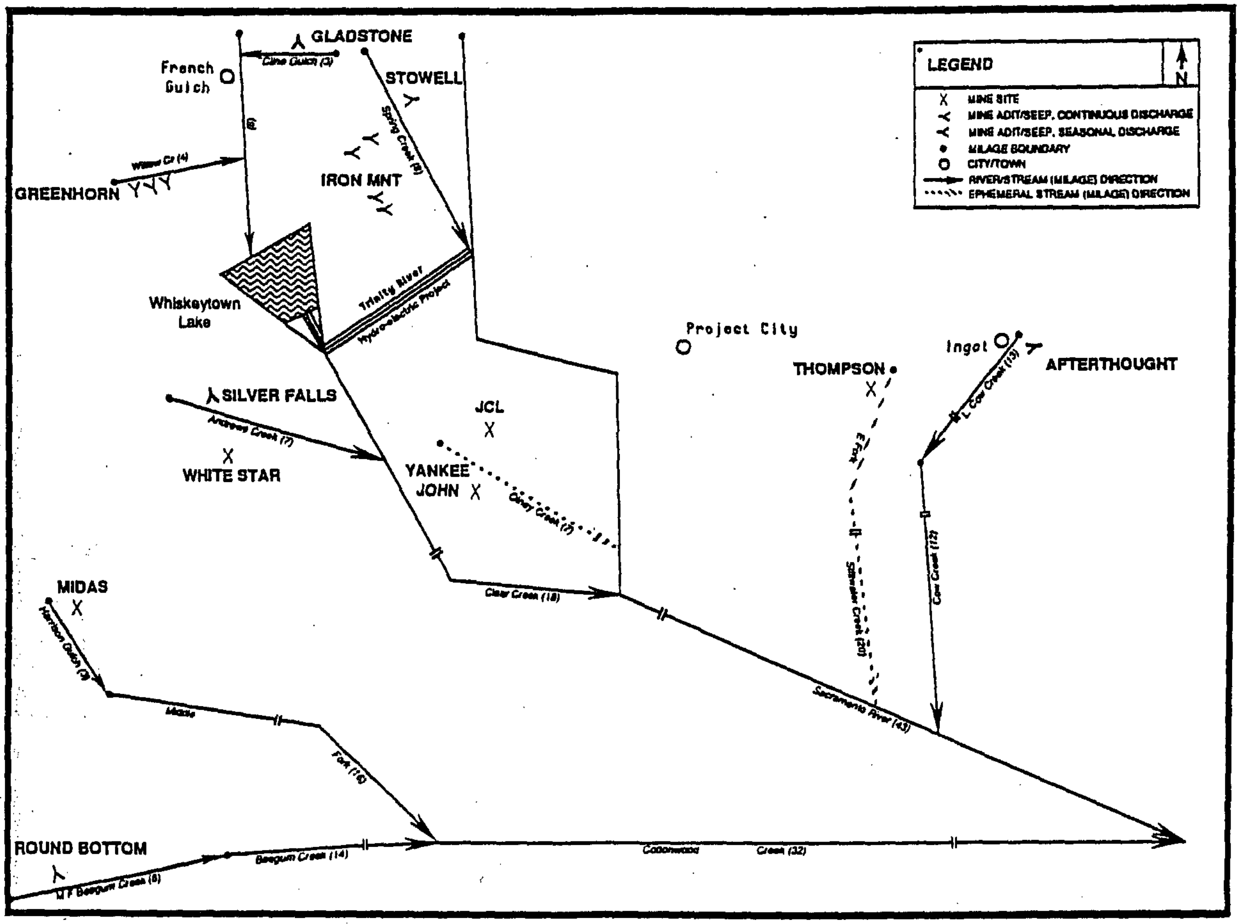


PLATE 8. Inactive mines of the Upper Sacramento River watershed.

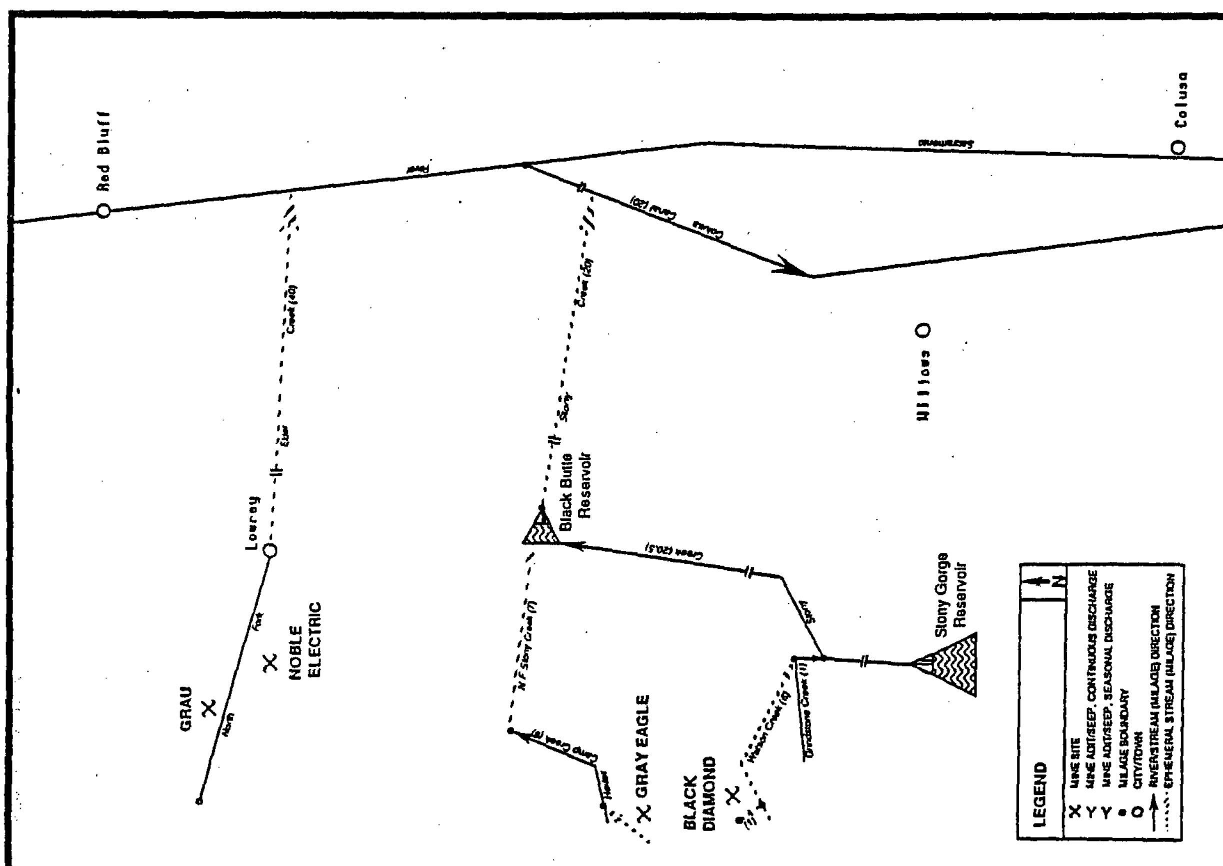


PLATE 9. Inactive mines of the Stony Creek / Elder Creek watersheds.

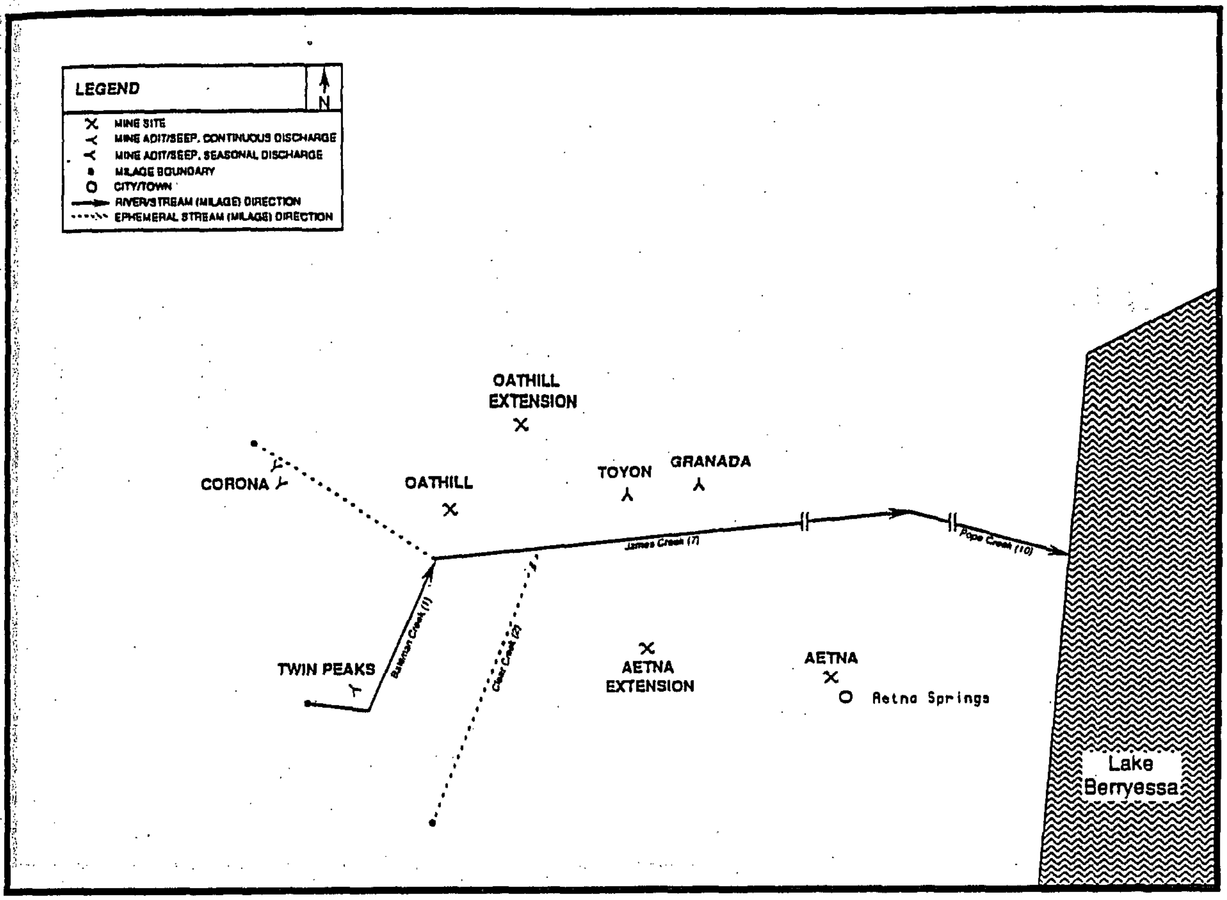


PLATE 10. Inactive mines of the Lake Berryessa, Pope Creek watershed.

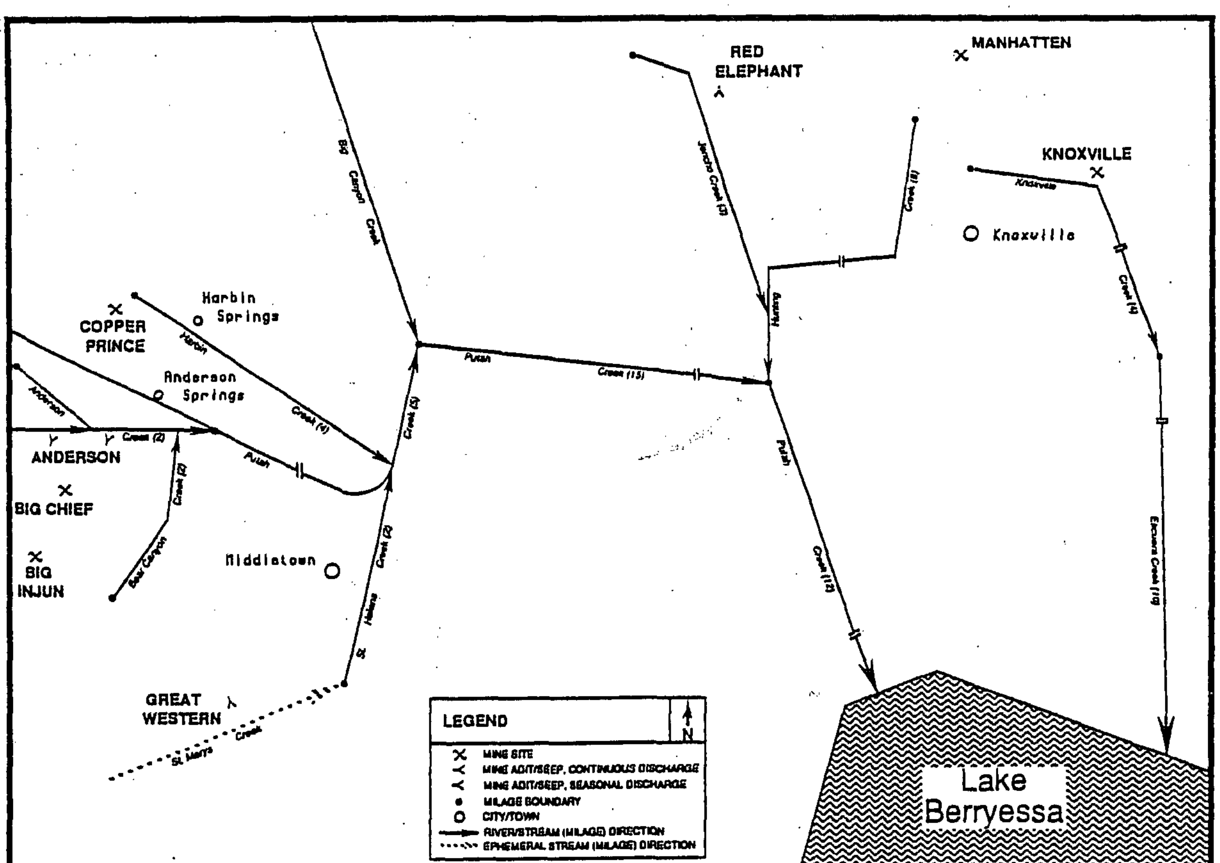


PLATE 11. Inactive mines of the Lake Berryessa, Putah Creek watershed.

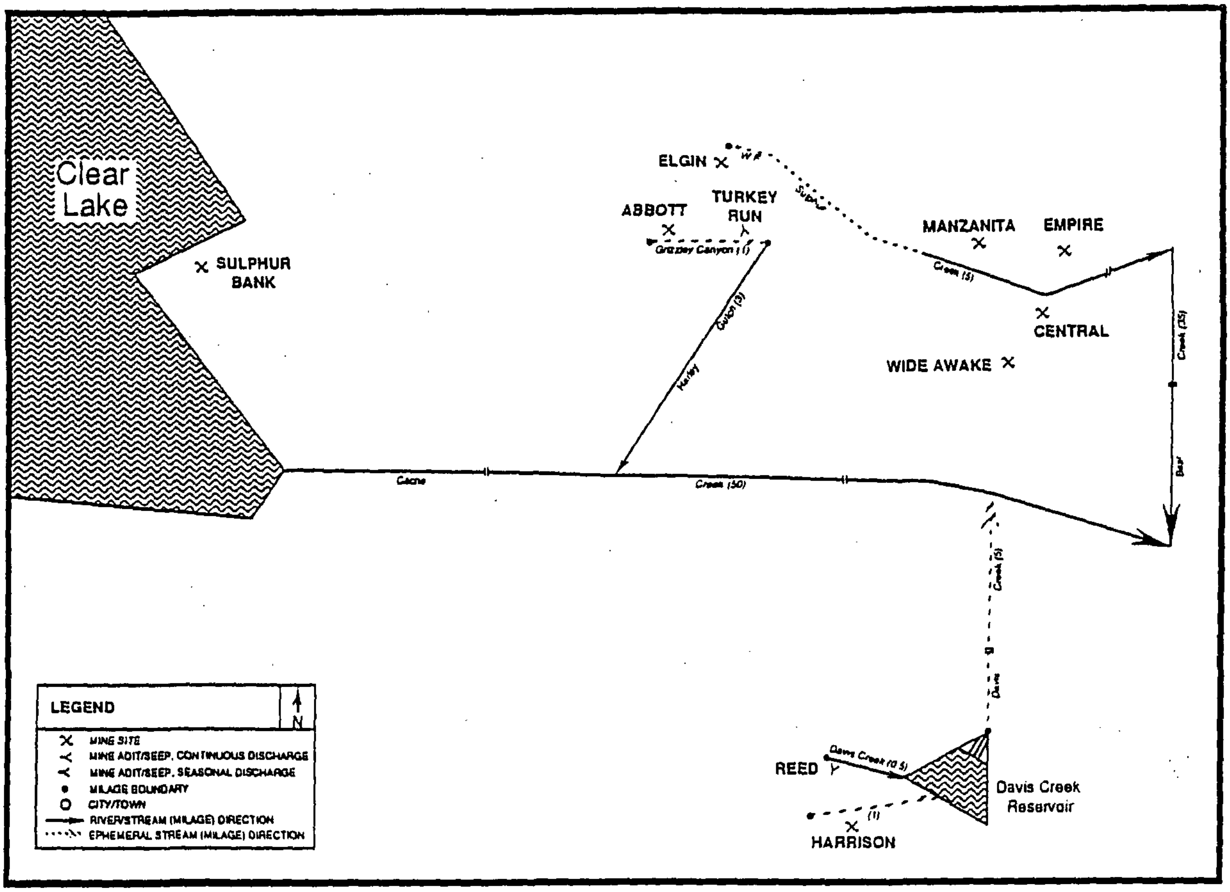


PLATE 12. Inactive mines of the Cache Creek watershed.

Table IV-1. SACRAMENTO VALLEY INACTIVE MINE CHARACTERISTICS. 1/

MAP. I D	MINE NAME	COUNTY	RECEIVING WATER SEQUENCE	USGS QUADRANGLE TITLE (MINUTES)	TOWNSHIP-RANGE	DISTRICT	PRO-DUCT	ORE MINERALOGY	PERENNIAL DISCHRG?	ONSITE PROCESS	START -UP
** WATERSHED : Folsom Lake											
1	Funnybug	El Dorado	Weber Cr - SF American Riv - Folsom Lake	Shingle Springs (7.5)	Sec 3 T12N R10E	Foothill	Cu, Au	Pyrite,chalcopyrite,spheler ite,arsenopyrite,stibnite,gal ena,hematite	unk		
2	Big Buzzard	El Dorado	Folsom Lake	Pilot Hill (7.5)	Sec 29 T11N R8E	W. Foothill	Cu,Au, Zn	Sphalerite, pyrite, chalcopyrite, galena	no	5 stamp mill	
3	Pillikan(areas 1-11)	El Dorado	NF American Riv - Folsom Lake	Pilot Hill (7.5)	Secs 21,28 T11N R8E	Flagstaff Hill	Cr	Chromite, dunite, pyroxenite, garnierite	no	Mill	1894
4	Lilyama	El Dorado	Hastings Cr - SF American Riv - Folsom Lake	Coloma (7.5)	Sec 3 T11N R9E	W. Foothill	Cu,Au, Ag	Chalcopyrite, bornite, hematite, scheelite, pyrite	yes	Ball mill, flotation plant	1860
5	Black Oak	El Dorado	Johntown Cr - Dutch Cr - SF American Riv - Folsom Lake	Garden Valley (7.5)	Sec 27,34 T12N R10E	Garden Valley	Au	Pyrite	no	Ball mill, flotation plant	
6	Georgia Slide	El Dorado	Canyon Cr - MF American Riv - Folsom Lake	Georgetown (7.5)	Sec 3 T12N R10E		Au	pyrite	unk	Stamp mill	
7	El Dorado	El Dorado	Little Sailor Cr - Big Sailor Cr - Dutch Cr - SF American Riv	Garden Valley (7.5)	Sec 34 T12N R10E	Foothill	Cu, Au	Chalcopyrite, pyrrotite, pyrite	unk		
8	Alhambra	El Dorado	Rock Creek - SF American Riv - Folsom Lake	Garden Valley (7.5)	Sec 6 T11N R11E		Au	Arsenopyrite, pyrite	yes	Mill and flotation plant	1883
** WATERSHED : Bear River/Dry Creek											
9	Valley View	Placer	Coon Cr - Feather Riv	Lincoln (7.5)	Sec 13 T13N R6E	Dairy Farm	Cu, Au, Ag	Chalcopyrite, cuprite, pyrite, zinc sulphides	yes	40 stamp mill	186~
10	Dairy Farm	Placer	Camp Far West Lake	Camp Far West (7.5)	Sec 27 T14N R6E	Dairy Farm	Cu, Ag, Au	Copper sulfides	no	Cyanide plant	1904
11	Spenceville	Nevada	Little Dry Cr - Dry Cr - Bear Riv	Camp Far West (7.5)	Sec 26,35 T15N R6E	Spenceville	Cu, H2SO4	Gossan, chalcopyrite, pyrite, bornite	yes	Smelter	1862
12	Empire	Nevada	Little Wolf Cr - Wolf Cr - Bear Riv	Grass Valley (15)	Sec 35 T16N R8E	Sulphur Creek	Hg	Cinnabar	yes	Cyanide plant, 20, 60 stamp mills, tailings pond	
13	Idaho-Maryland	Nevada	Wolf Cr - Bear Riv	Grass Valley (15)	Sec 26 T16N R8E	Grass Valley	Au	Pyrite, chalcopyrite, galena	no	20 stamp mill	1865
14	Lava Cap	Nevada	Little Clipper Cr - Clipper Cr - Little Greenhorn Cr - Greenhorn Crk - Bear Riv	Colfax (15)	Sec 28 T16N R9E	Nevada City	Au	Pyrite, arsenopyrite, sphalerite, galena	yes	Stamp mill, cyanide plant	1861
** WATERSHED : Yuba River											
15	Banner	Nevada	Little Deer Cr - Deer Cr - SF Yuba Riv - Yuba Riv	Colfax (15)	Sec 16 T16N R9E	Nevada City	Au	Pyrite, arsenopyrite, sphalerite, galena	unk	None	1889
16	Champion	Nevada	Deer Cr - Yuba Riv	Nevada City (15)	Sec 11,12 T16N R9E	Nevada City	Au	Pyrite, chalcopyrite, galena	yes	40 stamp mill, cyanide plant, tube mill, flotation plant	
17	Malakoff Diggin's	Nevada	Humbug Cr - South Yuba River	Alleghany (15)	Sec 4 T18N R10E		Au		yes		
18	Spanish	Nevada	Poorman Cr - SF Yuba Riv - Yuba Riv	Alleghany (15)	Sec 31 T18N R11E	Washington	Cu, Ba	Barite	yes	10 Stamp mill, flotation plant	1883
19	San Juan	Nevada	Sweetland Cr - Yuba Riv	French Corral (7.5)	Sec 12 T17N R7E	North San Juan	Au, Cu	Auriferous sulfides, chalcopyrite	no	Unknown	
20	Kenton	Sierra	Kanaka Cr - MF Yuba Riv - Yuba Riv	Alleghany (15)	Sec 4 T18N R10E	Alleghany	Au	Quartz	yes	Stamp mill	
21	Sixteen to One	Sierra	Kanaka Cr - MF Yuba Riv - Yuba Riv	Alleghany (15)	Sec 34 T19N R10E	Alleghany	Au	Arsenopyrite	yes		

Table IV-1. SACRAMENTO VALLEY INACTIVE MINE CHARACTERISTICS.

MAP I D	MINE NAME	COUNTY	RECEIVING WATER SEQUENCE	USGS QUADRANGLE TITLE (MINUTES)	TOWNSHIP-RANGE	DISTRICT	PRO-DUCT	ORE MINERALOGY	PERENNIAL DISCHRG?	ONSITE PROCESS	START -UP
22	Brush Creek	Sierra	Woodruff Cr - NF Yuba Riv - Yuba Riv	Goodyears Bar (7.5)	Sec 17, T19N R10E	Downieville	Au	Auriferous arsenopyrite, galena, pyrite, chlorlite, serpentine	yes	None	
23	Pick & Shovel	Yuba	Pats Gulch - Slate Cr - MF Yuba Riv - Yuba Riv	La Porte (7.5)	Sec 23 T21N R9E				yes		
24	Plumbago	Sierra	Buckeye Ravine - Wolf Cr - MF Yuba Riv - Yuba Riv	Alleghany (15)	Sec 1 T18N R10E	Alleghany	Au	Quartz	yes	Unknown	
25	Sierra Homestake	Sierra	N Yuba Riv - Yuba Riv	Sierra City (15)	Sec 1 T20N R12E	Alleghany	Au	Malachite, chalcopyrite	unk		
26	Zuver	Sierra	NF Yuba Riv - Yuba Riv	Sierra City (15)	Sec 12 T20N R12E	Allegheny	Cu		no		
27	Sierra Buttes	Sierra	N Yuba Riv - Yuba Riv	Sierra City (15)	Sec 29 T20N R12E	Allegheny	Au, Ag		unk	Rod mill, cyanide mill	
28	Columbo	Sierra	NF Yuba Riv - Yuba Riv	Sierra City (15)	Sec 19 T20N R12E	Sierra City	Au	Andesite	yes	10 stamp mill, cyanide mill, ball mill	1875
** WATERSHED : Butte Creek											
29	Mineral Slide	Butte	Little Butte Cr - Butte Cr - Sacramento Riv	Paradise (7.5)	Sec 3 T22N R3E		Au		unk	None	1887
** WATERSHED : Feather River											
30	Plumas-Eureka	Plumas	Jamison Cr - MF Feather Riv - Oroville Lake	Downieville (15)	Sec 23,26 T22N R11E	Johnsville	Au	Pyrite, chalcopyrite, arsenopyrite, galena	no	60 stamp mill	1851
31	Big Bend	Butte	Frazier Cr - NF Feather Riv - Lake Oroville	Big Bend Mountain (15)	Sec 8 T21N R5E				unk		
32	China Gulch	Plumas	Willow Cr - MF Feather Riv - Lake Oroville	Bucks Lake (15)	Sec 34 T23N R7E		Cu		unk		
33	Iron Dyke	Plumas	Taylors Cr - Indian Cr - EBNF Feather Riv - NF Feather Riv - Lake Oroville	Greenville (15)	Sec 34 T25N R10E	Taylorsvill e	Cu,Ag, Au	Malachite, azurite, pyrrhotite, chalcopyrite	no		1860
34	Walker	Plumas	Little Grizzly Cr - Indian Cr - EBNF Feather Riv - NF Feather Riv - Oroville Lake	Mt. Ingalls (7.5)	Sec 7 T24N R12E	Genessee	Cu, Au	Chalcopyrite,tetrahedrite,py rite,pyrrotite,chlcocite,sph alerite,galena	yes	Flotation plant, ball mill, crusher	1915
35	Reward #7	Plumas	Ward Cr - Indian Cr - EBNF Feather - NF Feather Riv	Genesee Valley (7.5)	Sec 14,23 T25N R11E	Genessee	Cu	Epidote, garnet, pyrite, chalcopyrite, bornite	no	unknown	
36	Beardsley	Plumas	WF Davis Cr - Davis Cr - Hosselkers Cr - Indian Cr - EBNF Feather - NF Feather Riv	Genesee Valley (7.5)	Sec 14 T26N R11E	Genessee	Cu, Au	Chalcopyrite, Bornite	no		1913
37	Lucky S	Plumas	Peters Cr - Lights Cr - Indian Cr - EBNF Feather - NF Feather Riv	Kettle Rock (15)	Sec 28,33 T27N R11E	Genessee	Cu, Au	Pyrite, sphalerite, chalcopyrite, galena	yes	5 stamp mill	
38	Superior-Engel	Plumas	Lights Cr - Indian Cr - EBNF Feather Riv - NF Feather Riv - Oroville Lake	Greenville (15)	Sec 17 T27N R11E	Lights Creek	Cu,Ag	Chalcopyrite, bornite	no	Stamp mill and oil flotation plant	1894
39	Mountain Meadows	Lassen	Mtn Meadows Cr - Mtn Meadows Res - Lake Almanor	Westwood (7.5)	Sec 29 T28N R10E		Cu		no		
** WATERSHED : Pit River											
40	Golden Eagle	Lassen	Silva Flat Reservoir - EF Juniper Creek - Pit River	Hayden Hill (15)	Sec 37 T36N R9E	Hayden Hill	Au		no	Mill and cyanide plant	
** WATERSHED : Shasta Lake											
41	Coggins	Shasta	Little Castle Cr - Sacramento Riv - Shasta Lake	Dunsmuir (15)	Sec 16 T38N R4W		Cr		no		1942
42	Castella	Shasta	Indian Cr - Castle Cr - Sacramento Riv - Shasta Lake	Dunsmuir (15)	Sec 16 T38N R4W	Dunsmuir	None	None	no	Chromite mill	
43	Forest Queen	Shasta	NF Shotgun Cr - Sacramento Riv - Shasta Lake	Dunsmuir (15)	Sec 22,27 T37N R5W	Dunsmuir	Cr	Chromite	no	None	

Table IV-1. SACRAMENTO VALLEY INACTIVE MINE CHARACTERISTICS.

MAP ID	MINE NAME	COUNTY	RECEIVING WATER SEQUENCE	USGS QUADRANGLE TITLE (MINUTES)	TOWNSHIP-RANGE	DISTRICT	PRO-DUCT	ORE MINERALOGY	PERENNIAL DISCHRG?	ONSITE PROCESS	START-UP
44	Bully Hill	Shasta	Town Cr - Shasta Lake	Bollibokka Mtn (15)	Sec 16,22 T34N R3W	E. Shasta	Cu,Zn, Pb,Cd	Pyrite, sphalerite, chalcopyrite, galena, tetrahedrite, bornite	yes	Smelter, flotation plant	1860
45	Rising Star	Shasta	Horse Cr - Shasta Lake	Bollibokka Mtn (15)	Sec 15,21 T34N R3W	E. Shasta	Cu,Zn, Pb,Cd	Pyrite, sphalerite, chalcopyrite, galena, tetrahedrite, bornite	yes	Smelter, flotation plant	1860
46	Keystone	Shasta	West Squaw Cr - Shasta Lake	French Gulch (15)	Sec 14 T33N R6W	W. Shasta	Cu,Au, Ag,Zn	Copper sulfides	yes	Unknown	
47	Early Bird	Shasta	West Squaw Cr - Shasta Lake	French Gulch (15)	Sec 10 T33N R6W	W. Shasta	Cu, Zn	Chalcopyrite	yes		
48	Balaklala	Shasta	West Squaw Cr - Shasta Lake	Shasta Dam (7.5)	Sec 12 T33N R6W	W. Shasta	Cu, Zn, Ag,	Pyrite, chalcopyrite, sphalertite, galena, covellite	yes	Smelter near Coram	1890
49	Shasta King	Shasta	West Squaw Cr - Shasta Lake	Shasta Dam (7.5)	Sec 1 T33N R6W	W. Shasta	Cu,Zn, Cd,Au		yes		
50	Mammoth	Shasta	Little Backbone Cr - Shasta Lake	Lamoine (15)	Sec 32 T33N R6W	W. Shasta	Cu,Zn, Au,Ag	Pyrite, chalcopyrite, sphalerite	yes	Smelter 4 miles away near Kennett	1900
51	Sutro	Shasta	Little Backbone Cr - Shasta Lake	Lamoine (15)	Sec 29,30 T34N R5W	W. Shasta	Cu		yes		
52	Golinsky	Shasta	Little Backbone Cr - Shasta Lake	Lamoine (15)	Sec 28 T34N R5W	W. Shasta	Cu,Zn, Au	Copper sulfides	yes	Unknown	
** WATERSHED : Sacramento Riv, Upper											
53	Stowell	Shasta	Spring Cr - Sacramento Riv	Shasta Dam (7.5)	Sec 13 T33N R6W	W. Shasta	Cu	Chalcopyrite	yes		
54	Gladstone	Shasta	Cline Gulch - Clear Cr - Whiskeytown Lake - Sacramento Riv	French Gulch (15)	Sec 18 T33N R6W	French Gulch	Au	Quartz, pyrite, galena, sphalerite, arsenopyrite	no	30 stamp mill	
55	Afterthought	Shasta	Little Cow Cr - Cow Cr - Sacramento Riv	Millville (15)	Sec 10,11 T33N R2W	E. Shasta	Cu,Zn, Au,Cd	Sphalerite, chalcopyrite	yes	Flotation plant, smelter	1903
56	Thompson	Shasta	EF Stillwater Cr - Stillwater Cr - Sacramento Riv	Project City (7.5)	Sec 34 T33N R4W	E. Shasta	Cu	Pyrite, chalcopyrite, bornite, quartz	no	Unknown	
57	Iron Mountain	Shasta	Spring Cr - Keswick Res - Sacramento Riv	French Gulch (15)	Sec 34,35 T33N R6W	W. Shasta	Cu,Zn, Au,Ag	Pyrite, chalcopyrite, sphalerite	yes	Flotation mill, cyanide plant	1879
58	Greenhorn	Shasta	Willow Cr - Crystal Cr - Clear Cr - Whiskeytown Lake	French Gulch (15)	Sec 31 T33N R7W	French Gulch	Cu,Au, Ag,Cd	Pyrite, chalcopyrite, chalcocite	yes	Copper sedimentation plant	1900
59	JCL	Shasta	Olney Cr - Sacramento Riv - Shasta Lake	Redding (7.5)	Sec 8 T31N R5W				unk		
60	Yankee John	Shasta	Olney Cr - Sacramento Riv	Redding (7.5)	Sec 17 T31N R5W				no		
61	White Star	Shasta	Andrews Cr - Clear Cr - Sacramento Riv	French Gulch (15)	Sec 18,19 T31N R6W				no		
62	Silver Falls	Shasta	Andrews Cr - Clear Cr - Sacramento Riv	French Gulch (15)	Sec 18,19 T31N R6W	Igo	Ag,Au	Tetrahedrite, galena, pyrite, sphalerite, chalcopyrite	yes	Unknown	
63	Midas	Shasta	Harrison Gulch - MF Cottonwood Cr - Cottonwood Cr - Sacramento Riv	Chanchenulla Pk (15)	Sec 3,4 T29N R10W	Harrison Gulch	Au	Quartz	no	20 stamp mill, cyanide plant	
64	Round Bottom	Shasta	MF Beegum Cr - Beegum Cr - Cottonwood Cr - Sacramento Riv	Dubakella Mtn (15)	Sec 5 T28N R10W	Platina	Cr	Chromite	yes	Unknown	
** WATERSHED : Stony Cr / Elder Cr											
65	Grau	Tehama	NF Elder Cr - Sacramento Riv	Raglin Ridge (7.5)	Sec 17 T25N R7W		Cr	Chromite, serpentine	no		
66	Noble Electric	Tehama	NF Elder Crk - Sacramento Riv	Raglin Ridge (7.5)	Sec 17 T25N R7W		Cr	Chromite, serpentine	no		1915

Table IV-1. SACRAMENTO VALLEY INACTIVE MINE CHARACTERISTICS.

MAP ID	MINE NAME	COUNTY	RECEIVING WATER SEQUENCE	USGS QUADRANGLE TITLE (MINUTES)	TOWNSHIP-RANGE	DISTRICT	PRODUCT	ORE MINERALOGY	PERENNIAL DISCHRG?	ONSITE PROCESS	START-UP
67	Grey Eagle	Glenn	Heifer Camp Cr - NF stony Creek - Black Butte Reservoir - Stony Cr - Colusa Drain	Chrome (7.5)	Sec 25 T22N R7W		Cr	Chromite	no		
68	Black Diamond	Glenn	Watson Cr - Grindstone Cr - Stony Cr - Black Butte Reservoir - Stony Cr - Colusa Drain	Chrome (7.5)	Sec 25 T22N R7W		Cr	Chromite	no	None	1892
** WATERSHED : Cache Creek											
69	Sulfur Bank	Lake	Clear Lake	Clearlake Highlands (7.5)	Sec 6 T13N R7W	Clear Lake	Hg, sulphur	Cinnabar, marcasite, pyrite	no	Knox-Osborne, 3 Scott furnaces, several D-retorts and rotary furnace	1873
70	Elgin	Colusa	WF Sulphur Cr - Sulphur Cr - Bear Cr - Cache Cr	Wilbur Spring (15)	Sec 13 T14N R6W	Sulphur Creek	Hg,sulphur	Cinnabar	unk	Retort furnace	
71	Empire	Colusa	Sulphur Cr - Bear Cr - Cache Cr	Wilbur Spring (15)	Sec 29 T14N R5W	Sulphur Creek	Hg	Cinnabar	no	D-Retort	
72	Manzanita	Colusa	Sulfur Cr - Bear Cr - Cache Cr	Wilbur Spring (15)	Sec 29 T14N R5W	Sulphur Creek	Hg,Au, sulph	Cinnabar	no	Stamp and Huntington mills, retort furnace	1863
73	Central	Colusa	Sulphur Cr - Bear Cr - Cache Cr	Wilbur Spring (15)	Sec 28 T14N R5W	Sulphur Creek	Hg	Cinnabar	no		
74	Wide Awake	Colusa	Sulfur Cr - Bear Cr - Cache Cr	Wilbur Spring (15)	Sec 29 T14N R5W		Hg	Cinnabar	no	Large Scott Furnace, small pipe furnace	1875
75	Abbott	Lake	Grizzly Canyon - Harley Gulch - Cache Cr	Wilbur Springs (15)	Sec 32 T14N R5W	Sulphur Creek	Hg	Cinnabar	no	Scott furnace, rotary kiln, cyclone dust collector	1862
76	Turkey Run	Lake	Grizzly Canyon - Harley Gulch - Cache creek	Wilbur Springs (15)	Sec 32 T14N R5W	Sulphur Creek	Hg		yes		
77	Reed	Yolo	Davis Cr - Cache Cr	Knoxville (15)	Sec 25 T12N R5W	Knoxville			yes		
78	Harrison	Yolo	Davis Cr - Cache Cr	Knoxville (15)	Sec 35 T12N R5W				unk		
** WATERSHED : Lake Berryessa,Putah											
79	Knoxville	Napa	Knoxville Cr - Eticuera Cr - Lake Berryessa	Morgan Valley (15)	Sec 7 T11N R4W	Knoxville	Hg	Cinnabar, pyrite	no	Scott furnace, D-retort, rotary pipe furnace	1862
80	Manhattan	Napa	Hunting Cr - Putah Cr - Lake Berryessa	Morgan Valley (15)	Sec 1 T11N R5W		Hg	Cinnabar	unk		1863
81	Red Elephant	Napa	Jericho Cr - Hunting Cr - Putah Cr - Lake Berryessa	Morgan Valley (15)	Sec 3 T11N R5W	Knoxville	Hg	Cinnabar	no	Rotary furnace	
82	Copper Prince	Lake	Putah Cr - Lake Berryessa	Whispering Pines (7.5)	Sec 19 T11N R7W		Cu	Azurite, malachite, sulphide	unk		
83	Big Chief	Lake	Anderson Cr - Putah Cr - Lake Berryessa	Whispering Pines (7.5)	Sec 35 T11N R8W	Mayacmas	Hg	Cinnabar	no	Rotary kiln	1916
84	Big Injun	Lake	Bear Canyon Cr - Putah Cr - Lake Berryessa	Whispering Pines (7.5)	Sec 35 T11N R8W	Mayacmas	Hg	Cinnabar	no		
85	Anderson	Lake	Anderson Cr - Putah Cr - Lake Berryessa	Whispering Pines (7.5)	Sec 35 T11N R8W	Mayacmas	Hg	Cinnabar, pyrite, calcite	yes	Pipe retort furnace, D-retort furnace	

Table IV-1. SACRAMENTO VALLEY INACTIVE MINE CHARACTERISTICS.

MAP I D	MINE NAME	COUNTY	RECEIVING WATER SEQUENCE	USGS QUADRANGLE TITLE (MINUTES)	TOWNSHIP-RANGE	DISTRICT	PRODUCT	ORE MINERALOGY	PERENNIAL DISCHRG?	ONSITE PROCESS	START-UP
86	Great Western,old/new	Lake	St. Marys Creek - St. Helena Creek - Putah Creek - Lake Berryessa	Mount St Helena (15)	Sec 16,17 T10N R7W	Mayacma	Hg	Cinnabar, pyrite	yes	Brick, Scott, and Herreshoff furnace, 4 D-retort furnaces	1873
** WATERSHED : Lake Berryessa,Pope											
87	Corona	Napa	James Cr - Pope Cr - Lake Berryessa	Detert Reservoir (7.5)	Sec 32 T10N R6W	Mayacmas	Hg, Cu	Cinnabar, serpentine, pyrite	yes	Scott and pipe furnaces	1895
88	Twin Peaks	Napa	Bateman Cr - James Cr - Pope Cr - Lake Berryessa	Detert Reservoir (7.5)	Sec 4 T9N R6W	Mayacmas	Hg	Cinnabar, serpentine, chromite, millerite (nickel sulphide)	yes	Rotary pipe furnace	1902
89	Oat Hill	Napa	James Cr - Pope Cr - Lake Berryessa	Detert Reservoir (7.5)	Sec 33 T10N R6W	Mayacmas	Hg	Cinnabar, calcite, pyrite	no	Scott Furnace, rotary furnace	1867
90	Aetna Extension	Napa	James Cr - Pope Cr - Lake Berryessa	Detert Reservoir (7.5)	Sec 34 T10N R6W	Aetna Springs	Hg	Cinnabar, millerite	no		1864
91	Oat Hill Extension	Napa	James Cr - Pope Cr - Lake Berryessa	Detert Reservoir (7.5)	Sec 27 T10N R6W	Mayacmas	Hg	Cinnabar	no		
92	Aetna	Napa	James Cr - Pope Cr - Lake Berryessa	Detert Reservoir (7.5)	Sec 3 T9N R6W		Hg	Cinnabar	no	Scott furnace, rotary furnace, mill, 2 D-retort furnaces	
93	Grenada	Napa	James Cr - Pope Cr - Lake Berryessa	Detert Reservoir (7.5)	Sec 34 T10N R6W	Mayacmas	Hg	Cinnabar	no	None	
94	Toyon	Napa	James Cr - Pope Cr - Lake Berryessa	Detert Reservoir (7.5)	Sec 34 T10N R6W	Mayacmas	Hg	Cinnabar	no	Small furnace	

1/ The mineralogical characteristics of the mines were taken from DOM, 1957; DMG, 1966, 1970a-b; CJMG, 1956, 1937a-b, 1936a-b, 1942, 1946, 1947a-b; and CSMB, 1918, 1915, 1916. Map Identification Numbers correspond to mines areally located on Figure IV-1. Mineral formulas, names, and abundances in California can be found in Table F-1.

Table IV-2. AVERAGE WATER QUALITY CHARACTERISTICS OF SACRAMENTO VALLEY MINE DRAINAGE OR DRAINAGE INFLUENCED STREAMS SAMPLED BETWEEN 1987 AND 1991 (AVERAGES FROM TABLE C-1 AND C-2).

MRP I.D. NO.	MINE	ADIT	AVE. Eh (mV)	AVE. FLOW (l/s)	MEDIAN pH	ARSENIC	CADMIUM	CHROMIUM	COPPER	LEAD	NICKEL	ZINC	SILVER	TOTAL IRON (MG/L)
						AVERAGE TOTAL CONCENTRATION (UG/L)								
	Kanaka Creek mines 4/		191	752	6.46	20	<0.1	1	<1	<5	<4	<10	<1	<0.030
9	Valley View		427	0.11	1.70	75	5,500	170	123,500	39	650	245,000	<10	660
11	Spenceville 2/			15.5	7.08	3.1	0.18	<1	375	<5	<4	299	<1	1.09
12	Empire (Nevada Co.)		229	8.13	6.66	49	<0.1	<1	<1	<5	<4	11	<1	4.7
14	Lava Cap		275	5.86	7.60	57	0.2	<1	2	<5	<4	19	<1	0.16
16	Champian			2.26		<1	0.7	<1	1	<5	<4	11	<1	1.5
17	Malakoff Diggn's		176	21.9	6.52	4.5	<0.1	34	21	<5	44	41	<1	19
18	Spanish	Upper	68	2.30	5.67	16	3.8	<1	193	110	19	21	<1	37
		16 to 1	240	2.92	3.50	6.2	5.3	1	267	29	110	2,050	<1	2.05
22	Brush Creek	Main	83	26.9	7.62	221	<0.1	2.1	1	<5	133	<10	<1	<0.030
		Upper	87	6.51	7.10	62			<1		29			
23	Pick & Shovel		126	2.21	6.28	1.5	<0.1	1	<1	<5	137	14	<1	0.03
24	Plumbago		235	3.27	7.90	264	<0.1	2.2	2	<5	15	<10	<1	0.065
28	Columbo		166	31	7.01	0.8	<0.1	2.5	<1	1	<4	<10	<1	<0.03
34	Walker			0.55	7.34	<1	0.1	<1	250	<5	<4	10	<1	
37	Lucky-S		130	3.64	6.04	<2	2.7	<1	72	<5	<4	298	<1	25
44	Bully Hill			0.85	4.30	<2	248	<1	5,053	31	24	13,375	<1	0.223 3/
45	Rising Star			2.66	3.30	865	130	3	3,100	45	12	30,000		153 3/
46	Keystone			2.15	3.18		78		9,658	21 3/		16,705		17.9
47	Early Bird 1/			0.17	2.50		487		99,365			116,400		
48	Balaklala	Main		3.85	2.91		320		18,800			27,692		147 3/
		Weil		0.28	2.71		42		109,463			172,308		8,720 3/
49	Shasta King 1/	Upper 3/		0.3	2.25		334		64,000			58,900		223
		Lower		0.15	2.20	320 3/	349	20 3/	63,800	100 3/		67,200		1,008
50	Mammoth	300 level		0.04	1.79		1,450		166,675			257,475		883
		Gossen #2		2.09	2.16	20 3/	183		104,920	<50 3/		25,438		19.2
		Friday-Lowden		9.63	2.91		70		6,547			11,910		24.2
51	Sutro 3/	Upper		2.7	3.80		8		960			410		1.06
		Middle		8.13	6.80		1.5		107			387		0.23
		Lower		19.2	6.5		17.3		1,210			1883		0.45
52	Golinsky 3/			0.86	2.90		309		12,413		24	27,035		29.6
53	Stowell			1.26	3.48		31		4,625			6,615		26.8 3/
55	Afterthought			0.88 3/	2.70	25	340	2	14,000	91	32	93,000	<1	104 3/
	Spring Creek Debris Dam 5/		518	807	2.80	44	94	11	3,077	20	12	19,460	<1	125 3/
58	Greenhorn	North	424	0.04	2.34	105	665	10	69,333	30	137	160,000	<1	890
		Middle	171	0.49	5.16	8	2.75	<1	2,450	<5	<4	1,450	<1	29
		South	135	0.05	5.74	<1	12.5	<1	200	<5	<4	4,600	<1	120
62	Silver Falls			0	6.7	<1	<0.1	<1	<1	<5	<4	6	<1	
76	Turkey Run			0.19	7.83	<1	<0.1	3	<1	<5	<4	<1	<1	
77	Reed		94	0.16	6.33	59	<0.1	46	<1	<5	1,200	20	<1	
85	Anderson	West	-85	0.14	6.77	3.3	<0.1	4.3	9	<5	107	156	<1	7.00
		East	91	0.5	6.61	9.3	<0.1	<1	15	<5	92	73	<1	2.70
86	Great Western		172	0.33	7.36	<1	<0.1	4	1	<5	34	15	<1	0.79
87	Corona	Main		0.3	7.40	2.5	<0.1	33	0.5	<5	2,950	43	<1	53
		Water tunnel	120	2.87	5.73	<2	<0.1	41	<1	<5	9,350	197	<1	250
88	Twin Peaks		143	0.24	6.30	<1	0.13	5.7	<1	<5	1,800	29	<1	15

1/ Post-plug average.
2/ Below mine in Little Dry Creek.
3/ 1981-86 data.
4/ Drains watershed containing many mines including 16-to-1 and Kenton.
5/ Drains watershed containing Iron Mt. and Stowell Mines.

indicate that arsenic is present largely in the less toxic +5 state based on pH-Eh graphs. This is significant since arsenite (As^{3+}) is 1 to 2 orders of magnitude more toxic to aquatic organisms than the arsenate (As^{5+}) species (Moore and Ramamoorthy, 1984).

Other mines in the Sierra-Nevada range exhibited dissimilar characteristics. The commodities mined at individual sites included polymetallic (e.g., Spanish Mine), gold, chromium (mines in the American River watershed), and copper (Plumas Copper Belt) minerals. Spanish Mine outflows were slightly acidic (pH = 4-6) and contained low to moderate levels of most metals analyzed (Table IV-2). An air vent at the large gold mine, Empire, discharged slightly acidic water containing only nominal levels of nickel and arsenic. Chromite was mined in the American River watershed (Figure IV-1, Plate 1) using both surface and underground extraction techniques, although, water ponded in the open pits was relatively free of mining pollutants. Mines in the Feather River watershed (Plumas Copper Belt; Plate 4) exhibited the most anomalous drainage makeup. The main adit at Walker Mine had, at one time, discharged high volumes of low pH water to the N. F. Feather River watershed (Croyle, pers. comm.). The adit was plugged in 1986 and presently releases near neutral water containing moderate levels of copper originating from the raceway in front of the plug. Other metals were virtually absent in the drainage (Table IV-2). Adit outflows from the Lucky-S copper Mine tested slightly acidic and contained low to moderate levels of cadmium, copper, and zinc. Although the mineralogical surveys suggest otherwise (Table IV-1), the high acid and iron content typical of acid mine drainage waters was absent from Lucky-S outflows. Several reasons may explain these conditions including mineral morphology, residence time of the water, and the high elevation (6,800 feet MSL) in which low temperatures may preclude extensive mineral oxidation.

In the northern Sacramento Valley, adit releases from mines in the Shasta Mining District (map I.D. #s 44-58; Plates 7 and 8) exhibited quality conditions typical of classic acid mine drainage - low pH and high metals content (Table IV-2). Geological surveys for the area describe the presence of massive pyritic deposits that are easily degraded. High annual precipitation (40-80 inches/year) also contributes to the formation and discharge of strongly polluted water. The orebodies in the area were very mineralogically diverse as reflected in the wide range of compounds directly or indirectly mined including silver, arsenic, gold, copper, lead, and zinc. Most of these metals were also found in drainage which generally contained copper, iron, and zinc in the ppm range and lead, arsenic, and nickel in the tens of ppb. The low pH (2-4) and strong oxidizing conditions (Eh ca 500 mV; Table IV-2) keep the metals in solution. The largest discharging mines are located around Shasta Reservoir in the West Shasta Mining District and include the Iron Mt., Balaklala, Keystone, and Mammoth mine complexes.

Mines located in the western foothills were largely either chromite (Grau, Noble Electric, Grey Eagle) or mercury mines with little or no adit outflow (Table IV-1). Western foothill chromite mines were located in the rain shadow of Tehema and Glenn counties (Plate 9) and, although, the topography of the area is steep and mountainous, the absence of perennial drainage is likely due to limited rainfall. Further, ponded water in an open pit at Grey Eagle Mine tested neutral and was relatively free of metals, indicating unreactive mineralogy.

Inactive cinnabar (HgS) extraction mines are located in the Cache and Putah Creek watersheds (Table IV-1). Most of the western foothill mercury mines were dry with no perennial discharges. Adit drainage from a few mines (map I.D. #s 77, 85, 86, 87, 88) was characteristically high in iron, nickel, and carbonates (Table IV-2). Corona Mine discharged the highest volumes (2-3 l/s [ca 1/10 CFS]) of nickel-iron polluted water with the pH averaging around 5.7. The high nickel levels (measured up to 12 ppm) are explained by geological surveys reporting nickel sulfide (pentlandite or millerite) composing up to 5 percent of the surrounding orebody (CSMB, 1915). An extremely high carbonate concentration (300-600 mg/l Ca- and $MgCO_3$) buffers a solution that is calculated to have an acid content of around pH 2-3 in the absence of the carbonates. High iron levels measured in the waste stream confirm the acidity (assuming pyrite oxidation) and were spontaneously plating out as slightly ordered oxides ($HFeO_2$, FeO_3; Walker, pers. comm. from CDMG [Sacramento, CA] analysis; Chapman et al., 1983). The secondary minerals also contained other metals in high quantities such as tin and nickel, suggesting that if the water remained unaltered, soluble pollutants would become insoluble precipitates provided enough surface area was available for nucleation. Iron oxide formations were also observed at two mines located in the Sierra-Nevada range (Pick and Shovel and Spanish, upper adit). Other mercury mines in the area (e.g., Twin Peaks, Reed) exhibited similar drainage characteristics but with smaller outflows and lower constituent levels. Anderson Mine was anomalous in that the drainage was tested in a reducing state (Eh = -85 mV), although arsenic was undetectable or present at very low levels.

Silver was not found in any perennial drainage sampled (detection limit = <1 ppb). Other work shows mine water can contain silver in the pptr range but that 99 percent of it is sorbed to particulates and unfiltrable even in low pH waters (Jones, 1986).

B. Waste Rock Characteristics

Waste rock material excavated as a result of active mining operations is defined as either development waste or tailings (U.S.EPA, 1986). Mine development waste can include soils, overburden, or sub-grade ore removed to gain access to the more valuable ore. Tailings include the altered remains of ore after it undergoes physical and/or chemical treatment to extract the desired compound(s). One or both types were observed at almost every mine visited. In most cases, waste rock was removed from the site by dumping it into the nearest water course. It was apparent at these mines that high flows during the rainy season had eroded much of the material away into downstream waters, and only a fraction of the waste rock originally generated remained on-site.

The soil pH of waste rock material varied dramatically from site to site, ranging between 1.4 and 8.8 (Table IV-3), with no apparent large-scale geographical trends other than providing a representation of the diverse makeup of ore material in the Sacramento Valley. Soil pH is an instantaneous measure of acid at one point in time (Tucker et al., 1987). Further changes in pH occur from degradative weathering processes that generate more acid, make mineral bound carbonates available for buffering, or both. The test needed to determine potential acidity shifts is called net acid generation potential and is discussed below. Soil pH indicates the relative ease with which metals can migrate through, or off, a waste rock pile. Available metals are more mobile when dissolved in an acidified solution, and so, soil pH can be an important factor in determining the relative water quality threat of similarly sized waste rock piles. To determine site variability, replicate samples were collected from 10 mines and individually analyzed. With the exception of two mines, the intra-mine site variability (coefficient of variation) of pH was low, ranging from 1 to 13 percent (Table IV-4). Although 2-3 replicates hardly represent the total variability expected at a site, the method of collection attempted to obtain the most visually disparate material based on color, composition, and proximity to processing equipment. The variability is due completely to site conditions since laboratory replicates showed perfect precision (Appendix A). Waste rock material exhibiting a relatively homogenous acid content may indicate that acid is de-localized from source material and distributed throughout the pile during periods of saturation. It can also simply mean that the waste rock composition itself is homogenous with respect to pH influencing material. Sixteen of 52 samples tested at pH 4 or less which is considered the dividing line for defining a waste as "acid-toxic" (Sobek et al., 1978). From a recieving water standpoint, other factors such as slope, water contact, metals content, etc., may be more important in causing impacts, and therefore, soil pH is one of many factors used to assess what problems may result from any particular waste rock material.

Mercury levels were highest at western foothill mercury mines. It was difficult to determine the age of particular waste material but the highest levels between the mercury mines tested (0.2-140 g/kg, dw; Table IV-3) may be reflective of older operations (mid-1800s) that were less efficient at extracting mercury from the cinnabar ore. Calcine, the leftover ore after heat extraction, was collected at most of the mines as part of this study and had some of the highest levels of mercury. Pipe furnace and retort equipment used to extract mercury were apparently very inefficient - at one site, free mercury was found in the calcine tailings. There were no other strong geographic trends with any of the other metals which were highly variable between mine sites (up to 4 orders of magnitude for copper). The intra-site variability of waste rock metals content was also high, averaging around 50-70 percent and ranging up to 141 percent (Table IV-4). Inter- and intra-mine site variability would make runoff loading predictions very difficult. Regardless, the high metals content of most waste rock material indicates that site runoff can pose a substantial water quality threat.

The net acid generation potential (NAGP) of seven representative samples ranged from -48 to 11 tons of calcium carbonate needed to neutralize 1000 tons of material (the amount of material in an approximate acre-foot [Sobek et al., 1978];Table IV-5). Positive values indicate a tendency for acid to be formed beyond what inherent buffering compounds could neutralize. The test measures the full potential of a material to produce or neutralize acid from the products of leachable minerals. A digestion step releases alkaline compounds, mimicking the weathering conditions that exposed soils may experience over time. A soil pH below 6 is generally thought to indicate an acid generating material (Sobek et al., 1978). This held true for the samples tested in Table IV-5, however, soils with pH values above 6 are not good indicators of positive or negative NAGP measurements. This was apparent at Engle/Superior and Grey Eagle mines with measured pH values of 7.0 and 7.1 respectively corresponding to NAGP values of 4.8 (acid generating) and -48 (strongly alkaline). The low potential for Grey Eagle (-48) is expected from western foothill soils typically high in calcareous minerals. There was a complete lack of correlation between NAGP and pH due to the present unavailability of influencing compounds under normal saturating conditions. Further, the test may not be completely accurate in predicting pH shifts which also likely contributes to the lack of correlation. Soils with a pH below 6 may be good indicators of positive NAGP, although, positive potential was not limited to low pH soils. Material with a value of 5.0 or greater is defined as "potentially toxic material" (Sobek et al., 1978), but as with pH values, NAGP is only one factor in the overall assessment of waste rock material.

Table IV-3. WASTE ROCK CHARACTERISTICS OF SACRAMENTO VALLEY MINES.

WATERSHED	MAP I.D. #	MINE	pH 1/	TOTAL CONCENTRATION (MG/KG, DRY WEIGHT) 2/ ARSENIC	CADMIUM	CHROMIUM	COPPER	LEAD	MERCURY	ZINC	NICKEL	SILVER
Folsom Lake	2	Big Buzzard	3.5	4.6	0.8	6.4	210	270	1.4	86	ND	4.7
Bear River	9	Valley View	2.7	41	246	14	390	189	1.24	480	7.6	9
	10	Dairy Farm	1.9	91	2	17.9	1,350	370	3.8	455	12.5	14.5
	11	Spenceville	3.0	40	1.23	15.2	277	152	1.26	148	4.1	23.5
	13	Idaho Maryland	7.4									
	14	Lava Cap 3/	7.2	3,600	1.6	99	140	100	1.6	230	84	16
Yuba River	17	Malakoff Diggin's	4.5	1.7	ND	50	15	6	0.28	9.4	7	ND
	18	Spanish	5.1	340	ND	7.6	56	330	4.4	130	29	7
	20	Kenton	7.3									
	24	Plumbago	7.9						1.8			
Feather River	33	Iron Dyke	3.4	5	1.2	80	1,600	63	1.9	270	30	29
	34	Walker (tailings)	4.8	9	ND	2.3	790	70	0.15	44	ND	5.9
	34	Walker (mine)	4.1	20	ND	15	2,000	43	1.6	96	8	16
	35	Reward #7	7.4						4.8			
	36	Beardsley	4.4	55	2.4	2.8	16,000	2,700	3.4	240	3.4	2.1
	37	Lucky S	2.7	1200	4.2	21	640	4,300	3.2	890	24	39
	38	Superior/Engle	7.0	105	ND	13	6,550	50	0.95	165	13	15.8
	39	Mountain Meadows	8.0									
Pit River	40	Golden Eagle	7.8									
Shasta Lake	41	Coggins	7.0									
	43	Forest Queen	6.5	7.5	ND	2500	21	9	0.47	37	1,600	ND
	44	Bully Hill	3.6	690	24	14	3,005	1,620	19.3	2,975	5.2	7.5
	45	Rising Star	2.8	625	29	3.8	1,350	105	16	3,500	ND	4.7
	52	Golinsky	6.3									
Sacramento R., upper	54	Gladstone	5.1	800	ND	38	170	76	0.73	140	45	1.4
	55	Afterthought	4.7	500	17	7.8	1,090	4,000	17.2	4,300	5.6	28
	56	Thompson	3.9	11	2	20	940	13	5	260	4.2	3.3
	57	Iron Mt loadng area	1.4	180	4.3	16	480	76	4	580	7.4	0.7
	58	Greenhorn	3.8	140	ND	24	520	30	0.38	120	12	2.2
	60	Yankee John	7.3									
	62	Silver Falls	6.7									
	63	Midas	8.0									
	64	Round Bottom	7.6									
Stony Crk./Elder Crk	65	Grau	8.8									
	66	Noble Electric	8.7	2.8	ND	400	7.6	5.3	0.37	40	2,400	ND
	67	Grey Eagle	7.1									
Cache Creek	71	Empire (sulphur cr)	7.2						17			
	72	Manzanita	3.6	25	ND	54	40	4.1	785	21	22	1
	74	Wide Awake	7.9						13			
	75	Abbott	7.9						910			
	77	Reed	3.8	38	ND	440	52	9.3	19	50	870	ND
Lake Berryessa, Putah	79	Knoxville	7.9						4/			
	81	Red Elephant	7.3						240			
	83	Big Chief	2.5	16	15	23	22	19	840	94	10	0.7
	86	Great Western	7.6									
Lake Berryessa, Pope	87	Corona	2.6	4.7	ND	175	17	21.5	1,370	35.5	350	0.4
	88	Twin Peaks	2.6	ND	2.3	240	53	13	21	28	500	ND
	89	Oat Hill	5.8						590			
	90	Aetna Extension	7.6						6.8			
	92	Aetna	4.5	7	ND	23	36	24	620	56	27	ND
	93	Grenada	7.9									
	94	Toyon	8.2						86			

1/ Paste method.
2/ Samples prepared according to U.S.EPA, 1979.
3/ Complete dissolution with HCl before analysis.
4/ 14%.

Table IV-4. VARIABILITY OF WASTE ROCK METALS CONCENTRATIONS AT SEVERAL MINES.

MINE		pH	ARSENIC	CADMIUM	CHROMIUM	COPPER	LEAD	MERCURY	NICKEL
			TOTAL CONCENTRATION (MG/KG, DRY WEIGHT)						
Valley View		2.4	16	736	23	660	340	0.77	4.6
		3.7	22	ND	10	150	68	0.74	5.2
		1.9	85	2.4	8.6	360	160	2.2	13
	AVERAGE	2.7	41	246	14	390	189	1.24	7.6
	COV	28	76	141	47	54	60	55	50
Dairy Farm		1.8	42	1.2	3.8	1300	440	3.8	9
		2	140	2.8	32	1400	300	3.7	16
	AVERAGE	1.90	91	2.00	17.9	1350	370	3.8	12.5
	COV	5	54	40	79	4	19	1	28
Spenceville		3.1	6	0.8	16	270	76	1.8	6.1
		2.6	88	0.7	2.7	110	230	0.59	ND
		3.2	26	2.2	27	450	150	1.4	6.2
	AVERAGE	2.97	40	1.23	15	277	152	1.26	4.10
	COV	9	87	56	65	50	41	40	71
Afterthought		4.4	500	16	7.3	1300	4900	25	4.8
		5	500	18	8.2	880	3100	9.4	6.3
	AVERAGE	4.70	500	17	7.75	1090	4000	17	5.55
	COV	6	0	6	6	19	23	45	14
Oat Hill		7.7						880	
		3.8						300	
	AVERAGE	5.75						590	
	COV	34						49	
Big Buzzard		3.8							
		3.1							
	AVERAGE	3.45							
	COV	10							
Bully Hill		3.5	1200	22	12	960	2600	34	3.1
		3.6	180	26	16	5050	640	4.5	7.3
	AVERAGE	3.55	690	24	14	3005	1620	19	5.2
	COV	1	74	8	14	68	60	77	40
Corona		2.8	4.4	ND	200	14	16	940	480
		2.3	4.9	ND	150	20	27	1800	220
	AVERAGE	2.55	4.65	0.00	175	17	22	1370	350
	COV	10	5		14	18	26	31	37
Manzanita		4	ND	ND	68	45	ND	270	20
		3.1	50	ND	40	35	8.2	1300	24
	AVERAGE	3.55	25	0.00	54	40	4.10	785	22
	COV	13	100		26	13	100	66	9
Engle		7.9	10	ND	14	1100	ND	0.29	10
		6.1	200	ND	11	12000	100	1.6	16
	AVERAGE	7.00	105	0.00	13	6550	50	0.95	13
	COV	13	90		12	83	100	69	23

Table IV-5. NET ACID GENERATION POTENTIAL OF WASTE ROCK FROM SEVERAL MINES.

MINE SITE	SOIL pH (PASTE)	NEUTRALIZATION POTENTIAL 1/	ACID GENERATION POTENTIAL 2/	NET ACID POT
Iron Mt. Mine, loading area	1.4	-3.8	6.5	
Big Chief	2.5	-4.1	6.5	
Corona	2.6	-2.6	3.5	
Valley View	2.7	-1.6	5.5	
Afterthought	4.7	-4.9	6.5	
Engle/Superior	7.0	4.2	9	
Grey Eagle	7.1	49	1.5	

1/ As tons CaCO3 equivalent per 1000 tons of material.
2/ As tons CaCO3 equivalent to neutralize the acid formed by 1000 tons of material.

Loads were calculat
taken largely betwee
conditions during th
this survey. Estima
Mt. Mine, the load
loading and precipit
with the inclusion c
Detailed load calcu

Iron Mountain Min
from IMM were ca
Bureau of Reclama
The SCDD collects
and seepage, and b
came from this sou
with respect to fres
Mine also drains t
A certain amount c
never fully making

Leaching processe
exposed nature of
containing mineral
when similar cond
with Eh measuren
to breakdown forc
greater electrical t
environments bec
solubilized in wate
metals, mass balar
might be expected

Mines in the Littl
to IMM (Table
Shoemaker Gulc
calculations were
measured dischar
was not the case t
drainage sometin
subsequently flus
shallow weathere
pollution with gr
phenomenon is a
King mines (Hei
standard equival
respect to coppe
that were signific
sources depends

With the exceptic
expected during
through porous/
Evidence of adit
1983 from an a
loading surges t
various paramet
estimated to acc
The study result
material and see
degree than sur
for the total loa
an individual si
priorities. For

V. MASS LOADS

Loads were calculated for Sacramento Valley mines with perennial discharges using flow and concentration measurements taken largely between 1987 and 1992. The loads are somewhat comparable between sites because of the continued drought conditions during that period. For smaller discharging mines, loads were calculated with data collected primarily during this survey. Estimates for West Shasta District mines were made using 1989-92 data. Further, with the exception of Iron Mt. Mine, the loads represent a mass per time statistic during dry periods. Because of the strong correlation between loading and precipitation, the numbers presented here are considered to be underestimates. Actual loads would be higher with the inclusion of waste rock runoff/seepage contributions and an accounting for normal or extreme rainy seasons. Detailed load calculation methods are presented in Appendix A.

Iron Mountain Mine (IMM) was the single largest loader of mine drainage pollutants to the Sacramento Valley. Loads from IMM were calculated using weekly Spring Creek Debris Dam (SCDD) metals and outflow data collected by U.S. Bureau of Reclamation and regional board (Redding office) staff and are considered to be accurate (Heiman, pers. comm.). The SCDD collects and discharges water from the entire Spring Creek watershed including adit releases, waste rock erosion and seepage, and background stream flow. Between 57 and 85 percent of the estimated copper, cadmium, and zinc loads came from this source (Table V-1). Overall, 67 percent of the standard equivalent loads came from SCDD indicating that, with respect to freshwater metal objectives, it is the largest inactive mine source of the most toxic metals detected. Stowell Mine also drains to this watershed but contributes only about 1 percent to total SCDD loading (Heiman, pers. comm.). A certain amount of the loads from SCDD are intercepted at a small Sacramento River reservoir (Keswick) and settle out, never fully making it down the river under normal flow conditions.

Leaching processes within SCDD are likely facilitating the release of metals from waste rock alluvium. The low pH and exposed nature of the reservoir should provide ideal habitat for acidophilic bacteria to break down sulfide and metal containing minerals flushed into the reservoir during the rainy season. Other investigators have shown increased leaching when similar conditions existed in underground workings. Further, SCDD water exhibits an elevated oxidizing potential with Eh measurements averaging around 500 mV. Under these conditions waste rock material is continuously exposed to breakdown forces that are greater than what is found in natural stream waters. The high conductivity of the water allows greater electrical transference which enhances oxidation processes (similar to the way rusting activity increases in coastal environments because of salty air). As waste rock degrades, metals held within the mineral matrix are released and solubilized in water acidified from sulfide oxidation. Even though conditions in SCDD probably enhance the release of metals, mass balance estimates show that about 15 percent of the incoming metal loads are retained in the reservoir. As might be expected, most of the metals leaving the reservoir are dissolved in the water.

Mines in the Little Backbone Creek watershed contributed about 22 percent of the standard equivalent loads, second only to IMM (Table V-1). Mammoth, Golinsky, and Sutro mines drain to this creek which flows into Shasta Reservoir. Shoemaker Gulch drains the southern end of the Mammoth Mine complex and also flows to Shasta Reservoir. Load calculations were made by averaging instream loads measured below the mine complex and the sum of all individually measured discharges (see Appendix A). Although the two methods should intuitively produce similar loading values, this was not the case because of unquantified banking processes going on in the watershed. During dry periods, polluted mine drainage sometimes never fully arrives downstream, leading to a certain amount of build-up in the watershed which is subsequently flushed out under high flow conditions (Heiman, pers. comm.). Further, there may be subsurface flow in the shallow weathered bedrock (Walker, pers. comm.) that would not be visible as it enters the lake. The movement of mine pollution with ground water has been documented at Penn Mine (Bond, pers. comm.). Regardless of the mechanisms, the phenomenon is also observed in the West Squaw Creek watershed draining Balaklala, Keystone, Early Bird, and Shasta King mines (Heiman, pers. comm.). West Squaw Creek also enters Shasta Lake and contributed about 7 percent of the standard equivalent loads (Table V-1) with calculation methods identical to those used for Little Backbone Creek. With respect to copper, cadmium, and zinc, the 3 aforementioned sources located in the West Shasta District discharged loads that were significantly higher than other Valley mines (Figure V-1). The relative magnitude of other, smaller, acid mine sources depends on the pollutant of concern.

With the exception of IMM, the loads in Table V-1 are underestimates because they did not account for discharge increases expected during the wet season. Short duration adit surges result from rainfall or snow-melt moving into tunnel complexes through porous/fractured overburdens, vertical air shafts, and caved stopes (CH2MHill, 1984; Croyle, pers. comm.). Evidence of adit surges can be seen in Table C-2 where Balaklala Mine outflows were measured at 589 l/s during January 1983 from an average dry period flow of about 1-30 l/s. Rainfall runoff from waste rock also contributes to seasonal loading surges but is difficult to accurately characterize. A pilot study was conducted at Spenceville Mine to measure various parameters of rainfall runoff. By extrapolating measurements taken during a single storm event, surface runoff was estimated to account for approximately 5-18 percent of the total annual loads coming from this site (wet + dry season). The study results and loading methods are detailed in Appendix B. Most rainfall infiltrates into permeable waste rock material and seeps out later near the streambed low-point. Seepage water can strip pollutants from waste rock to a greater degree than surface runoff because of a longer residence time. Therefore, measuring surface runoff would not account for the total load increases induced by rainfall. Regardless, the relative pollutants contribution caused by precipitation at an individual site would depend on the magnitude of any existing perennial discharge and, thus, would affect cleanup priorities. For mines with no perennial releases, wet season discharges would represent 100 percent of the total loads

Table V-1. LOADING ESTIMATES FROM INACTIVE MINES WITH PERENNIAL DISCHARGES DURING A DROUGHT PERIOD, 1987-91.

MINE SITE DISCHARGE	TOTAL ANNUAL LOADS IN KILOGRAMS (PERCENT OF TOTAL IN PARENTHESES) (NA=NOT AVAILABLE; ND=NOT DETECTED) 9/								STANDARD EQUIVALENT LOADS 1/
	ARSENIC	CADMIUM	CHROMIUM	COPPER	NICKEL	ZINC	LEAD	IRON	
SCDD 5/	858 (50)	1,529 (85)	214 (74)	36,300 (57)	234 (18)	209,352 (80)	390 (69)	NA	378,162 (67)(60)
Little Backbone Crk. & Shoemaker Gulch mines 7/	59 (3.4)	186 (10)	15 (5.21)	18,961 (30)	32 (2.51)	36,760 (14)	81 (14)	NA	123,559 (22)(20)
West Squaw Crk. mines 6/	ND (0.00)	38 (2.1)	ND (0.00)	6,928 (11)	ND (0.00)	7,537 (2.9)	ND (0.00)	NA	39,674 (7)(6)
SRCSD (1985) 4/	ND	60	1,676	2,863	1,573	15,340	359	ND	34,872 (6)
Penn Mine 3/	NA	57	3	4,455	28	16,860	NA	6375	33,545 (5)
Afterthought 2/	0.7 (0.04)	12 (0.66)	0.06 (0.02)	488 (0.76)	0.88 (0.07)	3,008 (1.15)	2.5 (0.45)	2,873	4,640 (0.8)(0.7)
Rising Star	73 (4.2)	12 (0.66)	0.25 (0.09)	260 (0.41)	0.60 (0.05)	2,603 (1.00)	3.8 (0.68)	5,311	3,800 (0.7)(0.6)
Valley View	0.26 (0.02)	19 (1.1)	0.59 (0.20)	428 (0.67)	2.3 (0.18)	850 (0.33)	0.14 (0.02)	2,290	3,469 (0.6)(0.5)
Kanaka Creek mines	474 (28)	NA (0.00)	24 (8.3)	NA (0.00)	ND (0.00)	NA (0.00)	ND (0.00)	ND	3,013 (0.5)(0.5)
Spanish (upper+lower)	1.7 (0.10)	0.66 (0.037)	0.06 (0.02)	61 (0.09)	10.4 (0.82)	191 (0.07)	83 (15)	334	2,461 (0.4)(0.4)
Brush Creek	200 (12)	ND (0.00)	3.6 (1.24)	1.3 (0.002)	52 (4.12)	ND (0.00)	ND (0.00)	NA	1,294 (0.2)(0.2)
Bully Hill	ND (0.00)	7 (0.37)	NA (0.00)	135 (0.21)	1.4 (0.11)	359 (0.14)	0.8 (0.15)	288	1,192 (0.2)(0.2)
Spenceville	0.67 (0.04)	0.09 (0.005)	ND (0.00)	175 (0.27)	ND (0.00)	144 (0.06)	ND (0.00)	452	942 (0.2)(0.1)
Greenhorn	0.3 (0.01)	1 (0.05)	0.01 (0.003)	122 (0.19)	0.2 (0.01)	232 (0.09)	0.04 (0.01)	1,326	765 (0.1)(0.1)
Corona	0.02 (0.001)	ND (0.00)	4.0 (1.38)	ND (0.00)	875 (69)	18 (0.01)	ND (0.00)	73,384	326 (0.1)(0.1)
Plumbago	27 (1.6)	ND (0.00)	0.23 (0.08)	0.21 (0.00)	1.6 (0.12)	ND (0.00)	ND (0.00)	6.7	174 (0.03)(0.03)
Malakoff Diggings	3.1 (0.18)	ND (0.00)	24 (8.2)	14 (0.02)	30 (2.39)	28 (0.01)	ND (0.00)	1,037	122 (0.02)(0.02)
Empire	13 (0.73)	ND (0.00)	ND (0.00)	ND (0.00)	ND (0.00)	2.9 (0.00)	ND (0.00)	1,204	81 (0.01)(0.01)
Lucky S	ND (0.00)	0.31 (0.02)	ND (0.00)	8.2 (0.01)	ND (0.00)	34 (0.01)	ND (0.00)	2,870	73 (0.01)(0.01)
Lava Cap	10 (0.61)	0.04 (0.002)	ND (0.00)	0.37 (0.001)	ND (0.00)	3.4 (0.00)	ND (0.00)	30	72 (0.01)(0.01)
Columbo	0.77 (0.04)	ND (0.00)	2.4 (0.83)	ND (0.00)	ND (0.00)	ND (0.00)	0.93 (0.17)	ND	28 (0.005)(0.00)
Walker	ND (0.00)	0.002 (0.00)	ND (0.00)	4 (0.01)	ND (0.00)	0.18 (0.00)	ND (0.00)	NA	21 (0.004)(0.00)
Iron Dyke(Taylors Cr)	ND (0.00)	0.032 (0.002)	ND (0.00)	1.3 (0.002)	ND (0.00)	1.1 (0.00)	ND (0.00)	NA	9 (0.002)(0.00)
Twin Peaks	ND (0.00)	0.001 (0.000)	0.04 (0.01)	ND (0.00)	14 (1.09)	0.22 (0.00)	ND (0.00)	115	5 (0.001)(0.00)
Pick & Shovel	0.11 (0.006)	ND (0.00)	0.05 (0.02)	ND (0.00)	9.5 (0.75)	0.98 (0.00)	ND (0.00)	2.1	5 (0.001)(0.00)
Reed	0.30 (0.02)	ND (0.00)	0.23 (0.08)	ND (0.00)	6.1 (0.48)	0.10 (0.00)	ND (0.00)	NA	4 (0.001)(0.00)
Anderson Springs	0.16 (0.01)	ND (0.00)	0.02 (0.01)	0.27 (0.00)	1.9 (0.15)	1.8 (0.00)	ND (0.00)	73	4 (0.001)(0.00)
Champion	ND (0.00)	0.05 (0.003)	ND (0.00)	0.07 (0.00)	ND (0.00)	0.78 (0.00)	ND (0.00)	NA	3 (0.001)(0.00)
Great Western	ND (0.00)	ND (0.00)	0.04 (0.01)	0.01 (0.00)	0.36 (0.03)	0.16 (0.00)	ND (0.00)	8.3	0.3 (0.000)(0.00)
Turkey Run	ND (0.00)	ND (0.00)	0.02 (0.01)	ND (0.00)	ND (0.00)	ND (0.00)	ND (0.00)	NA	0.00 (0.000)(0.00)
TOTAL LOADS 8/	1,722	1,805	288	63,889	1,273	261,128	562	91,602	563,900

1/ The sum of [(average concentration(i)*average flow(i))/Inland Surface Water Plan Objectives(i)] for each metal excluding iron. Hardness = 50 mg/l.
2/ Loads were calculated using data from 1984.
3/ From Bond, 1990. Penn-Comanche Project, Summary of 1990 Monitoring data. CVRWQCB Memo from S. Bond to T. Pinkos. 6 December. (Annual average 1979-90).
4/ Sacramento Regional County Sanitation District wastewater treatement plant loads, 1985.
5/ SCDD = Spring Creek Debris Dam release. The SCDD watershed drains Iron Mt. and Stowell Mines.
6/ The sum of the loads coming from Balaklala, Keystone, Early Bird, and Shasta King mines.
7/ The sum of the loads coming from Mammoth, Golinsky, and Sutro Mines.
8/ Excludes Penn Mine and SRCSD loads.
9/ Loading values do not exclude uncertain digits.

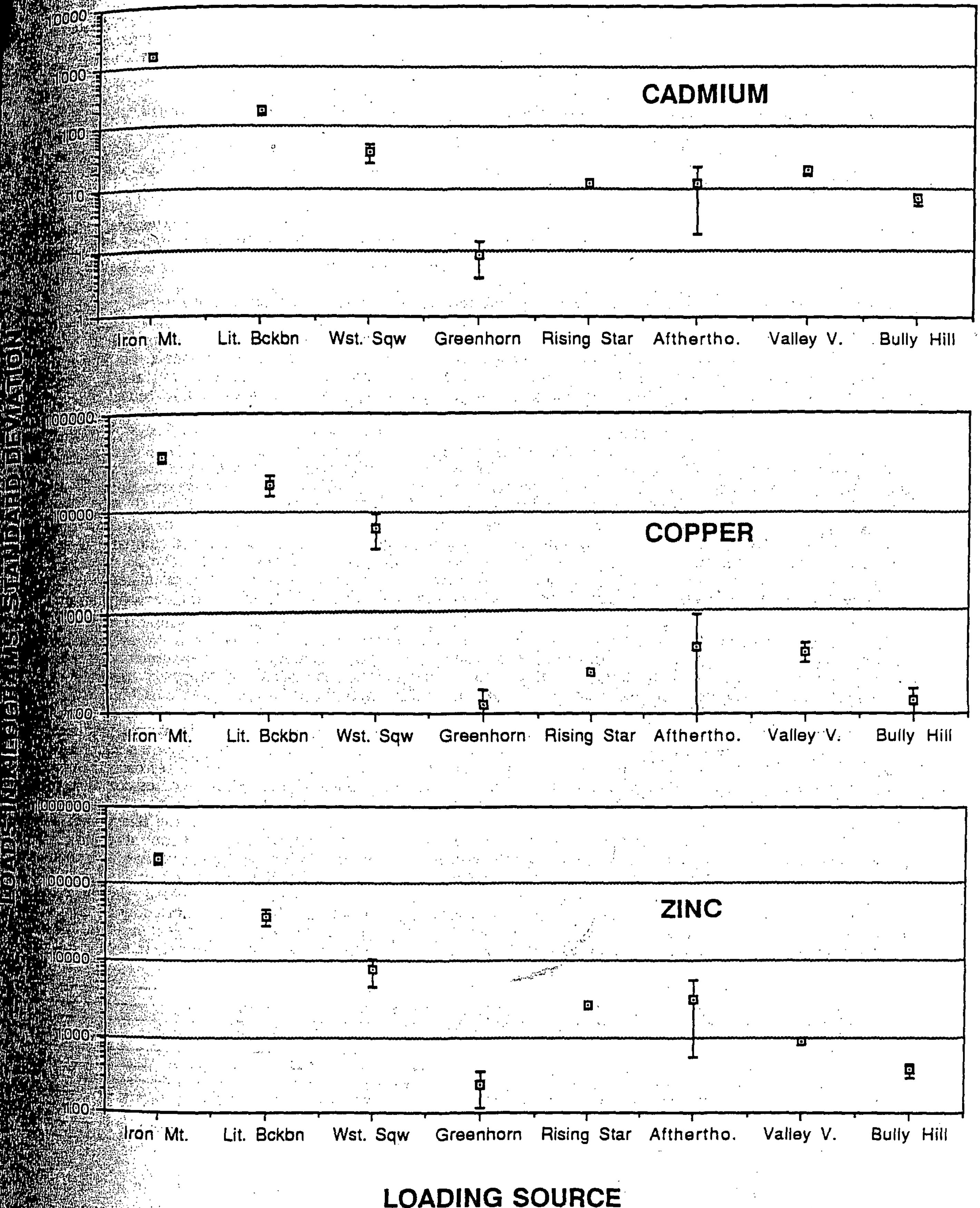


Figure V-1. VARIABILITY OF COPPER, CADMIUM, AND ZINC LOADING ESTIMATES.

coming from that site. At other mines, waste rock runoff is not as significant as adit releases - e.g., West Shasta District mines (Heiman, pers. comm.). The load estimates presented in Table V-1 largely do not account for these and other rainy season surges. It would be difficult to predict waste rock runoff loads because of the number of parameters involved including surface area, permeability, metals content, slope, rainfall characteristics, etc.

The present drought conditions also skew the load estimates in Table V-1 to the low end. Past estimates for SCDD show zinc loads have varied from 1.5 to 4 times the 209 thousand kg estimate (ca 45-52 inches precipitation in 1989-90) in Table V-1 for a normal rainfall year (ca 60 inches in 1984) and an extremely wet year (ca 115 inches in 1983), respectively (Heiman, unpub. data). Extrapolating these load increases to other mines and metals to account for the effect of varying annual precipitation may not be inappropriate.

Loads from the Sacramento Regional County Sanitation District (SRCSD) wastewater/sewage treatment plant were included for comparison. It ranked fourth in standard equivalent loads (ca 6 %) due, in part, to high lead discharges and made up about 3-6 percent of the combined copper, cadmium, and zinc loads.

Almost all of the mining regions are drained by watersheds intercepted with one or more major reservoir which have the potential to retain a certain fraction of the pollutants coming in from upstream. Pollutants attached to heavy particulate matter in feeder streams can settle out and become part of the sediment. The mass balance of pollutants through a reservoir is little understood but is important because dam releases have a substantial influence on the quality of downstream waters. To better define this transport component, the mass balance of copper into, and out of, Shasta Reservoir was estimated using data collected during the current drought period. The major inputs to the lake included 3 mine influenced streams (Shoemaker Gulch, West Squaw and Little Backbone Creeks) and four of the largest stream inputs without mine impacts (Big Backbone, Pit, McCloud, and Sacramento Rivers). The volumes and loads were used to calculate the concentration of copper expected in the dam releases, simulating the reservoir as a large mixing bowl where multiple inputs of differing quality are mixed to produce a final concentration with no physico-chemical interactions. The loading inputs were made largely for 1989 and compared to the copper concentration actually measured in release water between 1988 and 1991. The calculated copper concentration of Shasta Dam release water (5.74 ug/l) was higher than the average annual concentration reported by other studies (2.4 to 4.2 ug/l; Figure V-2 - details of the graph are presented in Table G-1). The 5.74 value was calculated with data collected largely during 1989 and is more comparable to the 4.2 ug/l copper average taken from fiscal year 1988-89 dam release data (from Heiman, 1989). The 2.4 ug/l value was averaged from fiscal year 1990-91 data. No statistical significance could be discerned because the calculated concentration was estimated using only 2 available measurements, causing the confidence interval to widen to useless proportions even though the relative standard deviation was rather low. Conversely, the actual copper concentration of Shasta Reservoir releases statistically declined by almost half over a 2 year period (Figure V-2). This decline may have resulted from drought induced loading reductions which are strongly correlated to annual precipitation (Heiman, unpub. data). Further, when feeder stream loads were changed to simulate no mine drainage input, the calculated copper concentration of 0.27 ug/l simply reflected upstream river quality (upper Sacramento [0.270 ug/l]; Pit [0.240 ug/l]; and McCloud Rivers [0.245 ug/l]; from Connor, unpub., Table H-1). Dam release water is not expected to exactly mimic upstream inputs if their quality represents unaffected background water. Reservoir water can pick up elements present in natural sediments from dissolution and physical resuspention. Other factors that can affect release quality include rainy season surges, draw point elevation, phased time differences of inputs and outputs, concentration differences, etc. All of these combined preclude the value of specifying a mass balance statistic based on this data. Regardless, Shasta Dam releases contain a level of copper that is approximately an order of magnitude greater than what is present in the incoming streams unaffected by mine drainage. This difference is probably influenced, to some extent, by mine drainage from Little Backbone and West Squaw creeks. It is expected that once the low pH streams reach the lake, a quick rise in pH to neutral would cause the metals to deposit to the lake bed, leaving only a small fraction in solution. What may be occurring is a continuous suspension of lighter floc and other particulates caused by wave action. Preliminary data on the lower Sacramento River shows an increasing metals gradient with depth, likely related to low density particulates and colloids travelling near the river bottom. Although there is more suspension energy in a river, there may be a related explanation that describes solids transport in a lake system. Work presently being conducted at Camanche Reservoir will help to understand how hydroxides (initially formed at the stream-lake confluence) and other particulate-bound metals are suspended or re-suspended and carried through reservoir bodies (Bond, pers. comm.).

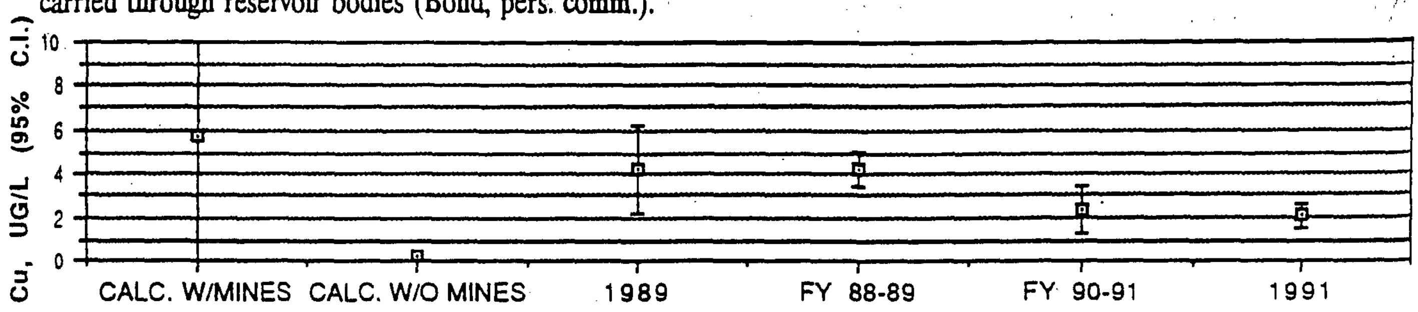


Figure V-2. COPPER CONCENTRATIONS IN SHASTA DAM RELEASE WATER. "CALC. W/MINES" = CONCENTRATION CALCULATED FROM STREAM AND MINE INPUTS; "CALC. W/O MINES" = CONCENTRATON CALCULATED FROM JUST STREAM INPUTS (N=2). ACTUAL CONCENTRATIONS MEASURED IN DAM RELEASE WATER WERE IDENTIFIED BY THE TIME PERIOD IN WHICH DATA WAS COLLECTED (N = 7 TO 22 PER TIME PERIOD). SEE TABLE G-1 FOR MORE SPECIFIC INFORMATION.

VI. RECEIVING WATERS

An assessment was made of the water quality impacts caused by inactive mines. Metals were analyzed in mine site receiving waters and compared to Inland Surface Water Plan (ISWP) objectives adopted to protect both human health and freshwater aquatic biota (SWRCB, 1991). Heavy metal objectives taken from the ISWP are EPA's hardness factored chronic criteria for freshwater biota. The 5.0 ppb arsenic level for human consumption was more conservative. A calcium carbonate concentration of 50 mg/l was used when site-specific hardness levels were unavailable. Most stream samples were collected during dry weather conditions at a distance below the mine where drainage was sufficiently mixed. Multiple sample concentrations were averaged and presented in Table VI-1. To indicate which compounds exceeded the objectives and the relative magnitude, the concentration/objective ratio is shown in parentheses to the right of the average.

Twenty-one of 31 receiving streams monitored were impacted by one or more metals exceeding ISWP objectives. In general, the copper objective was most frequently exceeded followed by zinc and cadmium. Ten streams showed exceedances for lead, nickel, and arsenic and none were measured for chromium or silver. Extremely high levels (100-1,500 times the objectives) were measured in streams with low dilution and minimal buffering capacity.

Impact length was not defined at all mine sites but can be inferred from stream flow and mine loading data. Where acid loading is large enough to overwhelm the buffering capacity of a stream, metals and other pollutants remain in solution. At watersheds in the Shasta Mining District, these conditions result in impacts that extend the length of the stream from the mine site (e.g., West Squaw and Little Backbone Creeks). Impact length at mine sites with atypical drainage characteristics (low- or non-acidic) is not as strongly controlled by pH. Other factors such as metal-specific behavior and the presence or absence of complexing agents appeared to determine how far a pollutant traveled downstream. For instance, nickel in drainage from Corona mine decreased in James Creek from 5 ppm, directly below the mine, to 3 ppm approximately 1.5 miles downstream. The decrease was largely due to dilution from two other stream inputs as the prevalence of iron hydroxides coating the streambed indicated that no significant co-precipitation or adsorption was occurring. Further, natural streams with unnaturally high metals levels loose the ability for sorption when all the available binding sites are filled (Chapman et al., 1983). Arsenic from mines in the Yuba River watershed (Allegheny-Downieville area) was also freely transported in receiving streams. The highest stream concentrations were recorded in Woodruff Creek (up to 30 ug/l) as a result of Brush Creek Mine drainage. Based on average flows for June, the mine was estimated to contribute about 0.3 ppb to the N.F. Yuba River concentration (Table VI-2). The increasing arsenic concentration from Downieville (1.3 ug/l) to Highway 49 (1.6 ug/l) appears to have been largely caused by Brush Creek Mine. Precision analyses (Appendix A) accounted for only a maximum possible increase of 0.2 ug/l due to indeterminant error. Arsenic is easily transported in streams not affected by acid mine drainage because it is present largely in the dissolved phase (50-90 %, Johnson and Thornton, 1987). Arsenic is endemic to this region as exhibited by it's presence in all feeder streams monitored (Table VI-2 and Table E-1) and by the mineralogical surveys conducted in the area showing the extensive presence of arsenopyrite (Carlson and Clark, 1956). Although the watershed makes a substantial contribution to overall Delta arsenic loading, concentrations in the Yuba River were below the drinking water objective (5.0 ug/l).

The Sacramento River periodically experiences objective exceedances (for copper, cadmium, and zinc) both below IMM at Keswick Reservoir and 250 miles downstream at Freeport. Objective exceedances at Freeport may be more frequent than originally thought when accounting for depth related concentration increases. There are a multitude of other inputs to the River along it's length including agriculture and urban runoff, but mine drainage has been previously shown to contribute the bulk of the copper, cadmium, and zinc loads (CVRWQCB, 1988). The Sacramento River has incurred the greatest impact from an incremental increase in metals discharged from the sum of all inactive mines around the Valley.

Stream impacts from mines with smaller discharges usually diminished quickly with distance from the site. A variety of plating and precipitation processes are probably responsible for declines that cannot be explained by dilution alone. For instance, at the Pick and Shovel Mine, low level nickel discharges (59 ppb) decreased to non-detectable about one mile below the mine. Similarly, copper levels decreased from 80 ppb to below detection (<1 ppb) over a 2 mile stretch of Devils Canyon Creek (from upper Spanish Mine adit), whereas the flow only increased by 4 times (Table C-1). Therefore, stream impact length can depend on a variety of factors including the specific behavior of the metal or metalloid, dilution capacity of the stream, mine loads, and the presence (or absence) of complexing agents.

Receiving water concentration surges are expected during wet periods from instream resuspension and increased mine site discharges. Metals deposited in the streambed during low-flow periods are scoured and transported downstream during high flows, freeing up new binding and deposition sites. Further, rainfall and snow-melt are known to flush out tunnel precipitates, resulting in immediate adit surges (CH2M Hill, 1986; Croyle, pers. com.). One lesser understood wet weather contribution is rainfall runoff from waste rock piles. To assess the severity of this discharge, Dry Creek was monitored above and below Spenceville Mine during a 3 inch rainfall event. The potential for impact was great because the waste rock material was highly enriched with several metals. Dry Creek copper levels below the mine ranged between 23 and 120 ppb and exceeded the 1-hour, hardness factored, copper objective (15 ppb) by up to 8 times for a 10-hour period (see Appendix B). The copper concentration in Dry Creek upstream the mine remained just above the detection limit (d.l.= <1 ppb) throughout the storm. Although the stream reached an extremely high flood stage condition during the storm, it was not enough to completely dilute copper discharges coming from the mine site which averaged around 3 ppm. Mine runoff also resulted in a 4 fold increase in the total suspended solids content over upstream levels (6.5-25 mg/l upstream and 25-114 mg/l below the mine; see Appendix B). Typically, an increase in suspended solids would indicate a greater capacity for the water to complex free metal ions. However, most waste rock particulate matter is already saturated with metals and is immediately stripped of the easily leachable fraction upon entering the stream (Brugam et al., 1988). Pollutants discharged under flood stage conditions are transported far downstream into tributary waters carried by high energy, fast

Table VI-1. AVERAGE METALS CONCENTRATIONS IN RECEIVING WATERS ABOVE AND BELOW SACRAMENTO VALLEY MINES (FROM APPENDIX C).

				AVERAGE CONCENTRATION, UG/L (CONCENTRATION/CRITERIA) 6/						
MINE	WATERBODY	LOCATION	CaCO3 (MG/L)	ARSENIC	CADMIUM	CHROMIUM	COPPER	LEAD	NICKEL	ZINC
Afterthought	Little Cow Crk	above		ND	ND	ND	12 (1.4)	ND	ND	5
		below	71	ND	0.4	ND	25 (2.8)	ND	ND	177 (
Anderson Springs	Creek near West adit	above		ND					6	8
		below	160	1			ND		3	5
	Anderson Springs Crk	above								
		below		ND	ND	1.5	0.5	ND	ND	ND
Balaklala, Keystone, Early Bird, and Shasta King	West Squaw Crk	above		NA	4 (6.1)	NA	32 (4.9)	NA	NA	55
		below		ND	11 (17)	ND	1653 (254)	4 (3.1)	ND	1947 (
Beardsley 4/	Hosselkus Crk	above								
		below		ND	ND	ND	2	ND	ND	ND
Brush Creek	Woodruff Crk	above 1/								
		below	100	22 (4.4)	ND	2	2	ND	11	ND
Bully Hill	Town Crk	above		ND	ND	ND	ND	ND	ND	ND
		below		NA	140 (212)	NA	3481 (536)	83 (64)	NA	11533 (
Corona	James Crk	above				0.5			125	ND
		below	450	ND		9	1		5400 (9.6)	145
		1.5 mi. below 4/	540	ND	ND	1	1	ND	3000 (2.8)	23
Empire (Nev. Co.)	Wolf Crk	above		ND	ND	ND	2	ND	ND	2
		below		ND	ND	1	2	ND	ND	5
Engle/Superior 4/	Lights Crk	above		ND	ND	ND	4	ND	ND	ND
		below		ND	ND	ND	3	ND	ND	ND
		3 mi. below		3	ND	ND	12 (1.8)	ND	ND	ND
Gladstone 4/	Cline Crk	above								
		below		23 (4.6)	ND	ND	ND	ND	ND	ND
Great Western	St. Marys Crk	above 3/								
		below		ND	ND	3.5	ND		4	60 (
Greenhorn	Willow Crk	above		ND	ND	ND	7	ND	ND	ND
		below	99	ND	6 (5.3)	1	619 (53)	ND	5	859 (
Iron Dyke 4/	Taylors Crk	above		ND	ND	ND	ND	ND	ND	ND
		below		ND	0.5	ND	21 (3.2)	ND	ND	18
Iron Mt. 7/	Sacramento R., Keswick Res.	above			.19		3.0			9.6
		below			.53 (2.4)		7.7 (1.4)			38.8 (
Kanaka Creek mines	Kanaka Ck @ M.F.Yuba R	below 8/	62	20 (4)	NA	1	NA	ND	ND	NA
Lucky-S 4/	Peters Crk	above 3/								
		below	28	ND	2.1 (5)	ND	67 (14)	ND	ND	299 (
Mammoth	Little Backbone Crk	below		NA	6.2 (8.9)	NA	597 (85)	NA	NA	963 (
Malakoff Diggn's	Humbug Crk	above	61	ND	ND	ND	1	ND	10	ND
		below	51			ND			15	8
Midas 4/	Harrison Gulch	above	ND	ND	ND	ND	ND	ND	ND	ND
		below	4	ND	ND	ND	ND	ND	ND	ND
Noble Electric 4/	N.F. Elder Crk	above		ND	ND	2	ND	ND	ND	5
		below		ND	ND	2	ND	ND	ND	5
Pick & Shovel	Pats Gulch	above		ND	ND	1	ND	ND	ND	ND
		below	78	ND	ND	0.5	ND	ND	59	9
		1 mi. below 4/		ND	ND	ND	ND	ND	ND	ND
Plumas Eureka 4/	Jamison Crk	above 2/								
		below		ND	ND	ND	ND	ND	ND	ND
Plumbago	Buckeye Ravine	above		0.9	ND	10	ND	ND	4.4	ND
		below	130	170 (3.4)	NA	9	NA	ND	ND	ND
Reed	Davis Crk	above		ND	ND	1	1	ND	2	10
		below	820	15 (3.0)	ND	16	1	ND	446	9
Reward #7	Ward Crk	above		ND						
		below	47	ND 5/	ND	ND	ND	ND	ND	ND
Rising Star	Horse Crk	above		NA	10 (15)	NA	110 (17)	NA	NA	60
		below		4	293 (444)	3	9933 (1528)	38 (29)	18	40000
Spanish	Poorman Crk	above		ND	0.1	ND	ND	ND	ND	5
		below	22	ND	0.0	ND	1	ND	ND	15
	Devils Canyon Crk	above		ND	ND	ND	ND			
		1 mi. below		ND	0.7 (1.1)	ND	20 (3.1)			
		2 mi. below		ND	ND	2	6.7 (1.0)	ND	6	2
Spenceville	Little Dry Crk	above	71	2.3	ND	ND	16 (1.3)	ND	ND	5.8
		below	102	4.2	0.5	ND	368 (31)	ND	ND	299
	Dry Crk	above	79	ND	ND	ND	2.4	ND	ND	1
		below	84	ND	0.1	ND	63 (5.0)	ND	ND	43
Twin Peaks	Bateman Crk	above		ND	ND	ND	ND	ND	ND	2
		below	78	NA	ND	1	1	ND	115	2.3
Valley View	irrigation water	above		ND	ND	4.6	4.4	ND	ND	ND
		below		ND	129 (195)	1.8	3010 (463)	ND	30	8650
Walker	Dollie Crk	above		ND	ND	1	3.5	ND	ND	12
		below		ND	ND	ND	59 (9.1)	ND	ND	5

1/ A significant portion of the upstream flow is composed of an upper adit discharge.
2/ No upstream site was discernable. 3/ The upstream portion was ephemeral. 4/ Based on one sample.
5/ One high detectable value was considered to be an analytical error.
6/ 4-day, hardness corrected EPA freshwater quality criteria. A hardness of 50 mg/l was used when no stream-specific hard was available. The human consumption arsenic level = 5.0 ug/l.
7/ From Heiman, 1988, 1990 and site specific objectives for the upper Sacramento River.
8/ Kanaka Creek below all mines in the watershed.

REFERENCES

Bond, S. 1988. Penn Mine Toxic Pits Cleanup Act technical investigation Report. CVRWQCB. GWPIS. 3 November.

___ Personal Communication. Engineering geologist with the CVRWQCB, Sacramento, CA.

Bounds, H. and A. Colmer. 1972. Comparison of the kinetics of thiosulfate oxidatin by three iron-sulfer oxidizers. Can. J. Microbiol. 18:735-740.

Brugam, R., S. Chakravery, and J. Lamkin. 1988. Sediment chemistry of lakes formed by surface-mining for coal in the midwestern U.S.A. Hydrobiologia. 164:221-233.

Burau, R., S. Colman, and S. Betts. 1988. Arsenic in irrigation water in San Joaquin Valley, CA. Final Report to SWRCB. U.C. Davis. April 1.

Butz, R. Personal Communication. Area engineer with the CVRWQCB, Sacramento, CA.

California State Mining Bureau (CSMB). 1918. Mines and mineral resources of Nevada Co. San Francisco, CA. December.

Carlson, D. and W. Clark. 1956. Lode gold mines of the Alleghany-Downieville area, Sierra County CA. CDMG 52(3):237-247.

Caruccio, F. 1975. Estimating the acid production of potential coal mine re-use. In: Chadwick and Goodman, Editors, The Ecology of Resource Degradation Renewal. Blackwell Scientific Publication, London, England. pp. 197-205.

California Division of Mines and Geology (CDMG). 1966. Mineral resources of California. Bull. 191. San Francisco, CA.

___ 1970a. Bulletin 193.

___ 1942. Quarterly chapter of state mineralogists. Report XXXVIII. Vol38, #1. San Francisco, CA. January.

___ 1970b. Trace elements in the Plumas copper belt, Plumas Co., CA. Special Report 103. Sacramento, CA.

California Journal of Mines and Geology (CJMG), 1946. State mineralogists report. Vol. 42, #3. San Francisco, CA, July.

___ 1936a. Gold mines of Placer Co. Vol 32, #1. San Francisco, CA. January.

___ 1936b. Mineral resources of Lassen Co. Vol. 32, #4. San Francisco, CA. October.

___ 1937b. Mineral resources of Plumas Co. Vol. 33, #2. San Francisco, CA. April.

___ 1947a. Mines and mineral resources of Siskiyou Co. Vol. 43, #4. San Francisco, CA. October.

___ 1937a. The geology of quicksilver ore deposits. Vol. 33, #1. San Francisco, CA. January.

___ 1947b. Mines and mineral resources of Lake Co. Vol 43, #1. San Francisco, CA. January.

___ 1956. Lode gold mines of the alleghany-Downieville area, Sierra Co., CA. Vol. 52, #3. San Francisco, CA. July.

___ 1915. Mines and mineral resources of Shasta, Siskiyou and Trinity Counties. San Francisco, CA. July.

California State Mining Bureau (CSMB). 1915. Mines and mineral resources of Colusa, Glen, Lake Marin, Napa, Solano, Sonoma, and Yolo counties. San Francisco, CA. July.

___ 1916. Mines and mineral resources of the counties of Butte, Lassen, Modoc, Sutter, and Tehema. San Francisco, CA. December.

___ 1908. Copper resources of California. Bulletin 50. San Francisco, CA. Sept.

Central Valley Regional Water Quality Control Board (CVRWQCB). 1991. An analysis of the toxic water quality impairments in the Sacramento-San Joaquin Delta/Estuary. CVRWQCB, Standards, Policies, and Special Studies Section (SPSS). Sacramento, CA. December.

___ 1988. A mass loading assessment of major point and non-point sources discharging to surface waters in the Central Valley, California, 1985. CVRWQCB, SPSS Section. Sacramento, CA. October.

___ Unpublished Data. Database of mines in Napa, Sierra, Butte, and Lake counties. CVRWQCB, Sacramento, CA.

CH2M Hill. 1985. Final remedial investigation report. Iron Mt. Mine area, Redding, CA. Remedial Planning/Field Investigation Team. Zone II. EPA 48.9117.0. August.

Chapman, B., D. Jones, and R. Jung. 1983. Processes controlling metal ion attenuation in acid mine drainage streams. Geochimica et Cosmochimica Acta. 47:1957-1973.

Connor, V. Unpublished Data. Metals concentration data for the Sacramento Valley.

moving flows. Further, infiltrated water emanating from a waste rock pile moves at a slower velocity than surface runoff and probably extends the duration of impact beyond the period of rainfall. Runoff from waste rock increased the downstream concentration of total metals and likely increased the streambed metals content. Other mine influenced receiving waters are expected to experience similar impacts and, therefore, Table VI-1 is an underestimate of the actual average concentration the streams experience year-round as a result of mine drainage.

Stream concentrations are also influenced by direct contact with waste rock piles regardless of the season. For instance, at Iron Dyke Mine, Taylors Creek disappears under a waste rock pile that was deposited directly in the streambed. The stream emerges from the other side with levels of cadmium (0.5 ug/l), copper (21 ug/l), and zinc (18 ug/l) above what was measured upstream (<0.1, <1, and <10 ug/l, respectively). Therefore, waste rock piles have the potential to enrich streams with an easily and freely leachable fraction not dependent on pH declines. Simple diffusion processes bring the metals into solution upon contact with water. Mining operations commonly removed unwanted waste rock from the site by dumping it into stream watercourses and allowing high winter flows to wash it away. At many mine sites waste rock still composes a portion of the stream bank.

Almost all streams influenced by mine drainage eventually pass through one or more major reservoirs. Reservoirs have the potential to alter the input-output balance between metals coming in from natural/man-caused sources and those leaving via dam releases. At Camp Far West, a reservoir in the Sierra-Nevada foothill range, upstream inputs from Bear River and Rock Creek were monitored along with dam release water. Arsenic levels were very slightly elevated in the release water (1.6 versus 1.3 and 1.1 ppb) but chromium (3.8 versus 2.8 and 5.3 ppb) and copper (2.9 versus 2.8 and 1.4 ppb) remained essentially unchanged based on laboratory variability measurements for that batch submission. Sampling occurred in June when the streams exhibited low flow conditions with no observable turbidity. It would appear that these metal inputs were simply passing through the reservoir system with very little concentration change. However, when streams are highly turbid, metals associated with heavy particulate matter are expected to settle out to the lakebed. After deposition, undisturbed metals can become even more tightly bound to carbonate, sulfide, and organic carbon material and are not easily leached from the sediment (Brugam et al., 1988; DiToro et al., 1989). By the time incoming particulate matter has been transported to the lake bottom, most of the leachable metals have been released to the water column (Brugam et al., 1988). Reservoir characteristics such as temperature and flow differentials, draw point elevation, distance to the dam release, stratification, etc., are also expected to influence release quality. For instance, during a storm event, rainfall runoff from Penn Mine travelled the length of Camanche Reservoir along the inundated Mokelumne riverbed (Rectenwald et al., 1978). The colder, heavier, runoff water eventually reached the dam's base where out-flows resulted in salmonid fish kills at the hatchery below. Based on this assessment, and the one presented in Section V, it appears that the fraction of metals transported through a reservoir depends on a variety of factors including dam characteristics and the quality of upstream inputs.

Mines can also cause receiving water impacts from increased siltation. Waste rock sediments flushed into adjacent streams can produce a transitory benthic environment prone to movement and scouring. This can shift the macro-invertebrate population to more sediment tolerant species such as the mayfly and caddisfly (Duba and Penrose, 1980). Further, sediment from inactive mines can prevent fishes such as sculpin, darters, and trout from inhabiting a stream because of the lack of clean gravel (Reash et al., 1988). Although acid and metals may be diluted to levels tolerated by resident biota, the long-term impacts from increased siltation are more subtle and can result in a faunal shift to more sediment tolerant organisms.

Table VI-2. ARSENIC LEVELS IN THE NORTH FORK FEATHER RIVER, 9 JUNE 1989 (FROM TABLE E-1).

FEEDER STREAM TRIBUTARY	ARSENIC (UG/L)	N. F. YUBA RIVER LOCATION	ARSENIC (UG/L)
		Bassett	1.1
Howard Creek	10		
Salmon Creek	1.2		
Sierra Buttes stream	1.2		
		Downieville	1.3
Downie River	2.1		
Goodyears Creek	1.8		
Woodruff Creek	21		
Fiddle Creek	1.7		
		Hwy 49	1.6

Croyle, W. Personal Communication. Area engineer with the CVRWQCB, Sacramento, CA.

Daniels, D. Personal Communication. Area engineer with the CVRWQCB, Sacramento, CA.

Di Toro, D. et al. 1989 (DRAFT). Toxicity of cadmium in sediments: the role of acid volatile sulfide. Draft U.S.EPA report, Environmental Research Laboratory, Narragansett, RI. August.

Division of Mines. 1957. Mineral commodities of CA. Revision of Bulletin 156. Bulletin 157. San Francisco, CA. December.

Duba, A. and D. Penrose. 1980. 1980. Impact of mining activities on water quality in western North Carolina. Water Resources Bulletin. AWRA. 16(6):1034-1040.

Doyle, F. and A. Mirza. 1989. Understanding the mechanisms and kinetics of acid and heavy metals release from pyritic wastes. In: Mining and Mineral Processing Wastes. U.C. Berkeley Dept. of Materials Science and Mineral Engineering, CA.

Drever, J. 1988. The geochemistry of natural waters. Second Ed. Prentice Hall, Englewood Cliffs, New Jersey.

Ehrlich, H, 1964. Bacterial oxidation of arsenopyrite and enargite. Economic Geology. 59:1306-1312.

Fillpek, L., D. Nordstrom, and W. Flicklin. 1987. Interaction of acid mine drainage with waters and sediments of West Squaw Creek in the West Shasta Mining District, California. Environ. Sci. Technol. 24(4):388-396.

Good, D. 1970. The relation of refuse pile hydrology to acid production. 3rd Symposium on Coal Mine Drainage Research. Mellon Institute. May.

Harries, J. and A. Ritchie. 1983. Runoff fraction and pollution levels in runoff from a waste rock dump undergoing pyritic oxidation. Water, Air, and Soil Pollution. 19:155-170.

Harris, D. 1982. Quantitative Chemical Analysis. Second Edition. W.H. Freeman and Company. New York.

Harrison, J. and V. Berkheiser. 1982. Anion interactions with freshly prepared hydrous iron oxides. Clays and clay minerals. 30(2):97-102.

Heiman, D. Personal Communication. Area engineer with the CVRWQCB, Redding, CA.

----- 1991. Iron Mt. Mine report, July 1990 through June 1991. CVRWQCB, Redding, California.

----- 1989. Iron Mt. Mine report, July 1988 through June 1989. CVRWQCB, Redding, California.

----- Unpublished Data. 10-year database from IMM. CVRWQCB, Redding, CA.

Hem, J. 1985. Study and interpretation of the chemical characteristics of natural waters. Third Ed. U.S.GS Water Supply Paper 2254.

Higgins, M. Personal Communication. Area engineer with the CVRWQCB, Sacramento, CA.

Ivarson, K. 1973. Microbiological formation of basic ferric sulfates. Can. J. Soil Sci. 53:315-323. August.

Jenke, D. , G. Pagenkopf, and F. Diebold. 1983. Chemical changes in concentrated, acidic, metal bearing wastewaters when treated with lime. Environ. Sci. Technol. 17(4):217-223.

Johnson, C. 1986. The regulation of trace element concentrations in river and estuarine waters contaminated with acid mine drainage: the adsorption of copper and zinc on amorphous oxyhydroxides. Geochimica et Cosmochimica Acta. 50:2433-2438.

Johnson, C. and I. Thornton. 1987. Hydrological and chemical factors controlling the concentrations of Fe, Cu, Zn, and As in a river system contaminated by acid mine drainage. Wat. Res. 21(3):359-365.

Jones, K. 1986. The distribution and partitioning of silver and other heavy metals in sediments associated with an acid mine drainage stream. Environ. Pollut. Ser. B. 12:249-262.

Kingsley, B. 1984. Quality assurance in a contract laboratory. In: AWWA water quality technology conference. 12th, 1984, Denver, CO. December.

Macdonald, D. and R. Clark. 1970. The oxidation of aqueous ferrous sulfate by Thiobacillus ferrooxidans. The Canadian J. of Chem. Eng. 48:669-676. Dec.

Malouf, E. and J. Prater. 1961. Role of bacteria in the alteration of sulfide minerals. J. of Metals. pp. 353-356. May.

Miller, T., F. Davis, J. Gratton, J. Poindexter, and G. Weatherford. 1979. Abatement of water pollution from inactive mines in CA: a legal institutional study. John Muir Institute, Inc., Napa, CA. CVRWQCB Contract. December.

Mills, A. and L. Mallory. 1987. The community structure of sessle heterotrophic bacteria stressed by acid mine drainage. Microb. Ecol. 14:219-232.

Moore, J. and S. Ramamoorthy. 1986. Heavy metals in natural waters. Applied Monitoring and impact assessment. Springer-Verlag. New York.

Moore, J. and D. Sutherland. 1981. Distribution of heavy metals and radionuclides in sediments, water, and fish in an area of Great Bear Lake contaminated with mine waste. Arch. Environ. Contam. Toxicol. 10:329-338.

Noike, T., K. Nakamura, and J. Matsumoto. 1983. Oxidation of ferrous iron by acidophilic iron-oxidizing bacteria from a stream receiving acid mine drainage. Water Res. 17:21-27.

Nordstrom, D. 1982. Aqueous pyrite oxidation and the consequent formation of secondary iron minerals. In: Acid Sulfate Weathering. Soil Science Society of America. Madison, WI.

Nordstrom, D., F. Jenne, and R. Avereth. 1977. Heavy metal discharges into Shasta Lake and Keswick Reservoirs on the upper Sacramento River, California: A reconnaissance during low flow. U.S.GS Water Resources Investigations 76-49. Menlo Park, CA. March.

Onyesko, S. 1985. Chemical abatement of acid mine drainage formation. Dissertation, Ph.D. in Engineering, U.C. Berkeley.

Potter. 1976. Acid mine drainage characteristics from Balaklala Mine, Shasta County, CA. U.S.GS. Professional Paper.

Reash, R., J. Van Hassel, and K. Wood. 1988. Ecology of a southern Ohio stream receiving fly ash pond discharge: changes from acid mine drainage conditions. Arch. Environ. Contam. Toxicol. 17:543-554.

Rectenwald, H., M. Christofferson, and B. Finlayson. 1978. A review of the aquatic toxicity from the Penn Mine area, Mokelumne River Basin, CA. CDFG Environmental Services Branch. Laboratory Memorandum Report No. 77-2. August.

Shumate, K., E. Smith, P. Dugan, R. Brent, and C. Ranelles. 1971. Development of a conceptual model for pyrite oxidation systems. In: Acid Mine Drainage formation and abatement. Ohio State University Research Foundation. Study performed for the U.S.EPA, Program No. FWPCA Grant No. 14010 FPR. April.

Singer, P. and W. Stumm. 1970. Acidic mine drainage: the rate determining step. Science. 167:1121-1123.

Sobek, A., W. Schuller, J. Freeman, and R. Smith. 1978. Field and laboratory methods applicable to overburdens and mine soils. Industrial Environmental Research Laboratory, Office of Research and Development. U.S.EPA. EPA-600/2-78-054. March.

Sullivan, P., J. Yelton, and K. Reddy. 1988a. Iron sulfide oxidation and the chemistry of acid generation. Environ. Geol. Water Sci. 11(3):289-295.

---- 1988b. Solubility relationships of aluminum and iron minerals associated with acid mine drainage. Environ. Geol. Water Sci. 11(3):283-288.

State Water Resources Control Board (SWRCB). 1972. Principal areas of mine pollution. Basin Planning area 5A Sacramento River. Prepared for the SWRCB by CDMG, Sacramento, CA. June.

---- 1991. California inland surface waters plan. Water Quality Control Plan for inland waters of California. 91-12 WQ. SWRCB, Sacramento, CA. April.

Taylor, B., M. Wheeler, and D. Nordstrom. 1984. Isotope composition of sulfate in acid mine drainage as a measure of bacterial oxidation. Nature, Letters to Nature. 308:538-541. April.

Tucker, G., W. Berg, and D. Gentz. 1987. pH. In: R. Williams and G. Schuman, eds. Reclaiming mine soils and overburden in the western U.S., analytic parameters and procedures. Soil Conservation Society of America. Arkeny, Iowa.

U.S.EPA. 1986. Quantities of cyanide-bearing and acid-generating wastes generated by the mining and beneficiating industries, and the potentital for contaminant release. Final Report. EPA/SW/530-86/025. Versan, Inc. Springfield VA. June 27.

------ 1983a. Guidance for preparation of combined work/quality assurance project plans for water monitoring. Office of Water Regulations and Standards. U.S.EPA, Washington D.C. 27 May.

------ 1982. Test methods for evaluating solid waste, physical/chemical methods. SW-846, 2nd Edition, U.S.EPA.

------ 1983b. Methods for chemical analysis of water and wastes. U.S.EPA Environmental Monitoring and Support Laboratory, Research and Development. EPA-600/4-79-020. Revised March 1983.

Waggoner, M. Personal Communication. Area engineer with the CVRWQCB, Sacramento, CA.

Walker, S. Personal Communication. Engineering geologist with the CVRWQCB, Sacramento, CA.

Wichlacz, P. and R. Unz. 1981. Acidophilic, heterotrophic bacteria of acidic mine waters. Applied and Environ. Microbiology. 41(5):1254-1261.

Windom, H. J. Byrd, R. Smith, Jr., and F. Huan. 1991. Inadequacy of NASQAN data for assessing metal trends in the Nation's river. Environ. Sci. Technol. 25(6):1137-1141.

APPENDICES

METHODS

SPENCEVILLE MINE RAINFALL RUNOFF MONITORING

INDIVIDUAL MINE DESCRIPTIONS BY WATERSHED

APPENDIX A
METHODS

...elected by two criteria: 1) mines that were known water quality threats, and 2) mines that were ... The inactive mines in Buer et al., 1979, were included as known water quality threats. Mines ... mining journals were considered major producers. Reports reviewed for major producers included ... 1966 and 1970b. Lode gold mines that produced over 1 million dollars were included (from CDMG, ... periodically added if there was a known discharge or were near other visited mines (eg., Turkey ... Black Oak). There was extensive overlap in the mines included between the two criteria, i.e., very few ... 1979 survey.

... AND QUALITY CONTROL PROCEDURES

...mples were collected using, 1 liter, polyethylene bottles pre-preserved by the laboratory with 2.5 ... nitric acid. Samples were collected from mine drainage before contact with the receiving waters. ...ples were collected just upstream the drainage and below after thorough mixing. Samples were ... laboratory on ice and analyzed within 2 weeks. The July, 1989 samples were analyzed by Cal-Enseco, ... CA; the rest were analyzed by Anlab Laboratory, Sacramento, CA. Approved laboratory methods ... followed for the analysis of total arsenic, cadmium, chromium, copper, nickel, lead, silver and zinc. ...ments used for the analyses - the Perkin-Elmer 460, 5000, or 5100 - was coupled with graphite furnace ...orption spectroscopy. Concentrations of metals generally over 35-50 ppb were analyzed by ICPES. ...sium were analyzed by atomic absorption spectroscopy for the hardness analysis. Electrical conductivity, ... measured respectively using a Myron L Digital meter and a YSI 53560 Water Quality Monitoring ... silver chloride - platinum electrodes. Flow measurements were made with a Swoffer 2100 current ...

...mples were included blindly along with each sample batch submitted to the laboratory. Batch submissions ... number of laboratory or travel blanks (triple de-ionized water and preservative), a large number ... (splits) for precision, and sample spikes. For the spikes, triple de-ionized water was fortified using ... absorption standard metal solutions (EM Industries, Inc., Cherry Hill, NJ) at concentrations expected in ... An intermediate standard solution of all metals (except silver) served as the primary source - two serial ... per spike. Spike samples were prepared at the regional board laboratory using glassware that was ... percent nitric acid, and rinsed with triple de-ionized water prior to use.

...was calculated as the quotient of the analysis levels to the quantity supplemented. Analytical precision ... from replicate sample results using the "modified Shewart" method (U.S.EPA, 1983a). Replicate ... (A+B) were separated into four ranges (<20, 20-<50, 50-<100, and above 100 ug/l) before calculation ... comparisons at differing concentration levels.

...were collected using wide-mouth glass jars with teflon lined lids. Sub-samples were composited at a ... locations from the waste rock piles based on texture and color, roughly simulating a representative ... waste rock type according to it's surficial abundance. Samples were stored at room temperature for up to ... prior to preparation and analysis. Sediment was dried at room temperature, crushed, and passed through ... stainless steel screen prior to analysis (protocol in Sobek et al., 1978). Approved laboratory methods (EPA, ... for the total analysis of arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc. Soil ... with a 2:1 sediment:water ratio ("paste method"). Acid base accounts were performed according to Sobek ... producing compounds are detected using the Leco sulfide detection method which are stoichiometrically ... buffering capacity determined after extraction with hot acid. Net acid generating capacity values were ... amount of carbonate needed to obtain a pH of 8. Samples were split for precision measurements.

... QUALITY CONTROL RESULTS

...for June and July, 1989, are considered erroneous because of faulty equipment. Redox measurements were ... stream temperature and therefore, the natural stream Eh values ranged between approximately 100 and ... mV). Abnormal ionic influence in waste streams was indicated by redox extremes outside this range (e.g., negative or high [400-500] values). Therefore, Eh measurements should be used as a gross indicator of the water redox potential.

Accuracy: With the exception of the low level zinc analyses and a few isolated submissions, spiked recoveries were generally good (Table A-1). Zinc recovery of spiked de-ionized (D.I.) water was consistently variable at the low level concentration (10-20 ug/l) but was good to exceptional at the high spike levels (24-200 ug/l). With the exception of two batch submissions, the low level zinc recoveries were statistically different from a normalized population of 100 +- 30 (95% C.I.) percent. Both the high and low zinc recovery values were similar to the performance of other nationwide laboratories using the same methods (Table A-2). The general over-recoveries of zinc at the low spike levels would indicate contamination although, on a selective basis as indicated by the high variability. The spiking method of spiking used would have resulted in consistent errors among the other metals, indicating interferents. Regardless, most of the low level zinc values in this report should be assigned a high variability (e.g., +- 2X or 3X).

Other anomalies include the 13 June 1989 submission. It is unknown why this submission had such poor results, however, it should be noted that 1) the blank results showed some slight chromium contamination, and 2) the laboratory performed analyses only on one batch (see footnote 1, Table A-1). The 28 December 1989 submission shows no recovery of nickel at 10 ug/l and poor recovery at 20 ug/l. Since past analysis of this compound by the same laboratory was consistently exceptional, it is assumed to be a sample mixup error. Although both the high and low concentration recoveries of all compounds for the 30 April 1990 submission were consistently above 100 percent, the fault likely lies in the spiking procedure which was a "new technique" being tested.

Precision: The precision of laboratory replicate samples, reported as coefficient of variation (COV) in percent, was fair to good (Table A-3). Most of the highly variable replicates were reported in the "A+B<=20" range and reflect the statistically induced variation of concentrations approaching zero. Other reputable laboratories double the acceptable precision threshold to account for this phenomenon at concentrations below 10 ug/l (Kingsley, 1984). Although the COVs outside of 30 percent were above expected EPA methodology COVs (or Relative Standard Deviation [RSD]) (Table A-2), EPA commissioned only one laboratory to participate in the analysis. Alternately, the ASTM methodology performance results reflect averages from several laboratories (as many as 80), although, the extraction techniques are slightly different. For Cd, Cr, Ni, Cu, and Pb the ASTM methods contain 2 fewer boildown/reflux steps than the corresponding EPA methods: The difference in recoveries would unlikely be substantial since most of the acid-labile metals in the preserved samples would already be in the dissolved state prior to the extraction step. Based on this assumption, the ASTM precision values would more realistically reflect actual method precision attainability and are also closer to the variabilities reported here.

2. Sediment

Precision: Laboratory replicate results for the sediment samples were excellent (Table A-4). Values (COVs) ranged from 0.0 to 20.2 percent, although, a majority were below 10 percent. The paste method pH analyses were perfectly precise.

D. MASS LOADING CALCULATIONS

Mass loads for Iron Mt. Mine were calculated using the monthly average of weekly metals data and daily flow measurements of Spring Creek Debris Dam release water (Table A-5). Data from water year 1989 and 1990 were used for the calculations. Concentration data was collected by U.S.BR and regional board staff (Redding office). Flow data was obtained from the regional board, Redding office, which is essentially U.S.BR data corrected for low flow inaccuracies.

Loads for mines in the Little Backbone and West Squaw creek watersheds were calculated using both downstream creek flows and the sum of all individual sources in the watersheds (Table A-6). Both sites were used to account for banking processes going on in the watersheds. Data was obtained largely from surveys conducted by Dennis Heiman of the Redding office during dry periods between 1989 and 1992.

For most other mines, loads were calculated as the product of average flow and concentration data collected between 1987 and 1991. For a few Shasta District mines (e.g., Afterthought, Sutro mines) any available data from the 1980s was used. For mines with limited data on lead, nickel, iron, arsenic, chromium, any existing concentration values were used regardless of the year in which they were collected.

Table A-1. ANALYTIC RECOVERY PERCENTAGES OF SPIKED SAMPLES SUBMITTED BLINDLY TO THE LABORATORY. 1/

SUBMISSION	METALLIC ION 2/	SPIKE, UG/L (LO/HI)	NUMBER, N (LO/HI)	AVERAGE RECOVERY, % (+- 95% C.I.) LOW (LO)	HIGH (HI)	LAB & TRAVEL BLANK RANGE, UG/L (N)
[illegible]3, '89	Arsenic	10 /-	4 /-	104 +- 7	- +-	<1-1.0 (2)
	Cadmium	10 /-	4 /-	99 +- 1	- +-	<0.20 (2)
	** Chromium	10 /-	4 /-	148 +- 19	- +-	3.8-4.1 (2)
	* Copper	10 /-	4 /-	133 +- 23	- +-	<1.0 (2)
	* Lead	10 /-	4 /-	133 +- 22	- +-	<5.0 (2)
	* Mercury	10 /-	4 /-	61 +- 11	- +-	<0.20 (2)
	Nickel	10 /-	4 /-	97 +- 3	- +-	<4.0 (2)
	** Zinc	10 /-	4 /-	293 +-104	- +-	<10 (2)
[illegible]7, '89	Arsenic	10 /100	3 / 2	93 +- 8	97 +- 7	<2 (2)
	Cadmium	10 /100	3 / 2	96 +- 6	89 +- 13	<0.1 (2)
	Chromium	10 /100	3 / 2	97 +- 8	94 +- 11	<1 (2)
	Copper	10 /100	3 / 2	107 +- 8	110 +- 0	<1 (2)
	Lead	10 /100	3 / 2	103 +- 8	98 +- 4	<5 (2)
	Mercury	10 /100	3 / 2	91 +- 1	99 +- 49	<0.2 (2)
	Nickel	10 /100	3 / 2	90 +- 0	98 +- 9	<4 (2)
	** Zinc	10 /100	3 / 2	180 +- 48	105 +- 22	<5 (2)
[illegible]1, '90	Arsenic	10 /100	3 / 3	93 +- 16	95 +- 6	<2 (3)
	Cadmium	10 /100	3 / 3	100 +- 0	87 +- 2	<0.1 (3)
	Chromium	10 /100	3 / 3	103 +- 8	99 +- 2	<1 (3)
	Copper	10 /100	3 / 3	103 +- 8	107 +- 8	<1 (3)
	Lead	10 /100	3 / 3	103 +- 8	98 +- 0	<5 (3)
	Mercury	10 /100	3 / 3	88 +- 8	98 +- 3	<0.5 (3)
	Nickel	10 /100	3 / 3	97 +- 8	97 +- 8	<4 (3)
	** Zinc	10 /100	3 / 3	173 +- 42	100 +- 12	<5 (3)
[illegible]16, '89	Arsenic	10 /100	1 / 1	90 +- -	97 +- -	-
	Cadmium	10 /100	1 / 1	110 +- -	91 +- -	-
	Chromium	10 /100	1 / 1	100 +- -	96 +- -	-
	Copper	10 /100	1 / 1	100 +- -	110 +- -	-
	Lead	10 /100	1 / 1	110 +- -	110 +- -	-
	Mercury	10 /100	1 / 1	100 +- -	99 +- -	-
	Nickel	10 /100	1 / 1	110 +- -	94 +- -	-
	** Zinc	10 /100	1 / 1	140 +- -	95 +- -	-
[illegible], '89	Arsenic	10 / 50	2 / 4	100 +- 0	99 +- 3	<2 (2)
	Cadmium	10 / 50	2 / 4	100 +- 2	96 +- 3	<0.1 (2)
	Chromium	10 / 50	2 / 4	90 +- 0	96 +- 6	<1 (2)
	Copper	10 / 50	2 / 2	105 +- 22	102 +- 0	<1 (2)
	Lead	10 / 50	2 / 2	105 +- 22	108 +- 0	<5 (2)
	Mercury	10 / 50	2 / 2	88 +- 2	92 +- 4	<0.2 (2)
	Nickel	10 / 50	2 / 4	100 +- 0	100 +- 7	<4 (2)
	Zinc	10 / 50	2 / 4	125 +- 22	106 +- 3	<5 (2)
	Iron	- / 50	- / 2	- +-	104 +- 45	<30 (2)
	Silver	- / 50	- / 2	- +-	106 +- 0	<1 (2)
Dec 28, '89	Arsenic	10 /200	2 / 2	120 +- 0	80 +- 0	<2-3 (3)
	Cadmium	10 /200	2 / 2	94 +- 18	95 +- 0	<0.1 (3)
	Chromium	10 /200	2 / 2	110 +- 45	105 +- 0	<1-1 (3)
	Copper	10 /200	2 / 2	80 +- 0	105 +- 0	<1 (3)
	Lead	10 /200	2 / 2	110 +- 45	95 +- 0	<5 (3)
	Mercury	10 /200	2 / 2	96 +- 9	118 +- 11	<0.2-0.4 (3)

Table A-1. ANALYTIC RECOVERY PERCENTAGES OF SPIKED SAMPLES SUBMITTED BLINDLY TO THE LABORATORY. 1/

SUBMISSION DATE	METALLIC ION 2/	SPIKE, UG/L (LO/HI)	NUMBER, N (LO/HI)	AVERAGE RECOVERY, % (+- 95% C.I.) LOW (LO)	HIGH (HI)	LAB & TRAVEL BLANK RANGE, UG/L (N)
	** Nickel	10 /200	2 / 2	0 +- 0	95 +- 22	<4 (3)
	** Zinc	10 /200	2 / 2	240 +- 0	110 +- 0	<5 (3)
	Arsenic	20 /-	2 /-	90 +- 0	- +- -	-
	Cadmium	20 /-	2 /-	90 +- 0	- +- -	-
	Chromium	20 /-	2 /-	115 +- 22	- +- -	-
	Copper	20 /-	2 /-	103 +- 11	- +- -	-
	Lead	20 /-	2 /-	100 +- 0	- +- -	-
	Mercury	20 /-	2 /-	108 +- 11	- +- -	-
	** Nickel	20 /-	2 /-	50 +- 0	- +- -	-
	Zinc	20 /-	2 /-	115 +- 89	- +- -	-
Jan 18, '90	Arsenic					
	Cadmium	10 /100	2 / 2	82 +- 2	85 +- 4	<0.1 (2)
	Chromium					
	Copper	10 /100	2 / 2	90 +- 0	110 +- 0	<1 (2)
	Lead					
	Mercury	10 /100	2 / 2	88 +- 0	97 +- 7	<0.2 (2)
	Nickel					
	* Zinc	10 /100	2 / 2	130 +- 45	100 +- 0	<5-8 (2)
Apr 30, '90	Arsenic	18 / 45	2 / 2	112 +- 25	108 +- 4	<2 (3
	Cadmium	18 / 45	2 / 2	117 +- 0	118 +- 20	<0.1 (3
	Chromium	18 / 45	2 / 2	125 +- 13	115 +- 7	<1 (3
	Copper	18 / 45	2 / 2	128 +- 0	127 +- 20	<1-2 (3
	Lead	18 / 45	2 / 2	106 +- 25	114 +- 11	<5 (3
	Mercury	18 / 45	2 / 2	117 +- 25	- +- -	<0.2 (3
	* Nickel	18 / 45	2 / 2	139 +- 25	112 +- 4	<4 (3
	Zinc	18 / 45	2 / 2	122 +- 0	120 +- 9	<5-9 (3

1/ Analyses by Anlab Laboratory, Sacramento, CA except for June 13, '89 submission which was performed by Cal Enseco, Inc., West Sacramento, CA.

2/ Statistically different from 100 +- 30 (p-=0.95):
- * Average recovery between 100 +- 30-<40%.
- ** Average recovery outside 100 +- 40%.

Table A-2. THE GENERAL PRECISION AND ACCURACY OF METHODS USED.

METALS	EPA 1/ METHODS	O.C.R. 2/	R.S.D. 3/			RECOVERIES			ASTM 4/ METHODS	O.C.R. 2/	R.S.D. 3/			RECOVERIES		
Arsenic	206.2	5 - 100 ug/l	20 ug/l	50 ug/l	100 ug/l	20 ug/l	50 ug/l	100 ug/l	D2972-84C	5-100 ug/l	6.0 ug/l	22 ug/l	72 ug/l	6.0 ug/l	22 ug/l	72 ug/l
			3.5 %	2.2 %	1.6 %	105 %	106 %	101 %			15 %	14 %	8.6 %	87 %	105 %	99 %
Cadmium	213.2	0.5-10 ug/l	2.5 ug/l	5.0 ug/l	10.0 ug/l	2.5 ug/l	5.0 ug/l	10.0 ug/l	D3557-84D	0.5-10 ug/l	1.3 ug/l	2.5 ug/l	6.0 ug/l	1.3 ug/l	2.5 ug/l	6.0 ug/l
			5.0 %	3.2 %	3.3 %	96 %	99 %	98%			84 %	61 %	46 %	118 %	87 %	112 %
	200.7	not reported	2.5 ug/l	14 ug/l	50 ug/l	2.5 ug/l	14 ug/l	50 ug/l	D4190-82	not reported	S = 0.044X + 6.08 (overall)			50 ug/l	500 ug/l	1000 ug/l
			16 %	16 %	12 %	116 %	93 %	96 %			S = 0.025X + 4.96 (single)			100 %	97 %	97 %
Chromium	218.2	5 - 100 ug/l	19 ug/l	48 ug/l	77 ug/l	19 ug/l	48 ug/l	77 ug/l	D1687-86C	5-100 ug/l	8.0 ug/l	10 ug/l	28 ug/l	8.0 ug/l	10 ug/l	28 ug/l
			0.5 %	0.4 %	1.0 %	97 %	101 %	102 %			28 %	32 %	18 %	83 %	108 %	101 %
Copper	220.2	5 - 100 ug/l	Not available at this time						D1688-84F	5-100 ug/l	5.0 ug/l	11 ug/l	32 ug/l	5.0 ug/l	11 ug/l	32 ug/l
											77 %	21 %	25 %	180 %	109 %	113 %
	200.7	not reported	11 ug/l	70 ug/l	250 ug/l	11 ug/l	70 ug/l	250 ug/l	D4190-82	not reported	S = 0.038X + 5.58 (overall)			50 ug/l	500 ug/l	1000 ug/l
			40 %	8 %	5 %	100 %	96 %	94 %			S = 0.031X + 0.956 (single)			101 %	99 %	99 %
Iron	200.7	not reported	20 ug/l	180 ug/l	600 ug/l	20 ug/l	180 ug/l	600 ug/l	D4190-82	not reported	S = 0.051X + 14.3 (overall)			50 ug/l	500 ug/l	1000 ug/l
			15 %	6 %	3 %	95 %	99 %	99 %			S = 0.013X + 10.7 (single)			110 %	94 %	94 %
Lead	239.2	5 - 100 ug/l	25 ug/l	50 ug/l	100 ug/l	25 ug/l	50 ug/l	100 ug/l	D3559-85D	5-100 ug/l	12 ug/l	24 ug/l	72 ug/l	12 ug/l	24 ug/l	72 ug/l
			1 %	2 %	4 %	88 %	92 %	95 %			30 %	14 %	14 %	87 %	87 %	90 %
Mercury	245.2	not reported	0.5 ug/l	1.0 ug/l	5.0 ug/l	10 ug/l			D3223-86	not reported	.21 ug/l	3.4 ug/l	9.6 ug/l	.21 ug/l	3.4 ug/l	9.6 ug/l
			8 %	4 %	4 %	87 to 100 %					79 %	44 %	39 %	166 %	100 %	95 %
Nickel	249.2	5 - 50 ug/l	Not available at this time						D1886-84E	5-100 ug/l	8.0 ug/l	30 ug/l	80 ug/l	8.0 ug/l	30 ug/l	80 ug/l
											20 %	17 %	12 %	95 %	97 %	101 %
	200.7	not reported	30 ug/l	60 ug/l	250 ug/l	30 ug/l	60 ug/l	250 ug/l	D4190-82	not reported	S = 0.078X + 5.47 (overall)			50 ug/l	300 ug/l	800 ug/l
			11 %	14 %	5.8 %	93 %	92 %	98 %			S = 0.029X + 7.17 (single)			106 %	96 %	94 %
Silver	272.2	1 - 25 ug/l	25 ug/l	50 ug/l	75 ug/l	25 ug/l	50 ug/l	75 ug/l	D3866-82C	1-25 ug/l	2 ug/l	9 ug/l	22 ug/l	2 ug/l	9 ug/l	22 ug/l
			2 %	1 %	1 %	94 %	100 %	104 %			41 %	19 %	26 %	98 %	90 %	91 %
Zinc	289.1	.05 - 1 mg/l	7 ug/l	56 ug/l	310 ug/l	7 ug/l	56 ug/l	310 ug/l	D1691-84C	.01-2 mg/l	1.16 mg/l	1.5 mg/l	1.8 mg/l	1.16 mg/l	1.5 mg/l	1.8 mg/l
			118 %	45 %	37 %	306 %	111 %	99 %			233 %	302 %	147 %	107 %	96 %	98 %
	200.7	not reported	16 ug/l	80 ug/l	200 ug/l	16 ug/l	80 ug/l	200 ug/l	D4190-82	not reported	S = 0.025X + 8.38 (overall)			50 ug/l	500 ug/l	
			45 %	10 %	6 %	119 %	103 %	101 %			S = 0.011X + 6.67 (single)			102 %	100 %	

1/ U.S.EPA, 1983b. 2/ Optimum concentration range. 3/ Relative Standard Deviation. 4/ ASTM, 1988.

Table A-3. AVERAGE ANALYTICAL PRECISION FROM REPLICATES SUBMITTED BLINDLY. 1/

SUBMISION DATE	REPLICATE SUM (A+B)	COEFFICIENT OF VARIATION OF REPLICATE PAIRS IN PERCENT (N) 2/								
		As	Cd	Cr	Cu	Fe	Pb	Hg	Ni	Zn
13JUN89	<=20	13(3)		*35(7)*	*51(3)*		*141(1)*	*141(1)*	6(1)	
	20 TO <50								*57(1)*	27(1)
	50 TO <100									
	>=100	4(2)	*52(1)*		*48(1)*				5(1)	0(1)
	# BELOW DETECTION	(2)	(6)		(3)		(4)	(5)	(3)	(5)
07JUL89	<=20		*94(2)*	*141(1)*	0(2)			*141(3)*	18(1)	28(2)
	20 TO <50									
	50 TO <100									
	>=100	8(1)			*101(1)*					*92(1)*
	# BELOW DETECTION	(3)	(2)	(3)	(1)		(4)	(1)	(3)	(1)
17JUL89	<=20		*39(4)*		*71(2)*			28(1)		0(1)
	20 TO <50				3(1)					3(2)
	50 TO <100				2(1)					
	>=100				0(2)					
	# BELOW DETECTION	(6)	(2)	(6)			(6)	(5)	(6)	(3)
31JUL89	<=20	0(1)	*47(3)*	14(2)	20(1)				8(1)	*141(1)*
	20 TO <50		5(1)	0(1)	0(1)		3(1)		3(2)	8(1)
	50 TO <100	2(1)					22(1)			
	>=100	*87(1)*	0(2)		3(3)					3(3)
	# BELOW DETECTION	(4)	(1)	(4)	(2)		(4)	(6)	(4)	(2)
16AUG89	<=20	0(1)		0(1)	*71(2)*				0(1)	
	20 TO <50									
	50 TO <100									6(1)
	>=100			4(1)					0(1)	3(1)
	# BELOW DETECTION	(1)	(2)				(2)	(2)		
01SEB89	<=20	0(1)	*141(1)*	24(2)	*71(2)*					7(1)
	20 TO <50								9(1)	3(1)
	50 TO <100	2(1)		0(1)						0(1)
	>=100								3(3)	1(1)
	# BELOW DETECTION	(3)	(4)	(2)	(3)		(5)	(5)	(1)	(1)
17OCT89	<=20	0(1)		*47(1)*					0(1)	0(1)
	20 TO <50									
	50 TO <100									
	>=100									
	# BELOW DETECTION		(1)		(1)		(1)	(1)		
28DEC89	<=20	11(1)	6(2)	18(3)						
	20 TO <50			3(1)					0(1)	4(1)
	50 TO <100					3(1)				
	>=100	6(2)	5(1)		1(3)		6(7)		4(3)	1(4)
	# BELOW DETECTION	(1)	(1)	(1)	(1)	(1)		(3)		(1)
18JAN90	<=20		3(3)		0(1)			*52(3)*		11(1)
	20 TO <50									
	50 TO <100									
	>=100		2(1)		4(4)			2.2(1)		3(4)
	# BELOW DETECTION							(1)		
4APR90	<=20	28(1)	1(2)	0(2)						
	20 TO <50	7(1)	0(1)	3(1)	0(1)		4(2)	7(1)		0(1)
	50 TO <100	9(2)							6(1)	
	>=100		4(2)	1(1)	2(4)	10(2)	3(1)		2(4)	4(5)
	# BELOW DETECTION	(1)						(1)		
29JUN90	<=20	16(1)		0(1)						
	20 TO <50						5(1)		0(1)	
	50 TO <100									
	>=100		4(1)		6(1)					7(1)
	# BELOW DETECTION									

1/ Analyses by Anlab Laboratory, Sacramento, CA except for the June 13, 1989 submission which was performed by Cal Enseco, Inc., West Sacramento, CA.

2/ "Modified Shewart" variation (U.S.EPA, 1983a). N=number of replicate pairs.
* x * indicates variation outside of accepted limits.

Table A-4. WASTE ROCK METAL VARIABILITY OF LABORATORY REPLICATES.

			TOTAL CONCENTRATION (MG/KG, DRY WEIGHT)								
MINE		pH	ARSENIC	CADMIUM	CHROMIUM	COPPER	LEAD	ZINC	NICKEL	MERCURY	SILVER
Iron Mt. loading area		1.4									
		1.4									
	AVERAGE	1.40									
	COV	0.00									
Rising Star		2.8	650	30	3.8	1400	100	3500	ND	16	5.2
		2.8	600	28	3.8	1300	110	3500	ND	15	4.2
	AVERAGE	3	625	29	4	1350	105	3500	0	16	5
	COV	0.0	5.7	4.9	0.0	5.2	6.7	0.0		4.6	15.0
Bully Hill		3.6	190	27	15	5000	630	4000	7	4.6	14
		3.6	170	25	17	5100	660	3900	7.5	4.3	14
	AVERAGE	4	180	26	16	5050	645	3950	7	4	14
	COV	0.0	7.9	5.4	8.8	1.4	3.3	1.8	4.9	4.8	0.0
Big Buzzard		3.1									
		3.1									
	AVERAGE	3.10									
	COV	0.00									
Corona		2.8									
		2.8									
	AVERAGE	2.80									
	COV	0.00									
Spenceville		2.6	90	0.8	2.4	120	240	40	ND	0.59	46
		2.6	85	0.6	3	100	220	46	ND	0.58	55
	AVERAGE	3	88	1	3	110	230	43	0	1	51
	COV	0.0	4.0	20.2	15.7	12.9	6.1	9.9		1.2	12.6

Table A-5. LOADS CALCULATED FOR IRON MT. MINE AT SPRING CREEK DEBRIS DAM. 1/

YEAR	MONTH	TOTAL FLOW/MONTH (CFS)	CADMIUM 4/ MG/L	CADMIUM 4/ S.E.	CADMIUM 4/ N	CADMIUM 4/ KG	COPPER 4/ MG/L	COPPER 4/ S.E.	COPPER 4/ N	COPPER 4/ KG	ZINC 4/ MG/L	ZINC 4/ S.E.	ZINC 4/ N	ZINC 4/ KG
1988	OCT	28	0.3800	0.0000	2	26	8.100	0.0000	2	555	46.0	0.000	2	3,151
	NOV	463	0.0877	0.0387	3	99	3.730	1.3100	10	4,225	15.2	13.140	10	17,263
	DEC	946	0.0820	0.0000	1	190	1.667	0.1639	8	3,858	11.4	1.561	8	26,422
1989	JAN	581	0.0534	0.0124	5	76	1.448	0.0927	9	2,058	8.4	2.306	9	11,950
	FEB	390	0.0763	0.0208	3	73	1.588	0.2133	8	1,515	11.5	4.037	8	10,964
	MAR	1,904	0.0242	0.0087	5	113	0.807	0.2070	27	3,759	4.0	1.152	27	18,479
	APR	1,705	0.0285	0.0065	4	119	0.811	0.1850	30	3,383	4.2	0.612	27	17,720
	MAY	1,487	0.0545	0.0233	2	198	1.766	0.5089	17	6,424	8.9	2.827	17	32,466
	JUN	1,164	0.0700	0.0000	1	199	2.033	0.2141	8	5,788	10.6	0.808	8	30,275
	JUL	596	0.1167	0.0226	3	170	4.730	0.6710	4	6,897	20.5	3.526	4	29,856
	AUG	372	0.1870	0.0000	1	170	5.617	0.3253	3	5,112	26.2	4.126	3	23,875
	SEP	49	0.3090	0.0000	1	37	8.175	1.0079	4	980	48.8	6.902	4	5,853
	OCT	246	0.6500	0.0000	1	391	3.927	1.3924	6	2,363	21.2	11.334	6	12,729
	NOV	551	0.1273	0.0641	3	172	3.830	1.5449	7	5,163	16.9	5.928	7	22,748
	DEC	149	0.1312	0.0424	5	48	4.830	0.7060	7	1,761	20.3	4.345	7	7,395
1990	JAN	560	0.0685	0.0417	4	94	2.161	1.0662	11	2,961	10.8	9.525	11	14,786
	FEB	656	0.0253	0.0051	4	41	1.124	0.1001	8	1,804	4.2	1.149	8	6,753
2/	MAR	475	0.0288	0.0038	5	33	1.062	0.1076	5	1,234	4.0	0.594	5	4,679
	APR	293	0.0840	0.0384	3	60	1.764	0.3465	8	1,264	14.4	5.777	8	10,349
	MAY	181	0.0903	0.0651	3	40	1.875	0.7192	11	831	17.3	8.883	11	7,645
	JUN	2,318	0.0290	0.0000	1	164	0.805	0.2738	15	4,563	4.6	0.834	15	25,948
	JUL	1,052	0.1380	0.0000	1	355	1.642	0.5295	6	4,225	18.1	7.692	6	46,543
	AUG	102	0.3690	0.0000	1	92	5.218	0.6400	5	1,302	60.3	9.375	5	15,048
	SEP	145	0.3670	0.0000	1	130	5.096	0.5533	5	1,808	57.7	4.836	5	20,484
MONTHLY AV		684	0.149				3.08				19.4			
LOAD/YEAR (KG)						1,546				36,917				211,691
LOAD SE (KG)						161				4,535				34,500

	ARSENIC	CHROM.	LEAD	NICKEL
AVE. CONC., UG/L (N=5)	44	11	20	12
COEFFICIENT OF VARIATION	0.55	0.45	0.20	0.58
ANNUAL LOAD (KG) 3/	858	214	390	234

1/ SOURCE: Heiman, D. Computer data sheets containing U.S.BR and regional board flow and concentration data. Redding, O
2/ Average of the surrounding month's flow. 3/ Using 7,969 CFS as annual outflow.
4/ MG/L=Concentration; S.E.=Standard Error; N=Number of samples; KG=Loads in kilograms.

Table A-6. LOADS CALCULATED FROM WESTERN SHASTA DISTRICT MINES.

MINE DRAINAGE	LOCATION	SAMPLE DATE	SOURCE 1/	ANNUAL LOADS, KILOGRAMS ARSENIC	CADMIUM	CHROMIUM	COPPER	NICKEL	LEAD	ZINC
West Squaw Creek watershed	Sum of all drainage	4-28-89	1		44.5		5,780			8,344
		4-17-91	2		23.5		5,895			5,326
		1-17-92	3	ND	58.6	ND	8,446	ND	ND	11,481
	Creek below drainage	4-28-89	1		37.0		4,987			8,383
		7-27-89	*		25.2		11,744			4,194
		4-17-91	2				8,826			11,480
		1-17-92	3				2,820			3,550
	AVERAGE				37.8		6,928			7,537
	STANDARD DEVIATION				13.0		2,729			3,034
	COEFFICIENT OF VARIATION				0.34		0.39			0.40
Little Backbone Creek watershed										
	Sum of all drainage	5-12-89	4		155		14,069			29,167
	Creek below drainage	5-12-89	4		114		12,310			20,805
	Creek below drainage	7-27-89	*	56	197	14	21,854	32	81	37,465
	AVERAGE			56	155	14	16,078	32	81	29,146
	STANDARD DEVIATION				34		4,147			6,801
	COEFFICIENT OF VARIATION				0.22		0.26			0.23
Shoemaker Gulch watershed										
	Friday-Lowden portal	5-12-89	4		39.8		3,766			12,028
	Gulch below mines	7-27-89	*	3	22.0	1	2,000	ND	ND	3,200
	AVERAGE			3	30.9	1	2,883			7,614
	STANDARD DEVIATION				8.9		883.0			4,414
	COEFFICIENT OF VARIATION				0.29		0.31			0.58
Total Little Backbone Crk and Shoemaker Gulch				59	186	15	18,961	32	81	36,760
Standard deviation					35		4,240			8,108
Coefficient of variation					0.19		0.22			0.22

1/ SOURCES * This study.
1 Heiman, D. 1989. Squaw Creek Survey, 28 April 1989. Memorandum from D. Heiman to J. Pedri. CVRWQCB Redding. 9-13.
2 Heiman, D. 1991. West Squaw Creek Survey - April 17, 1991. Memorandum from D. Heiman to J. Pedri. CVRWQCB, Redding. 6-4.
3 Heiman, D. 1992. West Squaw Creek Investigations. Memorandum from D. Heiman to J. Pedri. CVRWQCB, Redding. 2-14.
4 Heiman, D. 1989. Little Backbone Creek Survey -- 12 May 1989. Memorandum from D. Heiman to J. Pedri. CVRWQCB, Redding. 9-

APPENDIX B
SPENCEVILLE MINE RAINFALL RUNOFF MONITORING

A. Methods

Sequential, discrete, water samples were collected from a waste rock pile stream over the duration of a storm event occurring on 12-13 January 1989. Electrical conductivity and rainfall were also measured prior to each water sample. Samples were collected at 1/2 to 1 hour increments from the center channel of a sub-watershed of the mine site. Shoreline sub-surface grab samples were collected from Dry Creek above the mine and about 100 feet below at periodic intervals coinciding with site runoff sampling. Specific collection, preservation, and analytical methods are presented in Appendix A.

B. Results and Discussion

Approximately 3.15 inches of rain fell at the mine site over a 24 hour period during January 12-13, 1989 (Table B-1). Based on measurements up to 1810 MST (January 12), the runoff coefficient (Rv) was about 0.38. Later measurements were not included in the calculation of this number because of the longer time span between measurements (3 hours instead of 0.5-1 hour). Runoff coefficients from similar mine sites have been reported between 0.11-0.156 with higher values of 0.33 measured from very large storms (Harries and Ritchie, 1982). The January 12-13 event was considered large and the Rv of 0.38 is probably a higher than normal value due to quick oversaturation of the upper surface during intense rainfall. Infiltration is usually greater than runoff depending on the soil conductivity and present degree of saturation (Harries and Ritchie, 1987). Lighter rains were observed to be completely absorbed by the site even after long periods of precipitation.

The runoff contained high copper (2200-6000 ppb) and zinc (810-1800 ppb) levels and relatively low cadmium levels (2.5-4.7 ppb); mercury was also detected in runoff water (Table B-1). Electrical conductivity generally decreased in the runoff water from 800 to 190 uS/cm as the storm progressed. Salt buildup at the surface during the dry period could explain this decrease. Salts are carried to the surface of the pile via capillary action after infiltrated water solubilizes waste rock constituents below the surface. A majority of these salts would be flushed from the surface during the initial stages of the storm event. Metal concentrations and incipient rainfall were correlated, but not much else co-varied. Measurements of pH were not taken due to equipment malfunction. The samples showed very high visual turbidity.

Loads were calculated for copper, cadmium, and zinc from the single storm event. Total annual loads were extrapolated using the full area of the mine site (which was larger than the sub-watershed sampled) and an annual rainfall of 20.5 inches (average for Marysville). These rough estimates show that 5-18 percent of the total annual metal loads (dry + estimated rainfall runoff contributions) result from surface runoff discharges (Table B-2). The estimated loads from this site are distorted somewhat since they assumed all of the site's runoff makes it directly to the receiving water. At Spenceville Mine, a portion of the site runoff drains to an on-site pit. The pit further leaches metals from the waste rock. The pit then seeps water into nearby streams. In actuality, the runoff entering the pit is transformed to a less turbid solution and is slowly released well after the storm passes.

Copper in Dry Creek below the mine exceeded the EPA hardness factored criteria by 2-10 times (23-120 ug/l). Copper levels in Dry Creek above the mine were just above the detection limit during most of the storm (2-7 ppb). Zinc levels in Dry Creek below the mine were elevated above the upstream concentrations but did not exceed the criteria. The upstream watershed is gentle to rugged foothill scrub-oak rangeland.

Total suspended solids increased in Dry Creek from 4.5-59 mg/l above the mine to 5.5-114 mg/l below the mine. Runoff from a portion of the mine site and a nearby road likely contributed to the increase. Multi-colored water was observed coming from the mine site's variably composed waste rock piles.

Table B-1. WATER QUALITY OF RAINFALL RUNOFF FROM SPENCEVILLE MINE.

LOCATION	DATE, 1989 (MO/DAY)	TIME	RAINFALL (INCHES) INCIPIANT	RAINFALL (INCHES) CUMULATIVE	FLOW (CFS)	VELOCITY	EC (uS/cm)	TSS (MG/L)	HARDNESS (MG/L)	TOTAL CONCENTRATION (UG/L) CADMIUM	COPPER	ZINC	MERCURY
Mine site	JAN 12	1145	0.05	0.05	DRY								
		1245	0.05	0.10	DRY								
		1300	0.05	0.15	DRY								
		1330	0.05	0.20	0.21	1.4	800			4.4	6,000	1,500	0.5
		1400	0.10	0.30	0.06	0.4	720			3.6	4,100	1,300	1.0
		1428	0.05	0.35	0.16	1.7	600			4.4	5,300	1,400	<0.2
		1440	0.05	0.40	0.19	1.9	480			2.7	3,000	920	0.5
		1500	0.10	0.50	0.47	2.4	400			4.7	4,300	1,800	0.4
		1535	0.15	0.65	0.29	2.0	380			2.5	2,500	810	1.1
		1625	0.15	0.80	0.37	1.9	480			3.9	3,900	1,200	0.3
		1650	0.10	0.90	0.21	2.2	380			2.5	2,600	860	<0.2
		1750	0.10	1.00	0.18	1.2	510			4.0	4,200	1,400	<0.2
		1810	0.60	1.60	0.12	0.6	200			3.4	2,400	980	2.7
		2140	0.80	2.40	1.19	3.5	220			4.1	3,900	1,500	7.0
	JAN 13	740	0.60	3.00	1.19	3.5	190			2.5	2,200	850	2.2
		925	0.15	3.15	DRY								
Dry Creek above mine	JAN 12	1150					200	4.5	82		2	<5	<0.2
		1410					200	4.5	82		2	<5	<0.2
		1532					240	6.5	82		2	<5	<0.2
		1900					180	59	69		7	10	<0.2
Dry Creek below mine	JAN 12	1150					220	5.5	86		23	26	<0.2
		1300					220				31	30	<0.2
		1410					200	8	86		39	45	<0.2
		1500					220				56	64	<0.2
		1545					220	25	85		90	90	<0.2
		1800					220				31	35	<0.2
		1920					200	114	79		120	83	<0.2
		2140					100				63	68	<0.2

Table B-2. METALS LOADING COMPARISONS FROM SPENCEVILLE MINE RUNOFF.

LOADING PARAMETER	CADMIUM	COPPER	ZINC
kilograms per inch of rainfall from this event (kg/1.6 inches)	0.00049	0.4975	0.169
kilograms per year from the mine site (rainfall runoff) (kg/1.6)*20.5*2) 1/	0.02	20	7
kilograms per year from the mine site (dry period) (from Table ____)	0.09	175	144
percent of the total loads from rainfall runoff	18	10	5

1/ Annual rainfall = 20.5 inches at nearby Marysville.
Total annual loads from the mine site are approximately 2 time those measured.

Table [illegible]. WATER QUALITY CHARACTERISTICS OF MINE DRAINAGE [illegible]

MINE SAMPLE LOCATION	COUNTY	SAMPLE DATE	FLOW (l/s)	Eh (mV)	EC (uS/cm)	pH	HARDNESS AS CACO3 (mg/L)	ARSENIC (≤1.0)	CADMIUM (<0.10)	CHROMIUM (≤2.0)	COPPER (≤1.0)	NICKEL (≤4.0)	ZINC (≤10)	LEAD (≤5.0)	MERCURY (<0.20)	SILVER (≤0.50)	IRON (≤30)	SOURC
								CONCENTRATION, UG/L (DETECTION LIMITS IN PARENTHESES)										
BEAR RIVER/DRY CREEK WATERSHEDS																		
Empire	Nevada																	
air shaft discharge		13JUN89			525	6.60		53	ND	ND	ND	ND	5	ND	ND	ND		*
		13DEC89	5.98	229	489	6.66		92					ND				4,700	*
		13APR90	10.27		354	6.79		2					29					*
Lava Cap	Nevada																	
seepage discharge		14JUN89			390	6.80		58	0.1	ND	2	ND	25	ND	0.6	ND		*
		04SEP89	5.05		510	7.60												1
		13DEC89	6.34	275	518	7.42		70	0.3		2		12		ND		160	*
		82-86						42										2
		M-J 84	6.2															3
Spenceville	Yolo																	
Little Dry Crk. above mine		13MAR86			140	6.70					<25		85	590				4 1/
		22JUN87			140	8.00	55	<4	<100	<100								5
		03DEC87						<200	<5	<10	<25	<40	<20	<50	<0.2		<100	5
		01FEB88			131	7.60	76				60		<50					5
		07FEB89			204		83	7	<1		3.5	8	2.2				128	6
		28JUN89									30		20				400	7
		13JUN89	15.00		212	7.50		ND	ND	ND	3	ND	1	ND	0.5	ND		*
		11DEC89	16.02		297	6.83			ND		ND		ND		ND		130	*
		8JUN90	15.2		250	7.3			ND		2		3		0.2			*
Little Dry Crk. below mine		25JUL85					134	5	<2.0		1,500		930	<20			3,400	8
		13MAR86			120	6.80					64		140				490	5
		03DEC87						<200	<5	<10	110	<40	240	<50	<0.2		<100	5
		01FEB88			158	7.08	67				120		200					5
		07FEB89			224		88	7.5	<1		235	<5	128				500	6
		13JUN89	15.00		580	7.30	90	ND	0.2	ND	180	ND	140	ND	0.6	ND		*
		11DEC89	16.02		318	6.95	130		0.7		415		315		ND		1,050	*
		8JUN90			278	7.09			0.5		320		250		0.5			*
Dry Creek above Little Dry Crk		13JUN89						<1	<0.2	<2	2	<4	<10	<5	0.6	<0.5		*
		11DEC89		204	237	6.72			<0.1		2		<5		<0.2		210	*
		13JAN89			205		79				3.3		3		ND			* 2/
Dry Creek below Little Dry Crk		13JUN89			245	7.80		<1	<0.2	<2	32	<4	24	<5	<0.2	<0.5		*
		11DEC89		220	249	7.42			0.2		100		50		<0.2		330	*
		13JAN89			200		84				57		56		ND			* 2/
Valley View	Placer																	
adit discharge		01APR87				1.70		<200	4,500	130	97,000	760	230,000	<50		<10	510,000	9
		27APR90	0.11	427	6,280	2.44		150	6,500	210	150,000	540	260,000	78	ND		810,000	*
spring/seep above mine		08JUN89						1.9	ND	3.4	7.4	ND	ND	ND	ND	ND		*
irrig. water above mine		08JUN89						ND	ND	9.1	8.6	ND	ND	ND	ND	ND		*
		21DEC89		196	75	6.17			ND	1	2	ND	ND		ND		190	*
irrig. water below mine		08JUN89						ND	67.0	3.4	1,120	19.0	4,300	ND	0.1	ND		*
		21DEC89	2.18	247	607	4.59	220		190	2	4,900	41	13,000		ND		360	*
		27APR90	2.81	160	560	4.83			160	2	4,200	59	11,000		ND		440	*

SOURCE:

1. CVRWQCB Data sheet.
2. Cranmer Engineering, Inc. Monitoring data sheets. 35 data points averaged from 11-11-82 to 11-4-86.
3. Hydro-search, Inc. 1984. Report of WDR. June. 6 data points averaged from 4-4 to 5-31-84.
4. Newman, B. 1986. Inspection report.
5. S.S. Papadopulos & Assoc., Inc. 1988. Spenceville Hydrological Assessment Report. April.

Table C-1. WATER QUALITY CHARACTERISTICS OF MINE DRAINAGE & RECEIVING WATERS IN SEVERAL SACRAMENTO VALLEY WATERSHEDS.

6. Bond, S. 1989. Data sheet from Sierra Foothill Laboratory. March 3.
7. Bond, S. 1989. Spenceville mine. TPCA MINE exemption request review. October 4.
8. U.S. BLM. 1986. Memo & data sheet to William Crooks, CVRWQCB, February.
9. McDonald, A. 1987. Inspection data sheet.
* This study. 1/ Not included in the load estimates. 2/ Average of four samples.

YUBA RIVER WATERSHED

MINE	SAMPLE LOCATION	COUNTY	SAMPLE DATE	FLOW (l/s)	Eh (mV)	EC (uS/cm)	pH	HARDNESS AS CACO3 (mg/L)	ARSENIC (<1.0)	CADMIUM (<0.10)	CHROMIUM (<2.0)	COPPER (<1.0)	NICKEL (<4.0)	ZINC (<10)	LEAD (<5.0)	MERCURY (<0.20)	SILVER (<0.50)	IRON (<30)	SOURC
									CONCENTRATION, UG/L (DETECTION LIMITS IN PARENTHESES)										
Brush Creek																			
	main adit	Nevada	30MAR88	1/				186			22	70	290		72				2
			29MAY88					237											1
			06JUN88					210											1
			09JUN88			337	7.50	250											1
			17JUN88			336	7.50	230											1
			28JUN88			362	7.50	210											1
			03JUL88			341	7.50	217											1
			08JUL88			342	7.50	196											1
			09JUL88			367	7.50	270											1
			11AUG88			354	7.50	256											1
			03OCT88			365	7.50	240											1
			05NOV88			348	7.50	260											1
			05DEC88			387	8.20	210											1
			10APR89			331	7.40	176											1
			09JUN89			245		170		ND	4.2	ND	155	ND	ND	ND	ND		*
			12APR90	26.9	83	309	6.90	180			ND	2	110		ND			ND	*
	upper adit		30MAR88					61			<2	2	27	<10					1
			29MAY88					76											1
			06JUN88					68											1
			17JUN88			253		81											1
			28JUN88			284		75											1
			03JUL88			303		57											1
			08JUL88			316		69											1
			09JUL88			315		74											1
			11AUG88			365		62											1
			03OCT88			414		32											1
			05NOV88			423		41											1
			05DEC88			210		67											1
			10APR89			227		43											1
			12APR90	6.51	87	186	7.10	60				ND	29						*
	Woodruff Crk		28MAR88					20		<1	<5	<10	10	<5	<8	<0.5			1
	below mine		30MAR88					20			<2	4	10		<10				1
			29MAY88					21											1
			09JUN88			172	8.00	21											1
			28JUN88			214	8.30	25											1
			17JUN88			210	8.20	26											1
			03JUL88			193	8.20	22											1
			08JUL88			213	8.30	26											1
			09JUL88			235	8.40	29											1
			11AUG88			234	8.20	29											1

Table C-1. WATER QUALITY CHARACTERISTICS OF MINE DRAINAGE & RECEIVING WATERS IN SEVERAL SACRAMENTO VALLEY WATERSHEDS

MINE SAMPLE LOCATION	COUNTY	SAMPLE DATE	FLOW (l/s)	Eh (mV)	EC (uS/cm)	pH	HARDNESS AS CACO3 (mg/L)	ARSENIC (<1.0)	CADMIUM (<0.10)	CHROMIUM (<2.0)	COPPER (<1.0)	NICKEL (<4.0)	ZINC (<10)	LEAD (<5.0)	MERCURY (<0.20)	SILVER (<0.50)	IRON (<30)	SOURC
								CONCENTRATION UG/L (DETECTION LIMITS IN PARENTHESES)										
		03OCT88			209	8.20		26										1
		05NOV88			225	8.10		29										1
		05DEC88			174	7.90		17										1
		10APR89			108	7,90		7										1
		10APR89			111	7.90		7										1
		09JUN89	323		140	10.10		21	<0.2	4.5	<1	8.3	<10	<5	<0.2	<0.5		*
		15DEC89	87	211	192	7.77	100	30		2		5					<30	*
		12APR90	431	85	142	7.00		17				5						*
Champion																		
adit discharge	Nevada	15JUN89	2.26		107	5.8		ND	0.7	ND	1	ND	11	ND	ND	ND		*
Columbo	Sierra																	
adit discharge		09JUN89	42.79					2.4	ND	4.5	ND	ND	ND	2.9	ND	ND		*
		15DEC89	16.83	216	153	7.46		ND		2				ND			ND	*
		12APR90	31.82	115	153	7.01		ND		1				ND				*
Kanaka Creek mines 2/	Sierra																	
confluence with M.F. Yuba R.		14DEC89	278	191	182	6.86	79	25		2		ND		ND			ND	*
		13APR90	1,226		114	6.46	45	15		ND								*
M.F. Yuba R. above Kanaka Crk.		13APR90			60.1	6.54		ND										*
M.F. Yuba R. below Kanaka Crk.		13APR90			65	6.77		ND										*
Malakoff Diggins	Nevada																	
Hillar Tunnel discharge		23FEB89				6.80	40	9	<200	100	80	80	90	<20	0.5	<200	35,000	3
		14JUN89			117	6.50		ND	ND	ND	3	9	24	ND	0.3	ND		*
		14DEC89	26.32	176	163	6.52				2		68	24		ND		3,000	*
		13APR90	17.52		203	6.82					ND	19	26		ND			*
Humbug Crk. above mine		14JUN89			82	6.70		ND	ND	ND	1	7	ND	ND	ND	ND		*
		14DEC89		224	142	6.61	61			ND		12	ND		ND		40	*
Humbug Crk. below mine		14DEC89		210	133	6.67	51			ND		15	8		ND		110	*
Pick & Shovel	Sierra																	
adit discharge		06OCT89	1.24		733	6.75		3	ND	1.5	ND	180	21	ND	ND	ND		*
		19APR90	3.18	126	342	6.28		ND		ND		93	7				30	*
Pats Gulch above mine		06OCT89	0.71		58	7.25		ND	ND	1	ND	ND	ND	ND	ND	ND		*
		19APR90			27	6.58				ND		ND	ND					*
Pats Gulch below mine		06OCT89			378	6.79	130	ND	ND	1	ND	100	13	ND	ND	ND		*
		19APR90		125	83	6.62	26			ND		18	5					*
Pats Gulch 1 mile below mine		06OCT89			112	7.3		ND	ND	ND	ND	ND	ND	ND	ND	ND		*
Plumbago	Sierra																	
adit discharge		13MAY88			250	8.10		370		ND	6	40		ND	ND			4
		10JUN89	4.25		300			280	ND	5.2	ND	6.2	ND	ND	ND	ND		*
		20JUN89			284	7.90		85			ND		ND		ND			5
		14DEC89	2.29	235	325	7.39		320		1.5		ND					65	*
Buckeye Ravine above mine		10JUN89			130			1.7	ND	12	ND	8.8	ND	ND	ND	ND		*
		14DEC89		209	207	7.64		ND		8		ND					ND	*
Buckeye Ravine below mine		14DEC89		208	234	7.46	130	170		9		ND					ND	*
Sierra Buttes mines	Sierra																	
Howard Creek		09JUN89			24	4		1.2	ND	3	ND	ND	ND					*

Table C-1. WATER QUALITY CHARACTERISTICS OF MINE DRAINAGE & RECEIVING WATERS IN SEVERAL SACRAMENTO VALLEY WATERSHEDS.

MINE SAMPLE LOCATION	COUNTY	SAMPLE DATE	FLOW (l/s)	Eh (mV)	EC (uS/cm)	pH	HARDNESS AS CACO3 (mg/L)	CONCENTRATION, UG/L (DETECTION LIMITS IN PARENTHESES) ARSENIC (<1.0)	CADMIUM (<0.10)	CHROMIUM (<2.0)	COPPER (<1.0)	NICKEL (<4.0)	ZINC (<10)	LEAD (<5.0)	MERCURY (<0.20)	SILVER (<0.50)	IRON (<30)	SOURC
		15DEC89	60.66	201	44	6.60		ND		1	ND		ND				ND	*
Spanish	Nevada																	
Lower adit (16 to 1)		14JUN89			170	3.50		9	7.1	1	370	160	2,300	39	0.3	ND		*
		15DEC89	2.92	240	468	5.54		7	5.1	1	220	70	1,950	28	ND		3,400	*
		12APR90	1.38	89	5,060	4.05		2.5	3.7	ND	210	100	1,900	20	ND		3,850	*
		14AUG90	1.81	102	509	4.45	69										8,900	*
		26SEP88						<10	5	<5	170							
		03MAY89						<5	12	<5	590							
		20DEC89						<5	5	<5	200							
Poorman Creek above lower adit		15DEC90		208	62	6.46		ND	0.2	ND	ND	ND	10	ND	ND		ND	*
		12APR90		107	32	6.43			ND		ND		ND				ND	*
Poorman Creek below lower adit		14JUN89			57	6.20	25	ND	ND	ND	2	ND	14	ND	ND	ND		*
		15DEC89		211	72	6.26	28	ND	0.1	ND	ND	ND	15	ND	ND		ND	*
		12MAY90		96	33	6.35	12		ND		1		15					*
Upper adit		14AUG90	2.3	68	478	5.67	66.7	18	7.5	ND	80	19	21	110			37000	*
		27SEP88						5	4	<5	<100							6
		03MAY89						41	<29	<5	500							6
		31DEC89						<5	<1	<5	<50							6
Devels Canyon Cr above upper adit		03APR89						<5	<1	<5	<10							6
Devels Canyon Crk ca 1 mi below upper adit		26SEP88						<10	<1	<5	<10							6
		03APR89						<5	2	<5	60							6
		31DEC89						<5	<1	<5	<10							6
Devels Canyon Crk ca 2 mi below upper adit		14AUG90	8.9	51	175	7.53	98.84	ND	ND	2	ND	6	2	ND			ND	*
		27SEP88						<10	<1	<5	<1							6
		03MAY89						<5	<1	<5	20							6
		20DEC89						<5	<1	<5	<50							6

1/ Not included in the loading estimates.
2/ At the confluence with the M.F. Yuba R. Several mines exist in the watershed (e.g., Sixteen-to-One, Oriental, Kenton).
SOURCE:
1. Sierra County Case #1455, Brush creek Mine.
2. Clementsen, K. 1988. Data sheet from CH2M Hill. May 6.
3. Waggoner, M. 1989. Inspection report on Malakoff Diggins.
4. Daniels, D. 1988. Inspection report. Jun.10
5. Daniels, D. 1989. Inspection report. Jun.30
6. Vector Engineering, Inc. 1990. Operations and reclamation plan for the phase II exploration program, Spanish Mine, Washington, CA. VEI, Grass Valley, CA. May.
* This study.

FEATHER RIVER WATERSHED

MINE SAMPLE LOCATION	COUNTY	SAMPLE DATE	FLOW (l/s)	Eh (mV)	EC (uS/cm)	pH	HARDNESS AS CACO3 (mg/L)	ARSENIC	CADMIUM	CHROMIUM	COPPER	NICKEL	ZINC	LEAD	MERCURY	SILVER	IRON	SOURC
Beardsley	Plumas																	
Hosselkus Creek below mine		26AUG89			131	7.05		ND	ND	ND	2	ND	ND	ND	ND	ND		*
Engel/Superior	Plumas																	
Lights Creek above mine		27JUN89			120	6.70		ND	ND	ND	4	ND	ND	ND	0.4	ND		*
Lights Crk. below Superior Gulch		27JUN89			98	7.70		ND	ND	ND	3	ND	ND	ND	0.3	ND		*
Lights Creek 3 mi. below mine		27JUN89			134	7.30		3	ND	ND	12	ND	ND	ND	ND	ND		*

Table C-1. WATER QUALITY CHARACTERISTICS OF MINE DRAINAGE & RECEIVING WATERS IN SEVERAL SACRAMENTO VALLEY WATERSHEDS.

MINE SAMPLE LOCATION	COUNTY	SAMPLE DATE	FLOW (l/s)	Eh (mV)	EC (uS/cm)	pH	HARDNESS AS CACO3 (mg/L)	ARSENIC (<1.0)	CADMIUM (<0.10)	CHROMIUM (<2.0)	COPPER (<1.0)	NICKEL (<4.0)	ZINC (<10)	LEAD (<5.0)	MERCURY (<0.20)	SILVER (<0.50)	IRON (<30)	SOURC
								CONCENTRATION, UG/L (DETECTION LIMITS IN PARENTHESES)										
Iron-Dyke	Plumas																	
Taylors creek above mine		27JUN89			159	6.70		ND	ND	ND	ND	ND	ND	ND	ND	ND		*
Taylors creek below mine		27JUN89	2.30		90	6.70		ND	0.5	ND	21	ND	18	ND	ND	ND		*
Lucky-S	Plumas																	
lower shaft water		26AUG89	seep		57	6.73		ND	0.3	ND	1	ND	14	ND	ND	ND		*
adit discharge		26AUG89	3.22		106	6.54		ND	2.9	ND	80	ND	260	ND	ND	ND		*
		20APR90	4.06	130	101	6.04			2.5		63		335				25,000	*
Peters Creek below mine		26AUG89			101.7	7.01	42	ND	3.8	ND	110	ND	510	ND	ND	ND		*
		20APR90		140	36	6.45	13		0.4		24		88					*
Plumas-Eureka	Plumas																	
caved drainage shaft water		26JUN89			130	8.20		4	0.1	ND	2	ND	6	ND	0.2	ND		*
Jamison Creek below mine		26JUN89			150	6.50		ND	ND	ND	ND	ND	ND	ND	ND	ND		*
Reward #7	Plumas																	
Ward creek below mine		20DEC89		185	146	7.23		130	ND	ND	ND	ND	ND	ND	0.2		ND	*
		10APR90			108	6.41	47	ND										*
Ward creek above mine		10APR90			106	6.68		ND										*
Walker																		
main adit discharge	Plumas	26MAR88	0.57								290		10					1
		02JUN88	0.37								248		5.4					1
		16JUL88									240		<10					1
		03AUG88	0.28								220		<50					1
		03NOV88	0.28								229		7					1
		03NOV88	0.28								229		6.5					1
		03NOV88									240		40					1
		29JAN89	1.16								250		14					1
		29MAR89	0.93								450		<5					1
		20JUN89									310		20					1
		06JUN89									260		20					1
		06JUN89									280		10					1
		06JUN89			107	7.34		ND	0.1	ND	290	ND	9	ND	ND	ND		*
Dollie Creek above mine		03AUG88									8		23					1
		03NOV88	0.03								6.2		2.8					1
		03NOV88									7		45					1
		29JAN89	0.08								<2		<5					1
		20JUN89	1.25								<1		<10					1
		26JUN89			118	7.70		ND	ND	1	ND	ND	ND	ND	ND	ND		*
Dollie Creek below mine		03AUG88									69		7					1
		03NOV88	7.87								28		3					1
		26JUN89	15.15								90		10					1
		26JUN89	8.5		114	7.60		ND	ND	ND	49	ND	ND	ND	ND	ND		*

SOURCE: 1. Croyle, B. 1990. Walker mine data report (data collected post-plugging)
* This study.

Table C-1. WATER QUALITY CHARACTERISTICS OF MINE DRAINAGE & RECEIVING WATERS IN SEVERAL SACRAMENTO VALLEY WATERSHEDS.

MINE SAMPLE LOCATION	COUNTY	SAMPLE DATE	FLOW (l/s)	Eh (mV)	EC (uS/cm)	pH	HARDNESS AS CACO3 (mg/L)	CONCENTRATION, UG/L (DETECTION LIMITS IN PARENTHESES) ARSENIC (<1.0)	CADMIUM (<0.10)	CHROMIUM (<2.0)	COPPER (<1.0)	NICKEL (<4.0)	ZINC (<10)	LEAD (<5.0)	MERCURY (<0.20)	SILVER (<0.50)	IRON (<30)	SOURC
PIT RIVER WATERSHED																		
Golden Eagle	Lassen																	
Dammed pond water		03AUG89	0		325	6.60		9	ND	ND	3	ND	14	ND	ND	ND		*

SOURCE:
* This study.

MINE SAMPLE LOCATION	COUNTY	SAMPLE DATE	FLOW (l/s)	Eh (mV)	EC (uS/cm)	pH	HARDNESS AS CACO3 (mg/L)	ARSENIC (<1.0)	CADMIUM (<0.10)	CHROMIUM (<2.0)	COPPER (<1.0)	NICKEL (<4.0)	ZINC (<10)	LEAD (<5.0)	MERCURY (<0.20)	SILVER (<0.50)	IRON (<30)	SOURC
UPPER SACRAMENTO RIVER WATERSHED																		
Afterthought	Shasta																	
main adit		MAR78							1,230		48,900		313,000				330,000	1
		JUN78				2.60			720		25,600		149,000				96,000	1
		MAY82				2.57			800		33,500		185,000				160,000	1
		APR84	1.20			2.80			410		17,600		100,000				92,400	1
		JUN84	0.30			2.85			320		12,100		91,400				70,600	1
		AUG84	0.20			2.74			300		10,600		83,600				51,400	1
		DEC84	1.80			2.60			740		34,100		177,000				202,000	1
		12JUL89			3,000	2.70		25	340	2	14,000	32	93,000	91	<0.2	<1		*
Afterthought Crk. above mine		MAR78							60		1,720		1,120				430	1
		APR84	1.10			5.00			40		1,090		8,060				430	1
		DEC84	1.80			4.65			70		1,120		12,200				380	1
Afterthought Crk. below mine		MAR78							440		16,500		96,500				90,300	1
		MAY78				2.85			580		19,400		127,000				106,000	1
		APR84	2.30			2.90			260		9,480		61,200				42,900	1
		DEC84	3.70			2.65			420		18,300		98,500				760	1
		FEB85						142		<50		<50		50	<0.2			1
Little Cow Crk. above mine		MAR78							<10		<10		20				20	1
		MAY78				6.00			<10		<10		10					1
		JUN78				7.10					<10		<10					1
		MAY82				8.11			<10		<20		<20				200	1
		APR84	3,569			7.90			<0.2		<2		<20				110	1
		JUN84	748			8.45			<0.2		<2		7				50	1
		AUG84	296			7.97			<0.2		3		16				50	1
		DEC84				7.90			<0.2		90		5				60	1
		12JUL89			191	6.70		<	0	<1	<1	<4	<5	<5	<0.2	<1		*
Little Cow Crk. 0.5 mile below mine		MAY78				5.70			<10		0		0					1
		MAY82				8.14			<10		130		860				1,750	1
		APR84	3,572			7.80			<0.2		7		40				130	1
		JUN84	748			8.40			<0.2		2		60				70	1
		AUG84	296			8.63			1		8		60				50	1
		DEC84				7.75			0.2		11		110				170	1
		12JUL89			180	8.00	71	<	1	<1	17	<4	110	<5	<0.2	<1		*
Gladstone	Shasta																	
Cline Creek below mine		12JUL89			192	6.50		23	ND	ND	ND	ND	ND	ND	ND	ND		*

Table C-1 WATER QUALITY CHARACTERISTICS OF MINE DRAINAGE & RECEIVING WATERS IN SEVERAL SACRAMENTO VALLEY WATERSHEDS

MINE	SAMPLE LOCATION	COUNTY	SAMPLE DATE	FLOW (l/s)	Eh (mV)	EC (uS/cm)	pH	HARDNESS AS CACO3 (mg/L)	ARSENIC (<1.0)	CADMIUM (<0.10)	CHROMIUM (<2.0)	COPPER (<1.0)	NICKEL (<4.0)	ZINC (<10)	LEAD (<5.0)	MERCURY (<0.20)	SILVER (<0.50)	IRON (<30)	SOURC
									CONCENTRATION: UG/L (DETECTION LIMITS IN PARENTHESES)										
Greenhorn		Shasta																	
	North adit discharge		APR81	0.32			2.40			990		125,000		180,000				1,350,000	1
			APR82	0.95			2.40			920		138,000		152,000				1,113,000	1
			MAY83				2.70			920		118,000		78,000				642,000	1
			FEB84	0.47			2.70			1,510		117,000		151,000				931,000	1
			APR84	0.63			2.70			1,350		69,000		124,000				712,000	1
			SEP84	0.38			2.60			1,240		65,600		142,000				1,000,000	1
			DEC84	0.68			2.70			1,400		63,400		140,000				874,000	1
			12JUL89			5,540	2.34		170	680	12	80,000	190	160,000	91	ND	ND		*
			20DEC89	0.01	425	6,150	2.63			645	9	67,000	61	170,000	ND			1,000,000	*
			13APR90	0.06	422	5,650	2.60		39	670	9	61,000	165	150,000	ND	ND		780,000	*
	South adit discharge		FEB79				3.30			190		56,000		25,500					1
			APR82				3.00			123		57,100		26,000				42,000	1
			20DEC89	0.04	136	1,431	5.74			15	ND	200	ND	4,500	ND			120,000	*
			13APR90	0.06	134	1,364	5.87		ND	10		200		4,700					*
	Middle adit discharge		JAN81				2.70												1
			APR81				2.60			160		95,000		29,000				230,000	1
			APR82							160		101,000		38,700				221,000	1
			DEC84	0.03			2.90			160		87,300		33,300				48,500	1
			20DEC89	0.39	168	682	5.72			2	ND	1,500	ND	1,100	ND			29,000	*
			13APR90	0.60	173	718	5.16		8	3.1		3,400		1,800					*
	lower pile seep		AUG76				3.50					13,800		4,500				3,500	1
			FEB79				4.00			20				2,300					1
			JAN81									5,800							1
			APR81				3.60			<10		30		1,800				47,600	1
			APR82				3.70			12		4,010		1,990				230	1
			APR84	0.09			3.30			13		480		5,650				140,000	1
			SEP84	0.06			3.50			20		390		6,160				131,000	1
			DEC84	0.07			3.60			10		690		4,790				134,000	1
	Willow Crk. upstream mine		AUG76				6.90					60		50				220	1
			FEB79				7.20			<10		<20		<20					1
			APR81				7.80			<10		<20		30				370	1
			APR82				7.10			<5		<20		<6				110	1
			FEB84	129.70			7.80			<1		13		70				330	1
			APR84	75.70			7.50			<0.2		<2		<10				<50	1
			SEP84	14.70			7.60			<0.2		<2		7				370	1
			DEC84	102.00			7.60			<0.2		<2		10				260	1
			12JUL89	·		154	7.80		ND	ND	ND	ND	ND	23	ND	ND	ND		*
			20DEC89	33.09	177	149	6.45			ND	ND	ND	ND	ND	ND			590	*
			13APR90	30.58	114	152	7.00		ND	ND	ND	2	ND	ND	ND			280	*
	Willow Crk. downstream mine		FEB79				5.90			<10		500		330					1
			APR82				6.70			<5		120		300				540	1
			MAY83				6.70			3		590		290				2,460	1
			FEB84	152.00			7.00			7		580		610				3,730	1
			APR84	89.00			6.80			16		400		820				2,200	1
			SEP84	14.80			6.30					1,180		1,740				9,360	1
			DEC84	104.90			7.20			1		210		220				1,810	1
			12JUL89	56.63		378	4.70	130	ND	14	ND	1,600	9	2,700	ND	ND	ND		*
			20DEC89	41.08	140	233	6.83	85		3	2	390	ND	720	ND			4,400	*
			13APR90	35.68	77	268	6.78	82		3		460		820				5,100	*

Table C-1. WATER QUALITY CHARACTERISTICS OF MINE DRAINAGE & RECEIVING WATERS IN SEVERAL SACRAMENTO VALLEY WATERSHEDS.

MINE	SAMPLE LOCATION	COUNTY	SAMPLE DATE	FLOW (l/s)	Eh (mV)	EC (uS/cm)	pH	HARDNESS AS CACO3 (mg/L)	ARSENIC (<1.0)	CADMIUM (<0.10)	CHROMIUM (<2.0)	COPPER (<1.0)	NICKEL (<4.0)	ZINC (<10)	LEAD (<5.0)	MERCURY (<0.20)	SILVER (<0.50)	IRON (<30)	SOURC
									CONCENTRATION, UG/L (DETECTION LIMITS IN PARENTHESES)										
Iron Mountain		Shasta																	
	Spring Creek Debris Dam	1/	1980	3,256										28,400					2
		1/	1981	2,435										30,880					2
		1/	1982	5,239										25,490					2
		1/	1983	8,325										25,660					2
		1/	1984	2,917			2.90			88		1,690		21,040					2
		1/	1985	1,274			2.80			70		2,100		22,570					2
		1/	1986	3,794										33,080					2
		1/	1987	1,246			2.79			42		1,340		29,480					2
		1/	1988	1,586			2.83			118		2,870		23,330					2
		1/	1989	1,897			2.90			81		1,970		17,920					2
			13JUL89			1475	2.44		37	95	10	3,500	13	15,000	22	0.2			*
			26JUL89			2050	2.60		56	140	15	5,000	17	21,000	24	<0.2			*
			21DEC89		538	1626	2.86		47	92	12	4,900	<4	17,000	15				*
		1/	1990				2.80			56		1,460							2
			14APR90		499	1157	2.89		4.5	72	3	1,150	11	9,950	14.5				*
Midas		Shasta																	
	Harrison Creek above mine		26JUL89	1.98		300	6.80		ND	ND	ND	ND	ND	ND	ND	ND	ND		*
	Harrison Creek below mine		26JUL89			510	4.90		4	ND	ND	ND	ND	ND	ND	ND	ND		*
Round Bottom		Shasta																	
	adit discharge		26JUL89	seep		610	7.10		ND	1.2	16	ND	54	ND	ND	ND	ND		*
Silver Falls		Shasta																	
	ponded adit water		26JUL89	0		480	6.70		ND	ND	ND	ND	ND	6	ND	ND	ND		*
Thompson		Shasta																	
	pit water		13JUL89	0		197	6.30		ND	0.2	ND	10	ND	6	ND	ND	ND		*

1/ Annual average.
SOURCE:
1. California Department of Water Resources(CDWR).1985.The Greenhorn and Afterthought mines-A plan for the control and abatement of acid and heavy metal pollution Shasta County CA.Memorandum report CDWR Northern District. July
2. Heiman, D. 1991. Database printout from weekly Spring Creek Debris Dam sampling.
* This study.

STONY CREEK/ELDER CREEK WATERSHEDS

MINE	SAMPLE LOCATION	COUNTY	SAMPLE DATE	FLOW (l/s)	Eh (mV)	EC (uS/cm)	pH	HARDNESS AS CACO3 (mg/L)	ARSENIC	CADMIUM	CHROMIUM	COPPER	NICKEL	ZINC	LEAD	MERCURY	SILVER	IRON	SOURC
Gray Eagle		Glenn																	
	pit water		20JUL89	0		698	8.79		ND	ND	ND	1	ND	ND	ND	ND	ND		*
Noble Electric Co.		Tehama																	
	West ravine seepage		04AUG89	seep		540	8.20		ND	ND	5	ND	ND	ND	ND	ND	ND		*
	North Fork Elder Creek above mine		04AUG89			700	8.20		ND	ND	2	ND	ND	5	ND	ND	ND		*
	North Fork Elder Creek below mine		04AUG89	48.71		1030	8.30		ND	ND	2	ND	ND	5	ND	ND	ND		*

Table C-1. WATER QUALITY CHARACTERISTICS OF MINE DRAINAGE & RECEIVING WATERS IN SEVERAL SACRAMENTO VALLEY WATERSHEDS

MINE	SAMPLE LOCATION	COUNTY	SAMPLE DATE	FLOW (l/s)	Eh (mV)	EC (uS/cm)	pH	HARDNESS AS CACO3 (mg/L)	ARSENIC (<1.0)	CADMIUM (<0.10)	CHROMIUM (<2.0)	COPPER (<1.0)	NICKEL (<4.0)	ZINC (<10)	LEAD (<5.0)	MERCURY (<0.20)	SILVER (<0.50)	IRON (<30)	SOURC
									CONCENTRATION, UG/L (DETECTION LIMITS IN PARENTHESES)										

SOURCE:
* This study.

CACHE CREEK WATERSHED

MINE	SAMPLE LOCATION	COUNTY	SAMPLE DATE	FLOW (l/s)	Eh (mV)	EC (uS/cm)	pH	HARDNESS AS CACO3 (mg/L)	ARSENIC	CADMIUM	CHROMIUM	COPPER	NICKEL	ZINC	LEAD	MERCURY	SILVER	IRON	SOURC
Turkey Run		Lake																	
	adit discharge		25AUG89	0.19		803	7.83		ND	ND	3	ND	ND	ND	ND	ND	ND		*
Reed		Yolo																	
	adit discharge		25AUG89	0.32		3,010	6.33		59	ND	46	ND	1,200	20	ND	ND	ND		*
			27APR90	seep															*
	Davis Creek above mine		25AUG89	0.24		1,024	8.22		ND	ND	ND	1	ND	14	ND	ND	ND		*
			27APR90		94	907	8.07		ND		2		4	6					*
	Davis Creek below mine		25AUG89			3,450	6.67	1100	29	ND	30	1	875	10	ND	ND	ND		*
			27APR90	0.3	93	1,010	7.5	540	ND		1		17	7				100	*
Sulpher Creek mines **			02AUG89	4.73		>10,000	7.90		7	ND	3	1	8	36	ND	<20	ND		*

SOURCE:
* This study.
** Sulphur Creek below Central, Empire, Manzanita, Wide Awake, and Elgin mines.

LAKE BERRYESSA, PUTAH CREEK WATERSHED

MINE	SAMPLE LOCATION	COUNTY	SAMPLE DATE	FLOW (l/s)	Eh (mV)	EC (uS/cm)	pH	HARDNESS AS CACO3 (mg/L)	ARSENIC	CADMIUM	CHROMIUM	COPPER	NICKEL	ZINC	LEAD	MERCURY	SILVER	IRON	SOURC
Anderson Springs		Lake																	
	west adit		24AUG89	0.08		1,092	6.16		7	ND	9	15	240	260	ND	ND	ND		*
			18DEC89	0.15	-105	900	7.02		ND	ND	ND	ND	10	17				7,000	*
			09APR90	0.19	-65	1,081	6.77		3		4	11	70	190					*
	east adit		24AUG89	0.59		1,282	6.61		4	ND	ND	ND	74	61	ND	ND	ND		*
			18DEC89	0.53	122	1,347	7.21		6				32	84				2,700	*
			09APR90	0.37	59	1,208	6.58		18			30	170						*
	creek above West adit		09APR90		92	308	7.28		ND				6	8					*
	creek below West adit		18DEC89		71	346	6.96		2	ND		ND	ND	5				870	*
			09APR90		12	318	7.11	160	ND				6	5					*
	Anderson Springs creek below both adits		24AUG89			139	6.96		ND	ND	1	1	ND	ND	ND	ND	ND		*
			18DEC89		180	184	7.28		ND	ND	2	ND	ND	ND		ND		ND	*
			09APR90		103	244	7.58		ND				ND	ND					*
Great Western		Lake																	
	adit discharge		24AUG89	0.24		325	7.39		ND	ND	5	2	26	10	ND	ND	ND		*
			19DEC89	0.13	172	302	7.36				4	ND	17	10				790	*
			09APR90	0.63		321	7.50		ND	ND	3	1	59	26	ND	ND			*
	St Marys Creek below mine		19DEC89		160	720	7.44				3	ND	ND	ND				50	*
			09APR90			604	7.79				4	ND	8	120					*
Knoxville		Napa																	

Table C-1. WATER QUALITY CHARACTERISTICS OF MINE DRAINAGE & RECEIVING WATERS IN SEVERAL SACRAMENTO VALLEY WATERSHEDS.

MINE	SAMPLE LOCATION	COUNTY	SAMPLE DATE	FLOW (l/s)	Eh (mV)	EC (uS/cm)	pH	HARDNESS AS CACO3 (mg/L)	CONCENTRATION, UG/L (DETECTION LIMITS IN PARENTHESES) ARSENIC (<1.0)	CADMIUM (<0.10)	CHROMIUM (<2.0)	COPPER (<1.0)	NICKEL (<4.0)	ZINC (<10)	LEAD (<5.0)	MERCURY (<0.20)	SILVER (<0.50)	IRON (<30)	SOURC
	Knoxville Creek above mine		03AUG79				7.60									0.1		200	1
	Knoxville Creek below mine		03AUG79				7.50									0.4		200	1
Red Elephant		Napa																	
	ponded shaft Water		24AUG89			1474	7.41		ND	ND	ND	ND	ND	ND	ND	ND	ND		*

SOURCE:
1. Pinkos, T. 1979. Downstream water quality. CVRWQCB Internal memo. March 15.
* This study.

LAKE BERRYESSA, POPE CREEK WATERSHED

Aetna Etension, south slope		Napa																	
	creek below mine		24AUG89	0.32		778	7.52		ND	ND	8	ND	9	10	ND	ND	ND		*
Corona		Napa																	
	main adit discharge		15MAR79	3.50			5.60									0		8,000	1
			06MAY81	0.30		725	6.50		5	<10						1			2
			10AUG89	seep		754	7.40		<2	<0.1	44	<1	1,900	41	<5	<0.2	<1		*
			09APR90	0.29		1,051	5.73				21	1	4,000	44				53,000	
	water release tunnel		15MAR79	21.30			5.00									0		620,000	1
			10AUG89	3.10		1,593	5.00	630	<2	<0.1	71	<1	10,000	230	<5	<0.2	<1		*
			19DEC89	2.87	120	1,177	6.03				21		6,050	100				150,000	*
			09APR90	2.65		1,906	5.67				30		12,000	260				350,000	*
	James Crk upstream		15MAR79	4.90			6.40									0		400	1
	mine		19DEC89		124	258	6.89				1		130	<5				460	*
			09APR90			277	6.66				ND		120	ND				ND	*
	James Crk downstream		15MAR79	31.20			5.40					0		100		0		110,000	1
	mine		19DEC89		85	966	6.38				10		4,800	80				110,000	*
			09APR90			1,110	6.29	360			8	2	6,000	110					*
	James Crk downstream mine (1.5 mile down)		23AUG89	4.12		894	6.69	540	<2	<0.1	1	1	3,000	23	<5	<0.2	<1		*
Twin Peaks		Napa																	
	adit discharge at pipe		23AUG89	0.28		393	4.89		ND	0.4	10	ND	2,000	30	ND	ND	ND		*
			19DEC89	0.20	143	471	6.30			ND	3		1,800	30				16,000	*
			09APR90	0.25		416	6.43			ND	4		1,600	26				14,000	*
	discharge at base of waste pile		23AUG89	0.06		445	5.11		ND	ND	2	3	2,200	17	ND	ND	ND		*
	Bateman Creek above mine		23AUG89			176	5.92		ND	ND	ND	ND	ND	ND	ND	ND	ND		*
			19DEC89		170	97	6.61			ND	ND		ND	ND				ND	*
			09APR90			103	7.06			ND	ND		ND	5					*
	Bateman Creek below mine		23AUG89			294	6.66	140		ND	1	1	250	7	ND	ND	ND		*
			19DEC89		169	120	6.75	48		ND	ND		32	ND				60	*
			09APR90			127	6.99	47		ND	ND		62	ND					*

SOURCE:
1. Pearson, L. 1979. Inspection of Corona Mine/James Ck. area. CVRWQCB Internal Memo. April 12.
2. Crawford, E. 1981. Requirements checking Corona Mine, Napa County. CVRWQCB Internal Memo. June 9.
* This study.

Table C-2. WATER QUALITY CHARACTERISTICS OF MINE DRAINAGE AND RECEIVING WATERS IN THE SHASTA DAM WATERSHED

SAMPLE LOCATION	SAMPLE DATE YEAR	SAMPLE DATE MONTH/DAY	E.C. (uS/cm)	pH	FLOW (l/s)	HARDNESS AS CACO3 (mg/l)	TOTAL CONCENTRATION (UG/L) ARSENIC	CADMIUM	CHROMIUM	COPPER	IRON	LEAD	MERCURY	NICKEL	SILVER	ZINC	SOURCE
BALAKLALA MINE																	
main adit	1975	4 / 1	675	3.20	65.10			40		6,250	29,000					7,000	1
	1975	9 / 17	513	3.60	4.00			100		9,500	48,000	96				16,000	1
	1978	12 /	700	3.00	0.80			80		10,500						15,200	7
	1979	8 /		2.90	5.10			60		7,300	5,500					11,800	8
	1979	9 /		2.80	4.70			60		7,500	7,200					12,000	8
	1979	10 /		2.50	9.50			200		43,800	276,000					33,000	8
	1979	11 /		2.60	9.50			150		31,100	201,000					25,700	8
	1980	1 /		3.10	18.90			100		6,700	85,000					14,000	8
	1980	2 /		3.20	33.40			40		8,500	16,300					9,100	8
	1980	3 /		3.60	33.40			400		6,700	8,600					9,300	8
	1980	4 /		4.20	19.00			40		6,600	6,300					9,300	8
	1980	5 /		2.80	19.00					6,300	2,000					10,100	8
	1980	6 /		2.60	11.80					6,200	3,400					11,400	8
	1980	6 / 27						120		12,100						22,000	6
	1980	6 /			2.80					12,000	24,000					21,400	8
	1980	7 /		5.60	2.90					11,900	53,700					23,000	8
	1980	7 / 6						110		13,300						21,700	5
	1980	8 /		3.80	2.10					12,500	33,000					25,000	8
	1980	9 /		3.30	1.90					12,700	55,000					26,000	8
	1980	10 /		3.20	1.60					13,900						27,000	8
	1980	10 /			2.00					13,000	89,000					25,900	8
	1980	11 /		3.30	3.70					9,900	50,000					16,000	8
	1980	12 /		3.30	1.60					45,000	280,000					43,000	8
	1981	3 /			4.70			120		20,200	96,400					19,000	8
	1981	4 /			12.60			80		12,700	65,300					14,500	8
	1981	4 / 10						80		12,700	65,300					14,500	4
	1981	6 /		2.70	2.80			130		14,900	103,000					24,800	8
	1981	7 / 1		2.70	2.80			130		14,900	103,000					24,800	3
	1981	8 / 27		2.70				170		16,440	61,000					29,000	2
	1981	9 /		2.70	6.10			170		16,400	61,000					29,000	8
	1982	10 / 26	1550	2.80	19.03			110		17,000	132,000					19,000	23
	1982	11 / 23	1325	2.60	15.89			110		15,000	98,000					17,000	23
	1982	12 / 28	1250	2.60	35.14		40	80	0	13,000	68,000	60				13,000	23
	1983	1 / 27	820	2.80	279.49			50		9,000	50,000					6,100	23
	1983	3 / 1	3450	2.90	589.00			610		11,000	790,000					130,000	23
	1983	4 / 21	1310	2.90	37.58												23
	1984	4 / 9		2.90	12.60			70		9,430	144,000					45,700	10
	1984	6 / 22		3.10	9.50			90		11,700	176,000					19,400	15
	1985	1 / 10			17.90			90		12,600						17,600	11
	1985	4 / 4		2.48	14.80			90		15,500						20,600	11
	1985	10 / 4						90		11,500	191,000					19,500	16
	1986	4 / 7		2.57	25.20			50		6,400						8,000	12
	1986	6 / 24						110		11,400						18,400	13
	1986	6 / 10		2.70	3.20			120		15,000						22,500	13
	1986	12 / 23			2.50			108		12,500						20,000	14
	1987	10 / 6								25,800						46,000	18
	1987	11 / 10								18,900						25,000	19
	1988	1 / 29		2.70	28.40			60		10,400						14,500	20
	1989	3 / 13	2300	2.40	1.60			2,240		37,200						39,100	22
	1989	4 / 28			1.80			138		18,400						24,500	17
	1989	4 / 9	1830	2.60	2.40			171		26,800						28,700	21

Table C-2. WATER QUALITY CHARACTERISTICS OF MINE DRAINAGE AND RECEIVING WATERS IN THE SHASTA DAM WATERSHED.

SAMPLE LOCATION	SAMPLE DATE YEAR	MONTH/DAY	E.C. (uS/cm)	pH	FLOW (l/s)	HARDNESS AS CACO3 (mg/l)	TOTAL CONCENTRATION (UG/L) ARSENIC	CADMIUM	CHROMIUM	COPPER	IRON	LEAD	MERCURY	NICKEL	SILVER	ZINC	SOURCE
	1989	5 / 4	1650	2.70	1.60			137		18,600						23,500	21
	1989	5 / 31	1700	2.60	1.45			149		16,000						27,600	24
	1989	7 / 9	1810	5.40	1.45			148		14,900						27,500	25
	1989	7 / 31	1720	3.12	0.76			132		13,000						24,500	26
	1989	9 / 1	1690	3.13	0.42			160		15,400						29,600	27
	1989	10 / 2	1970	2.71	0.56			177		16,500						33,400	28
Weil adit	1982	10 / 26	8000		0.03			6,500		912,000	8,900,000					1,380,000	23
	1982	11 / 23	8000	2.30	0.02			6,600		886,000	8,740,000					1,380,000	23
	1982	12 / 28	8000	2.40	0.07			6,800		910,000	8,850,000					1,500,000	23
	1983	1 / 27	8000	2.30	0.03			6,800		569,000	8,500,000					1,400,000	23
	1983	2 / 28	8000	2.30	0.03			6,400		453,000	7,750,000					1,300,000	23
	1983	4 / 21	8000	2.20	0.03												23
	1984	4 / 9		2.52	0.06			4,020		199,000	9,580,000					1,690,000	10
	1985	1 / 10		2.55	0.03			5,960		310,000						1,430,000	11
	1985	4 / 4		2.55	0.02			4,300		216,000						1,180,000	11
	1986	4 / 7			0.00			700		120,000						160,000	12
	1986	6 / 10		2.15	0.01			3,000		490,000						580,000	13
	1986	12 / 23			0.10			1,030		158,000						190,000	14
	1987	10 / 6								109,000						143,000	18
	1987	11 / 10		2.71						316,000						532,000	19
	1989	4 / 28			0.38			34		5,250						5,430	17

SOURCE:1:Fuller,R.,Shay,J.,Ferreira,R.,and Hoffman,R.1978.An evaluation of problems arising from acid mine drainage in the vicinity of Shasta reservior ,Shasta County,California.Water-Resouces Investigation 78-32 May.
2:Heiman,D.1981.Inspection report.CVRWQCB Inspection report.September.
3:Heiman,D.1981.Compl.Ispect.-Silver King.CVRWQCB office memo July 1.
4:Heiman,D.1981.Compliance inspection-West Squaw Creek mines CVRWQCB Internal Memo.May 11.
5:Heiman,D.1980.Inspection,West Squaw Creeek/Balaklala,Silver King mines,Inc.,Shasta County CVRWQCB Internal Memo.September 2.
6:Silver King Mine,1980. Report.From Silver King Mines.Inc.Salt Lake City, Utar to CWQCB Redding .August 6.
7:Smarkel,k.1979.West Squaw drainage inspection Shasta County.CVRWQCB Internal Memo.February 5.
8:CVRWQCB.Balaklala,Keystone,and Shasta King mines.Table 1.Water quality information for Shasta King ,Keystone,and Balaklala mines.
10:Heiman,D.1984 inspection report .CVRWQCB Inspection report.May 14.
11:Heiman,D.1985.Water quality surveys-West Squaw Creek mines.CRWQCB.CVR Internal Memo.August 26.
12:Heiman,D.1986.Inspection report.CVRWQCB Inspection report.March 25.
13:Heiman,D.1986.Inspection report.CVRWQCB Inspection report.July 8.
14:Heiman,D.1987.Result of samples-Balaklala,Keystone and early Bird mines,23 December 1986.CVRWQCB Office Memo.January 29.
15:Heiman,D.1984.Data sheet. Reported by Environmental Laboratory to WQCB Redding July 13.
16:Heiman,D.1984.Data sheet. Reported by Environmental Laboratory to WQCB Redding October 28.
17:Heiman,D.1989.Squaw Creek survey.28 April 1989.CRWQCB.CVR Internal Memo.September 13.
18:Heiman,D.1984.Data sheet. Reported by Environmental Laboratory to WQCB Redding.november 17.
19:Heiman,D.1984.Data sheet. Reported by Environmental Laboratory to WQCB Redding december 16.
20:Heiman,D.1988.inspection-Balaklalaand Early Bird mines.CRWQCB.CVR Internal Memo.April 20.
21:Silver King Mine. 1989.Letter.From Silver King Mines.Salt Lake City.Utah to US EPA San Francisco,CA.and RWQCB.Redding,CA.June 5.
22:Silver King Mine. 1989.Letter.From Silver King Mines.Salt Lake City.Utah to US EPA San Francisco,CA.and RWQCB.Redding,CA.May 1.
23:Department of Water Resouces Northern District.1983.Quantification of acid and heavy metal discharges from mine portals and dumps at Balaklala, Keystone and Shasta King mines.Report to WRCB.CVR.Interagency Agreement #2-092-158-0(DWR #163109).
24:Silver King Mine. 1989.Letter.From Silver King Mines.Salt Lake City.Utah to US EPA San Francisco,CA.and RWQCB.Redding,CA.August 2.
25:Silver King Mine. 1989.Letter.From Silver King Mines.Salt Lake City.Utah to US EPA San Francisco,CA.and RWQCB.Redding,CA.August 22.
26:Silver King Mine. 1989.Letter.From Silver King Mines.Salt Lake City.Utah to US EPA San Francisco,CA.and RWQCB.Redding,CA.September 12.
27:Silver King Mine. 1989.Letter.From Silver King Mines.Salt Lake City.Utah to US EPA San Francisco,CA.and RWQCB.Redding,CA.October 4.
28:Silver King Mine. 1989.Letter.From Silver King Mines.Salt Lake City.Utah to US EPA San Francisco,CA.and RWQCB.Redding,CA.november 22.

Table C-2. WATER QUALITY CHARACTERISTICS OF MINE DRAINAGE AND RECEIVING WATERS IN THE SHASTA DAM WATERSHED

SAMPLE LOCATION	SAMPLE DATE YEAR	SAMPLE DATE MONTH/DAY	E.C. (uS/cm)	pH	FLOW (l/s)	HARDNESS AS CACO3 (mg/l)	TOTAL CONCENTRATION (UG/L) ARSENIC	CADMIUM	CHROMIUM	COPPER	IRON	LEAD	MERCURY	NICKEL	SILVER	ZINC	SOURCE
BALAKLALA MINE WATERSHED, WEST SQUAW CREEK																	
upstream mine	1979	10 /						<20		<20						<20	2
	1980	6 / 27						<10		<20						<20	1
	1983	9 / 14		7.65	20.70			35		130						150	3
	1984	1 / 4		7.10	693.80			<5		20						40	3
	1989	3 / 13	360	6.39				<2		4						35	5
	1989	4 / 9	46	6.86				<2		4						31	4
	1989	4 / 28			82.71			0		<4						21	6
	1989	5 / 4	71	7.04				<2		31						54	4
downstream Shasta King	1975	9 / 18	277	4.60	141.60			30		2,100	2,100	13				3,400	7
	1976	7 / 2	1100	2.50						22,000	36,000					66,000	9
	1980	7 / 16						40		7,410						7,860	8
	1982	10 / 27		3.22	51.82			30		2,700	11,000					3,200	34
	1982	11 / 23	260	3.00	305.82			10		1,600	8,800					1,900	34
	1982	12 / 28	178	3.20	566.34		10	10	0	1,100	8,000	0			0	910	34
	1983	1 / 27	86	3.40				0		580	4,200					340	34
	1983	2 / 28	200	3.40				10		510	22,000					2,600	34
	1983	4 / 21	180	3.40				10		660	13,000					2,800	34
	1983	9 / 14		2.98	48.10			30		2,150						7,390	3
	1984	1 / 4		3.55	880.70			6		720						1,550	3
	1984	4 / 9	144	3.98				6		831						1,160	4
	1989	3 / 13	200	3.51				9		1,010						1,240	5
	1989	4 / 28			195.10			6		809						1,360	6
	1989	5 / 4	151	4.09				8		924						1,280	4
lake confluence	1975	4 / 10	103	4.02	3483.00			5		650	650					630	7
	1975	9 / 18	607	3.00	169.90			30		5,100	15,000	11				5,600	7
	1976	7 / 2	620	2.60						6,600	6,200					8,600	9
	1980	5 / 26		3.50				8		1,650						1,800	18
	1980	5 / 16						20		4,260						4,950	19
	1980	5 / 7		3.51				<10		1,370						1,430	20
	1980	6 / 27						10		2,360						2,650	17
	1980	7 / 16						20		3,170						3,450	8
	1980	8 /						20		4,200						4,800	2
	1980	10 /						20		4,100						4,400	2
	1980	11 / 17						30		4,440						4,610	16
	1981	1 / 5						10		2,490	8,080					2,480	15
	1981	2 / 2						10		1,810						1,640	14
	1981	4 / 29		3.51				<10		1,260						1,320	12
	1981	4 / 10						100		1,680	10,400					1,630	13
	1981	7 / 1		2.97				20		3,430	13,200					3,790	11
	1981	8 / 27		3.00				40		4,820	3,610					5,630	10
	1981	8 / 5		3.10				30		4,210	3,480					5,020	10
	1981	9 /		3.00				40		4,800	3,600					5,600	2
	1981	11 /								1,300	6,800					1,000	2
	1982	10 / 29	150	4	214.08			10		820	1,500					1,100	34
	1982	11 / 23	95	3	662.62			10		560	2,000					630	34
	1982	12 / 29	60	4	1398.86		0	0	0	480	2,700	0			0	540	34
	1983	1 / 27	50	4				0		160	2,000					120	34

21:Silver King Mine. 1989.Letter.From Silver King Mines.Salt Lake City.Utah to US EPA San Francisco,CA.and RWQCB.Redding,CA.October 4.
22:Silver King Mine. 1989.Letter.From Silver King Mines.Salt Lake City.Utah to US EPA San Francisco,CA.and RWQCB.Redding,CA.November 22.

Table C-2. WATER QUALITY CHARACTERISTICS OF MINE DRAINAGE AND RECEIVING WATERS IN THE SHASTA DAM WATERSHED.

GOLINSKY MINE

SAMPLE LOCATION	SAMPLE DATE YEAR	MONTH/DAY	E.C. (uS/cm)	pH	FLOW (l/s)	HARDNESS AS CACO3 (mg/l)	ARSENIC	CADMIUM	CHROMIUM	COPPER	IRON	LEAD	MERCURY	NICKEL	SILVER	ZINC	SOURCE
main adit	1978	9 / 14	1,500	2.90						17,000						47,000	1
	1978	11 / 9		3.50				1,510		17,600	71,000					78,000	1
	1983	4 / 18		2.90	3			223		7,950	29,300					20,640	2
	1983	6 /		3	0			504		8,600	22,600					34,100	3
	1983	12 /		3	1			227		10,600	23,200					22,200	3
	1984	5 /		3	0			280		22,500	43,300					31,200	3

SOURCE 1.Smarkel,K. 1979. Little Backbone Creek acid mine drainage, Shasta County. CVRWQCB Internal Memo. March 23.
2.Heiman,D. 1983. Golisky Mine. CRWQCB.CVR Internal Memo. May 16.
3.Heiman,D. 1991. Data sheet from D. Heiman, CVRWQCB.

SUTRO MINE

SAMPLE LOCATION	SAMPLE DATE YEAR	MONTH/DAY	E.C. (uS/cm)	pH	FLOW (l/s)	HARDNESS AS CACO3 (mg/l)	ARSENIC	CADMIUM	CHROMIUM	COPPER	IRON	LEAD	MERCURY	NICKEL	SILVER	ZINC	SOURCE
Upper adit	1983	6															1
	1983	12		3.80	3				8	960	1,060					410	1
	1984	5															1
Upper Waste rock pile	1983	6		6.80	5				2	<10	110					900	1
	1983	12		6.90	15				<5	290	230					170	1
	1984	5		6.93	4				1	30	340					90	1
Lower adit	1983	6		6.40	20				18	1,200	560					2,000	1
	1983	12		6.80	17				14	1,010	80					1,550	1
	1984	5		6.50	21				20	1,420	710					2,100	1

SOURCE: 1. Heiman, D. 1991. Summary of water quality data. Data sheet from D. Heiman.

MAMMOTH MINE

SAMPLE LOCATION	SAMPLE DATE YEAR	MONTH/DAY	E.C. (uS/cm)	pH	FLOW (l/s)	HARDNESS AS CACO3 (mg/l)	ARSENIC	CADMIUM	CHROMIUM	COPPER	IRON	LEAD	MERCURY	NICKEL	SILVER	ZINC	SOURCE
main adit	1978	9 /		3				190		13,000						23,800	13
	1982	12 /		3				44		2,900	2,610					6,000	13
	1983	6 /		4	6			32		980	250					3,520	13
	1983	12 /		4	32			16		1,170	1,700					2,500	13
	1984	5 /		3	15			30		1,850	1,920					4,830	13
	1988	6 / 27		3				240		25,400	204,600					45,000	1
	1989	5 / 12			18.80			237		20,800						44,900	4
gossen #2 adit	1980	5 / 16					20	10		3,830	155,000	<50				1,220	2
	1983	6 /		4	11			15		3,500	23,000					1,400	13
	1983	12 /		4	13			8		4,000	11,300					1,000	13
	1984	5 /		5	10			10		2,470	8,260					1,800	13
	1984	3 / 8						110		14,800	69,900					20,500	3

Table C-2. WATER QUALITY CHARACTERISTICS OF MINE DRAINAGE AND RECEIVING WATERS IN THE SHASTA DAM WATERSHED.

SAMPLE LOCATION	SAMPLE DATE YEAR	MONTH/DAY	E.C. (uS/cm)	pH	FLOW (l/s)	HARDNESS AS CACO3 (mg/l)	ARSENIC	CADMIUM	CHROMIUM	COPPER	IRON	LEAD	MERCURY	NICKEL	SILVER	ZINC	SOURCE
							TOTAL CONCENTRATION (UG/L)										
	1988	6 / 27		4				11		5,250	19,150					1,430	1
	1989	5 / 12			6.06			70		8,270						12,800	4
	1989	5 / 24		2.10				191		130,000						31,900	5
	1989	7 / 18		2				186		112,000						27,700	6
300 level adit	1983	6 /		2	0			460		35,000	511,000					66,200	13
	1983	12 /		2	0			400		47,400	500,000					66,000	13
	1984	5 /		2	0			500		53,800	870,000					83,800	13
	1988	6 / 27		2				1030		150,400	1,280,000					172,400	1
	1989	5 / 12			0.06			110		63,300						19,500	4
Friday-Lowden adit	1983	6 /		3	38			87		5,950	39,600					13,200	13
	1983	12 /		3	43			113		15,800	170,000					22,000	13
	1984	5 /		3	31			110		9,700	59,200					19,000	13
	1984	11 /		3	18			120		11,100	66,700					22,200	13
	1988	6 / 27		4				41		5,080	24,200					6,820	1
	1989	5 / 12			13.12			97		9,100						16,300	4
	1989	6 / 6						34		3,640						5,610	7
	1989	6 / 22						32		3,190						5,230	7
Little Backbone Creek below mine	1978	9 /		3						3,200						5,500	13
	1982	12 /		5				6		500						840	13
	1983	4 /		5				<2		180						250	13
	1983	6 /		5				9		310						410	13
	1983	12 /		5				<5		260						290	13
	1984	2 / 7						3		330						700	12
	1984	5 / 30		5				6		540						680	12
	1984	5 /		5				6		450						740	13
	1984	11 /		4				2		420						640	13
	1985	6 / 11		5				5		300						540	13
	1985	6 / 6						7		400						810	10
	1987	5 / 4						2		410						640	9
	1987	6 / 11						5		520						670	8
	1989	5 / 12			124.03			29		3,140						5,310	4

SOURCE:
3. Heiman, D. 1984. Data sheet from CH2MHILL Laboratory. 3-19-84.
4. Heiman, D. 1989. Little Backbone Creek Survey, 12 May 1989. Memo to J. Pedri, CVRWQCB, Redding, CA. 10-28-1989.
8. Heiman, D. 1987. Data sheet from CH2MHILL Laboratory. 7-13-87.
9. Heiman, D. 1985. Data sheet from CH2MHILL Laboratory. 7-5-85.
10. Heiman, D. 1985. Data sheet from CH2MHILL Laboratory. 4-5-85.
11. Heiman, D. 1984. Data sheet from CH2MHILL Laboratory. 6-21-84.
12. Heiman, D. 1984. Data sheet from CH2MHILL Laboratory. 2-21-84.
13. Heiman, D. 1991. Summary of water quality data. Data table from D. Heiman (CVRWQCB).

EARLY BIRD MINE

SAMPLE LOCATION	YEAR	MONTH/DAY	E.C. (uS/cm)	pH	FLOW (l/s)	HARDNESS AS CACO3 (mg/l)	ARSENIC	CADMIUM	CHROMIUM	COPPER	IRON	LEAD	MERCURY	NICKEL	SILVER	ZINC	SOURCE
main adit	1984	4 / 9		2.61	0.63			210		33,700	162,000					19,000	1
	1985	1 / 10			0.18			160		51,400						30,000	1
	1985	4 / 4			0.30					39,100						22,700	2
	1986	6 / 10		2.48	0.32			150		44,000						29,000	1
	1986	12 / 23						250		80,000						46,000	1
	1987	8 / 6			0.17			460		130,000						79,000	1
	1988	1 / 27		2.85	0.13			130		44,900						29,700	1
	1988	6 / 28		2.25				2,320		370,000	4,520,000					520,000	9

Table C-2. WATER QUALITY CHARACTERISTICS OF MINE DRAINAGE AND RECEIVING WATERS IN THE SHASTA DAM WATERSHED.

SAMPLE LOCATION	SAMPLE DATE YEAR	MONTH/DAY	E.C. (uS/cm)	pH	FLOW (l/s)	HARDNESS AS CACO3 (mg/l)	TOTAL CONCENTRATION (UG/L) ARSENIC	CADMIUM	CHROMIUM	COPPER	IRON	LEAD	MERCURY	NICKEL	SILVER	ZINC	SOURCE
	1988	7 / 30			0.13					299,300							1
	1988	9 / 7			0.13					212,000							1
	1988	11 / 1			0.13					164,300						396,000	1
	1989	3 / 13	2,390	2.81	0.16			200		14,400						47,100	4
	1989	4 / 9	1,830	2.61	0.16			171		26,800						28,700	3
	1989	4 / 28			0.13			480		55,000						118,000	5
	1989	5 / 4	4,100	2.46	0.13			499		60,200						114,000	3
	1989	5 / 31	4,090	2.24	0.13			640		67,400						147,000	6
	1989	7 / 9	4,620	2.24	0.06			532		75,800						115,000	7
	1989	7 / 31			0.07			549		73,200						124,000	8
	1989	9 / 1	4,580	2.51	0.05			539		76,600						120,000	10
	1989	10 / 2	5,000	2.16	0.05			502		69,200						110,000	11

SOURCE 1:CVRWQCB. Data sheet from the Redding office.
2:Heiman,D.1985.Water quality surveys-West Squaw Creek mines.CRWQCB.CVR Internal Memo.August 26.
3:Silver King Mine. 1989.Letter.From Silver King Mines.Salt Lake City.Utah to US EPA San Francisco,CA.and RWQCB.Redding,CA.June 5.
4:Silver King Mine. 1989.Letter.From Silver King Mines.Salt Lake City.Utah to US EPA San Francisco,CA.and RWQCB.Redding,CA.May 1.
5:Heiman,D.1989.Squaw Creek survey.28 April 1989.CRWQCB.CVR Internal Memo.September 13.
6:Silver King Mine. 1989.Letter.From Silver King Mines.Salt Lake City.Utah to US EPA San Francisco,CA.and RWQCB.Redding,CA.August 2.
7:Silver King Mine. 1989.Letter.From Silver King Mines.Salt Lake City.Utah to US EPA San Francisco,CA.and RWQCB.Redding,CA.August 22.
8:Silver King Mine. 1989.Letter.From Silver King Mines.Salt Lake City.Utah to US EPA San Francisco,CA.and RWQCB.Redding,CA.September 12.
9:Heiman, D. 1988. Data sheet. From CH2M HILL. July 28.
10:Silver King Mine. 1989.Letter.From Silver King Mines.Salt Lake City.Utah to US EPA San Francisco,CA.and RWQCB.Redding,CA.October 4.
11:Silver King Mine. 1989.Letter.From Silver King Mines.Salt Lake City.Utah to US EPA San Francisco,CA.and RWQCB.Redding,CA.November 22.

SHASTA KING MINE

SAMPLE LOCATION	YEAR	MONTH/DAY	E.C. (uS/cm)	pH	FLOW (l/s)	HARDNESS AS CACO3 (mg/l)	ARSENIC	CADMIUM	CHROMIUM	COPPER	IRON	LEAD	MERCURY	NICKEL	SILVER	ZINC	SOURCE
upper adit	1983	9 / 14		2.10	<0.30			520		100,000						90,800	1
	1984	1 / 4		2.40	0.60			147		28,000	223,000					27,000	1
lower adit	1978	12 / 19	2,600	2.20	<0.06			120		115,000						100,000	2
	1980	7 / 16			0.06			410		66,000						76,000	3
	1982	10 / 27	4,900	2.29	0.02			520		80,000	1,720,000					97,000	6
	1982	11 / 23	5,400	2.40	0.09			550		81,000	1,730,000					99,000	6
	1982	12 / 28	3,500	2.40	0.71		320	280	20	57,000	396,000	100			0	42,000	6
	1983	4 / 21	2,450	2.40	3.00			150		24,000	185,000					27,000	6
	1984	1 / 4		2.40	2.50			165		32,500						28,500	1
	1989	4 / 28			0.22			310		51,700						63,500	5
	1989	4 / 9	3,530	1.34	0.13			277		50,000						47,000	4
	1989	5 / 4	3,480	2.21	0.13			295		56,000						58,000	4
	1989	5 / 31	3,650	2.07	0.13			340		56,300						70,900	7
	1989	7 / 9	3,940	4.96	0.13			421		71,200						78,600	8
	1989	7 / 31	4,110	1.96	0.13			450		75,900						87,500	9
lower seep	1984	1 / 4		3.30	0.30			7		1,210						1,250	1

SOURCE 1:Heiman,D.1984.West Squaw Creek surveys-September 1983 and January 1984 CVRWQCB Internal Memo. February 15.
2:Smarkel,k.1979.West Squaw drainage inspection Shasta County.CVRWQCB Internal Memo.February 5.
3:Heiman,D.1980.Inspection,West Squaw Creeek/Balaklala,Silver King mines,Inc.,Shasta County CVRWQCB Internal Memo.September 2.
4:Silver King Mine. 1989.Letter.From Silver King Mines.Salt Lake City.Utah to US EPA San Francisco,CA.and RWQCB.Redding,CA.June 5.

Francisco,CA.and RWQCB.Redding,CA.June 5.

Table C-2. WATER QUALITY CHARACTERISTICS OF MINE DRAINAGE AND RECEIVING WATERS IN THE SHASTA DAM WATERSHED

5:Heiman,D.1989.Squaw Creek survey.28 April 1989.CRWQCB.CVR Internal Memo.September 13.
6:Department of Water Resouces Northern District.1983.Quantification of acid and heavy metal discharges from mine portals and dumps at Balaklala, Keystone and Shasta King mines.Report to WRCB.CVR.Interagency Agreement #2-092-158-0(DWR #163109).
7:Silver King Mine. 1989.Letter.From Silver King Mines.Salt Lake City.Utah to US EPA San Francisco,CA.and RWQCB.Redding,CA.August 2.
8:Silver King Mine. 1989.Letter.From Silver King Mines.Salt Lake City.Utah to US EPA San Francisco,CA.and RWQCB.Redding,CA.August 22.
9:Silver King Mine. 1989.Letter.From Silver King Mines.Salt Lake City.Utah to US EPA San Francisco,CA.and RWQCB.Redding,CA.September 12.

RISING STAR MINE

SAMPLE LOCATION	SAMPLE DATE YEAR	MONTH/DAY	E.C. (uS/cm)	pH	FLOW (l/s)	HARDNESS AS CACO3 (mg/l)	ARSENIC	CADMIUM	CHROMIUM	COPPER	IRON	LEAD	MERCURY	NICKEL	SILVER	ZINC	SOURCE
main adit	1979	1 /		2.80				180		3,200	93,700					32,500	3
	1979	3 / 9		3.10				510		19,000	173,000					69,000	2
	1979	5 / 2		3.00				300		6,100	116,000					44,500	1
	1979	9 /		2.80	0.50			360		8,200	34,800					53,900	3
	1979	12 /		2.80	0.90			190		4,500	144,300					38,100	3
	1980	2 /		2.70	1.80			390		18,800	131,000					55,000	3
	1980	4 /		2.70	1.60			260		5,200	43,000					43,700	3
	1980	6 /		2.80	1.10			210		3,800	58,000					39,600	3
	1980	8 /		2.90	1.10			170		2,700	89,100					35,000	3
	1980	12 /		3.20	0.80			140		2,900	142,000					34,800	3
	1981	2 /		3.40	2.60			240		7,700	153,000					45,200	3
	1989	7 / 20	1900	3.30	2.55		865	130	3	3,100		45	<0.2	12	<1	30,000	*
	1989	7 / 20	1900	3.30	2.78			157		3,100						32,000	#
	AVERAGE		1900	2.96	1.44		865	257	3	7,100	107,082	45	0	12	0	43,442	
seep near adit	1979	3 / 9		2.90				260		29,500						11,500	2
	1979	5 / 2		2.90													1
	AVERAGE																
Horse Crk upstream mine	1979	5 / 2		5.70				10		110						60	1
	AVERAGE			5.70				10		110						60	
Horse Crk downstream mine	1979	3 / 9		2.50				380		15,400						46,000	2
	1979	5 / 2		2.80				290		8,100						38,000	1
	1989	7 / 20	2000	2.70	3		4	210	3	6,300		38	<0.2	18	<1	36,000	*
	1989	7 / 20	2000	2.70	3.28			247		6,700						39,600	#
	AVERAGE		2000	2.67	3.39		4	293	3	9,933		38	0	18	0	40,000	

Source 1.Smarkel,K.1979.Bully Hill and Rissing Star mine sampling inspection,Shasta County.CVRWQCB Internal Memo.June 19.
2.Smarkel,K.1979.Bully Hill and Rissing Star mine sampling inspection,Shasta County.CVRWQCB Internal Memo.April 9.
3:CVRWQCB.Bully Hill and Rising Star mines.
*.This study. The concentration of arsenic is average of replicates(1400 and 330 ppb).
#.It is the exactly same sample with *, but tested by Heiman, D.

APPENDIX D
INDIVIDUAL MINE DESCRIPTIONS BY WATERSHED

The characteristics of each mine visited are described as to their potential for water quality degradation. Historical information concerning mineralogy and past ore processing operations were taken from Table IV-1. Water concentration data was reported from Appendix C tables. Sediment characteristics were described from Table IV-3 and are reported as dry weight. Many of the Shasta District mines were not visited but have been extensively characterized by Redding Office staff. Information on these mines were taken from historic files.

FOLSOM LAKE WATERSHED

Folsom Lake watershed mines are located in the foothills and were worked for their chromium, copper, and gold content. Although the mineralogy suggests otherwise, no deleterious discharges were observed from the mines visited. This is due, in part, to the dry nature of the area (ca 20 inches/year, Folsom Dam) and the relatively low elevation topography.

Alhambra: Not visited. The mine is in a prospect stage with proposed plans for reopening and discharges a small volume of arsenic laden water (Butz, pers. comm.).

Big Buzzard: The mine is located near the top of a gradually sloping hill several hundred feet above Folsom Lake. Two shafts were observed with dry side adits extending from just below the shaft openings. The waste rock was reactive (pH=3.5) and contained moderate lead (270 mg/kg) and copper (210 mg/kg) levels. The waste rock was confined to a small area and was only slightly eroded. Rainfall runoff from the site would flow diffusely over a grassy field into an undefined channel before reaching the lake.

Black Oak: The gold mine site was overgrown with brush and any waste rock present was indistinguishable from the natural landscape. The surrounding soil did not appear reactive. One adit and one shaft was observed though neither showed evidence of discharges.

El Dorado, Funnybug, and Georgia Slide: Not visited.

Lilyama: Located at the base of several large hills, the mine complex is made up of two completely caved adits and several more above the main workings. The caretaker said one mine provided drinking water up until three years prior to the drought (in 1986). The adits were observed to be dry at the time of inspection. The caretaker also stated the site milled chromite ore from the Pillikan Mine. The waste rock piles were located in an ephemeral gulch, about 0.25 mile from Hastings Creek and appeared to be only slightly reactive. The majority of the waste material was large chunks of non-friable country rock. A sedimentation pond had been constructed below the mine site in the ephemeral drainage-way, but was full of silt. Another tunnel, apparently drilled to convey water from the underground workings, was draining a small volume of neutral, clear, water directly into Hastings Creek.

Pillikan (areas 1-11): The chromite workings are located over several square miles of small knolls above Folsom Lake and consist of several shafts and open pits. No discharges were observed, although, several open pits contained, neutral, ponded water. The waste rock did not appear reactive.

BEAR RIVER/DRY CREEK

The Bear River/Dry Creek watersheds contain mines from both the foothill copper and foothill gold belts. The copper belt mines (Spenceville, Dairy Farm, and Valley View) are characterized by the extensive sulfides in their geological makeup that are highly similar in reactivity to the Shasta District mines. Precipitation in the area is somewhat limited (ca 21 inches/year, Marysville). This, in conjunction with the low surrounding topography in the copper belt areas results in low or zero volume discharges from these mines. The gold belt mines exhibit arsenic containing drainage corresponding, in part, to a high precipitation average (34 inches/year, Colfax).

Empire: Located on a local knoll, the gold mine is now a state park with some apparent, periodic seepage near Little Dry Creek (Waggoner, pers. comm.). On the north side, outside the park, an air shaft (memorial adit) discharges (6-10 l/s) slightly acidic waters containing low to moderate arsenic (2-92 ug/l) and zinc (<10-29 ug/l) concentrations. The waste rock at the site appeared non-reactive although several tailings ponds had, in the past, been removed from the site (ibid).

Idaho-Maryland: New urban developments in the area made the mine complex nearly indistinguishable, but an apparent waste rock disposal site tested neutral. Much of the site had been paved over with streets and commercial construction.

Lava Cap: Located on a hillside, the mine is composed of a shaft and extensive gold processing works. Clear, neutral, arseniferous water is discharged (5-6.3 l/s) from a caved adit which is directly connected to the shaft. Arsenic concentrations in shaft water (ca 200-400 ug/l) were reduced by about half after passing through extensive, neutral (pH=7.2) waste rock piles. The waste rock samples were analyzed differently than the other mines: HCl dissolution was employed to completely dissolve the material representing the absolute (mineral, labile) metallic concentration. As expected, the arsenic content of the waste rock was high (3.6 g/kg). Other metals were also present but cannot be compared to the other mines because of the differing method of analysis. Erosion and subsequent downstream siltation results from ephemeral area drainage that passes over a failing tailings dam. The site is under consideration for re-activation.

Spenceville: The complex is composed of an extensive waste rock pile and a deep (ca 70 feet) pit filled with acidic water (pH ca 2.5). The mine is situated immediately adjacent the confluence of Little Dry Creek and Dry Creek. Much of the runoff water from the waste rock is diverted to the pit. Seepage to Little Dry Creek occurs resulting in high copper (64-500 ug/l), zinc (140-930 ug/l) and possibly cadmium (<1-0.7 ug/l) concentrations. Runoff from a portion of the site and pit overflow can make it directly to the stream during storm events. The acidic waste rock (pH=3.0) contained moderate copper (277 mg/kg), lead (152 mg/kg), and zinc (148 mg/kg) levels and high silver levels (23.5 mg/kg).

Dairy Farm: The polymetallic mine was worked for it's gold, copper, and silver using underground and open pit mining techniques. The mine is located on (and below) the shore of Camp Far West Reservoir. The site once contained cyanide leachate basins and tailings pits, and is presently composed of imported soils covering most of the site with a small amount of highly acidic (pH=2.7) exposed soils containing high copper (1350 mg/kg), lead (370 mg/kg), zinc (455 mg/kg), and silver (14.5 mg/kg) levels. California Fish and Game staff (Jack Linn) have observed an adit, uncovered when lake levels receded in the 1990 dry season, although no discharge was observed from it.

Valley View: The mine was worked for it's copper, gold, and silver from at least two shafts. A glory hole with a connected adit discharged a small volume (0.11 l/s) of highly acidic water from the the base of several small hills. The mine outflow (0.11 l/s) was highly acidic and contained very high levels of cadmium (4.5-6.5 mg/l), copper (97-150 mg/l), and zinc (230-260 mg/l) and high levels of arsenic (<200-150 ug/l), chromium (130-210 ug/l), nickel (540-760 ug/l), and lead (<50-78 ug/l). The drainage courses over a graded waste rock pile and into an irrigation watercouse that flows past the site and to the surrounding ranchlands. Most of the irrigation/mine water is pumped out of the channel before going very far. A clean spring also passes over the waste rock dumps and disappears underground. Exposed waste rock was observed at several locations on the site. The waste rock was acidic (pH=2.7) and contained moderate to high levels of cadmium (246 mg/kg), copper (390 mg/kg), lead (189 mg/kg), zinc (480 mg/kg), and silver (9 mg/kg).

YUBA RIVER

With a few exceptions, the mines in the Yuba River watershed (Allegheny/Downieville District) were worked for their gold content and are characterized by, alkaline, arsenic containing drainage. Gold deposits are closely associated with arsenopyrite (FeAsS2) which is the perceived source of arsenic in drainage that is very clear visibly. The general area receives high precipitation (67 inches/year, Downieville) and, subsequently, several of the mines have large volume discharges.

Banner: Not visited.

Champion: Located adjacent Deer Creek, the mine complex was difficult to distinguish because of recent urban developments, but perceived drainage was sampled and contained a few metals at just above detection.

San Juan: The area was very overgrown with brush and the mine site (waste rock, shaft, structures) could not be distinguished.

Spanish: Over four adits were observed near the site but the size of the complex extended throughout the watershed. Two adits are known to be discharging low to moderately acidic water containing moderate to high levels of copper (210-900 ug/l), lead (20-110 ug/l), zinc (1900-2300 ug/l), nickel (70-160 ug/l), and cadmium (3.7-7.1 ug/l). The upper adit discharges to Devels Canyon creek approximately 2-3 miles from Poorman Creek and contains high copper levels (80-900 ppb) among other metals. The lower adit (called 16 to 1) discharges over a vegetated waste rock pile for about 60 feet prior to entering Poorman Creek. Waste rock at the lower complex was deposited on the steep slope directly below the adit and into Poorman Creek. The waste rock was slightly acidic (pH=5.1) and contained moderate copper (330 mg/kg), zinc (130 mg/kg), and arsenic (340 mg/kg) levels. The mine is under county reclamation for a barite pit and there is some exploration in progress for potential re-activation of the mine.

Brush Creek: Located at the base of a mountainside the gold mine discharges above neutral water that is visibly clear with moderate (32-81 ug/l) to high (180-270 ug/l) arsenic levels from the upper an main adits, respectively, and moderate nickel levels (110-290 ug/l). The high volume of alkaline drainage from the main adit (ca 27 l/s) had been diverted from Woodruff Creek to holding ponds (Higgins, pers. comm.) resulting in a lower Woodruff Creek arsenic concentration during the later sampling runs. Waste rock was visibly non-friable and non-acid generating and had been deposited into the Woodruff Creek streambed composing a portion of the stream bank. The site is regulated under NPDES and TPCA permits and is being considered for re-activation (ibid).

Columbo: The gold mine is located near the base of a large mountain and 900-1000 feet from the Valley floor. The drainage water was clear and near neutral with a few metals at just above detection limits. Extensive waste rock piles appeared non-reactive. Several rusting gold leaching basins were scattered around the area.

Kanaka Creek mines: According to U.S.FS staff there are over 140 known mine sites in the Kanaka Creek watershed (Daniels, pers. comm.) including, Sixteen-to-one and Kenton. Although not all of the mines have a discharge, Kanaka Creek at it's confluence with the Yuba River, Middle Fork, provides the most accurate loading estimate from the sum of

all the mines. Kanaka Creek arsenic levels ranged from 18 to 25 ug/l, diluting to below detection in the M.F. Yuba.
Kenton: The mine is located at the base of a mountainside and in the Kanaka Creek watershed. No discharge was observed but the mine has been known to discharge at other times (Daniels, pers. comm.). An extensive number of waste rock piles were spread over the steep terrain down to the Kanaka Creek streambank and were non-reactive (pH=7.3).
Malakoff Diggin's: The mine complex consists of several large hydro-stripped hillsides that have been preserved in the Malakoff Diggin's state park. Water from one exposed depression drains a large volume of water (17-26 l/s) that flows through the Hiller Tunnel that was once used to collect gold in sluice-box fashion and contains nominal levels of nickel (9-80 ug/l) and zinc (24-90 ug/l). The major threat to water quality would appear to be erosional discharges to Humbug Creek during rainfall events. The soils collected from the site contained low levels of all metals and were moderately acidic (pH=4.5). The state park is under permit not to prevent vegetation of the hillside scars and are required to conduct water quality monitoring (Waggoner, pers. comm.).
Pick and Shovel: Located directly adjacent Pats Gulch, the moderate discharge (1-3 l/s) is slightly acidic (pH=6.28-6.75), contains moderate levels of nickel (93-180 ug/l), and causes heavy iron mineralization in the streambed of Pats Gulch directly downstream the mine. The discharge makes up most of the flow (in Pats Creek) below the mine but metal levels are undetectable and iron staining is not present at it's confluence with Slate Creek (ca 1 mile below the mine). No buildup of waste rock was observed at the mine site.
Plumbago: The gold mine is located at the base of a large mountainside and discharges a high volume (2-4 l/s) of above neutral water containing high arsenic levels (85-370 ug/l). Waste rock was alkaline and extensive over the steep terrain and made up the shoreline of Buckeye Ravine for several hundred feet. Mercury was the only metal analyzed and was present at 1.8 mg/kg. Ore processing equipment was present at the mine including rock crushing and milling machines and several mercury amalgamation shaker tables.
Sierra Buttes, Sierra Homestake: Not Visited.
Sixteen-to-one: Not visited although extensive information exists on the mine. The gold mine is periodically active and regulated under an NPDES permit. An arsenic laden discharge drains to Kanaka Creek (Daniels, pers. comm.).
Zuver: The mine adit was dry with no evidence of discharge and waste rock was indistinguishable from the surrounding landscape.

FEATHER RIVER WATERSHED

With the exception of Walker and Lucky S, the mines observed in this watershed do not discharge adit drainage although the waste rock piles were potential sources of metals. Although these mines are generally located in a copper produding belt, many of them were also worked for their gold and silver. The precipitation in the area varies from 26 inches/year (chico) to 40 inches/year (Quincy).
Big Bend: Not visited.
Beardsley: One main shaft and several shallow exploratory adits were observed around the complex. Located at the base of a mountain, there was no evidence of any adit or shaft discharges. Cement foundations were all that remained of what likely was an ore processing facility. Waste rock was moderately acidic (pH=4.4) and contained high levels of copper (16 g/kg) and lead (2.7 g/kg) and low to moderate levels of other compounds. The waste rock was composed of hard chunks of non-friable country rock. The ephemeral drainage route coursed through a meadow and a moderate sloped gulch before reaching Hosselkus Creek (perennial).
China Gulch: Not visited.
Iron-Dyke: This polymetallic mine was located at the base of a large mountain directly atop Taylors Creek. No water discharges were observed from an adit situated at the lowest elevated position in the complex. Waste rock had covered the Taylors Creek streambed which disappeared underneath the pile, re-appearing 70 feet later. Although the waste rock was somewhat acidic (pH=3.4), the pH of the downstream water tested unchanged after passing through the pile. However, the stream did pick up copper (21 ug/l), zinc (18 ug/l), and possibly cadmium (0.5 ug/l) with a corresponding reduction in the conductivity, indicating that unsaturated leaching occurs without any noticeable acid production. The waste rock contained high copper (1600 mg/kg) and silver (29 mg/kg) levels and moderate zinc (270 mg/kg) and lead (63 mg/kg) levels.
Lucky S: Located near 7,000 feet MSL, the main adit discharges a high volume (3.22-4.06 l/s) of slightly acidic water (pH 6.04-6.54) but contains moderate levels of cadmium (2.5-2.9 ug/l), copper (63-80 ug/l), and zinc (260-335 ug/l). Furthermore, although there was an apparent high iron level, no iron precipitates existed in the adit drainage or in Peters Creek below the adit. The waste rock was acidic (pH=2.7) and reflected the metals in mineralogical surveys (high arsenic, zinc, and lead), however, stream and ponded water below the waste rock was only slightly acidic. The waste rock appeared non-friable and remained as extracted grade in the unprocessed form. A series of ponds composed of earth and waste rock were crudely constructed below the site of most waste rock deposition.
Mountain Meadows: Located at the foot of a small mountain, the two observed adits were dry with no evidence of past adit discharges. Waste rock appeared non-reactive, non-friable, composed mostly of large country rock fragments. The

site was located on the side of steep, rocky, mountainous slopes. Not much waste rock was observed at either of the individual sites, although, the lower adit was directly adjacent Mt. Meadows Creek which likely served to transport sediment off-site during high flows. Metals were not analyzed.

Plumas-Eureka: The high elevation (6,500-10,000 feet MSL) gold mine is maintained as an historical state park. According to a ranger, there are an uncounted number of adits both inside and outside the Jamison Creek watershed - there are likely as many waste rock piles. According to a local fisherman, the Jamison Mine portion was the largest and most recently operated mine (1890-1940) in the complex. A flooded, caved, water shaft from the Jamison Mine portion was sampled and although it contained several metals at just the detection limits, the levels in the immediate receiving waters (Jamison Creek) below the suspected discharge point were below detection. Although the waste rock was not chemically characterized, the observed piles appeared to be composed of stable country rock, not prone to leaching and oxidation processes. Characterization of the volume of waste rock would be difficult because of the numerous prospects around the High Sierra Valley.

Reward #7: This copper/gold mine consists of several dry adits (some only partially completed in recent times [after 1960]) with no evidence of past adit discharges. Although the waste rock piles are extensive, they were composed largely of non-reactive (pH=7.4) rock fragments. Although a very high level of arsenic was measured in Ward Creek (130 ug/l) below the mine, a followup survey indicated that it was likely an artifact of the laboratory.

Superior-Engle: The once large mine is located at the base of a mountainside with extensive waste rock piles extending about 100-200 feet down a steep slope, composing a portion of the shoreline of Lights Creek. There were several adits located at the top of the waste rock pile but none showed evidence of discharges. The Superior Mine portion was not visited but watercourses above and below the area were sampled. The waste rock tested neutral (pH=7.0) with high copper (6550 mg/kg) and silver (15.8 mg/kg) levels and moderate zinc levels (165 mg/kg). Other offsite locations contained extensive, unvegitated, tailings piles (similar to Walker Mine tailings piles) but were not sampled.

Walker: The copper mine workings are located at the base of a mountain with a single discharging adit. The adit has been successfully plugged, reducing the copper loads by 98.2% (Croyle, pers. comm.). The present copper concentration (220-450 ug/l) in the discharge is a result of residual copper precipitates in the groundwater conveyance structure and is not a result of plug leakage (ibid). Waste rock piles remain moderately acidic (pH=4.1-4.8) and were composed of moderate to high levels of copper (790-2000 mg/kg), lead (43-70 mg/kg), and silver (5.9-16 mg/kg). Waste rock at the site varies from coarse rock fragments to tailings which were deposited into Little Grizzly Creek downstream from Dollie Creek.

BUTTE CREEK

Mineral Slide: Not visited.

PIT RIVER

Golden Eagle: The gold mine workings are composed of numerous open pit excavations and shafts spread around a large hill (Hayden Hill). The landscape is dry sagebrush with no discernable watercourse from the mine. Although there was ponded water in a man-made dam below the only observed adit, the water was near-neutral and contained nominal metals levels. The waste rock tested alkaline (pH=7.8) and appeared to be composed of earthen material (dirt). Even though the land had been extensively surface excavated, the low rainfall (ca 12.5 inches/year, Alturas) and lack of a nearby receiving water indicates a low threat from erosional processes.

SHASTA LAKE

The polymetallic mines in the Shasta Lake watershed are well known for their acidic drainage containing high concentrations of copper, cadmium, and zinc. Mine drainage in the area is a result of the extensive past underground mining activity that tapped into the massive pyrite formations. The streams carrying the drainage to the Lake are virtually devoid of aquatic life and trout kills at their confluence have been common occurrences. Several mines clustered in the West Shasta Mining District drain to West Squaw Creek and Little Backbone Creek. Two other discharging mines (Rising Star and Bully Hill) are located in the Eastern Shasta Mining District. Extensive monitoring data exists for these mines as conducted over the last 10 years by the Redding Office and, therefore, they were not visited for this study. Several abatement projects have been completed or are in progress at most sites. The rainfall in this area is high, averaging around 40-75 inches/year at Redding.

Balaklala, Keystone, Shasta King, Early Bird: Not visited but extensive information exists on these mines which are located within close proximity to each other. Acidic water with very high levels of cadmium, zinc, copper, and sometimes lead discharge from each mine. Discharges from 2 of Balaklala's adits flow over waste rock piles to West Squaw Creek. The Keystone Mine has one main discharging adit. Several of the mines have had their adits plugged in the past 10 years resulting in significant load reductions.

Bully Hill: This mine was operated on and off from 1860 to 1956 (U.S.GS, 1974) to extract silver, gold, copper, and zinc and contains one caved, discharging adit. The acidic drainage (pH 3.0-5.2) contains high cadmium (120-450 ug/l), copper (1.35 -10.9 mg/l), lead (10-600 ug/l), and zinc (9.4-24.4 mg/l) levels. The drainage courses over waste rock into adjacent Town Creek which continues to flow through a waste rock streambed and disappears under a large, filled, tailings reservoir. The water emanates again from below the tailings dam below the high waterline of the lake. The waste rock was reactive and contained high levels of copper (3005 mg/kg), lead (1620 mg/kg), and zinc (2975 mg/kg), and arsenic (690 mg/kg). The reactive waste rock is extensive and is assumed to be highly variable due to the smelters and flotation process plants that operated at various locations on the site.

Castella: Only a chromite processing complex existed here which serviced several mines in the area. The complex owner donated the land to the state (Castle Crags State Park) and, according to a ranger, the tailings piles were removed and the complex was revegatated and built over. A few dry adits were observed but none with any noticeable waste rock. The stream draining the area (Indian Creek) showed less than detectable metals.

Coggins: The chromite mine was located on the side of a steep mountain about 200-400 feet above the Castle Creek drainage. The one caved adit found showed no evidence of discharge and the waste rock piles consisting of crushed rock were non-reactive (pH=7). A portion of the waste rock appeared to have been planted with pines that were estimated at 15-20 years old.

Early Bird: Not visited but extensive information exists on this mine which is one of several mines located in the West Squaw Creek drainage. Low flows (0.05-0.63 l/s) discharge an acidic matrix with high copper (14-370 mg/l), zinc (19-520 mg/l), and cadmium (0.1-2.3 mg/l) concentrations.

Forest Queen: Three dry adits were observed at this chromite mine located on the top of a large mountain ridge. Waste rock was composed mainly of large crushed rock fragments that tested near neutral (pH=6.5) and contained high chromium (2.5 g/kg) and nickel (1.6 g/kg) levels. The mine was on a very steep slope several thousand feet above the nearest watercourse.

Golinsky: The mine is located near the top of a steep hill several hundred feet from the Lake shore. Past data shows acidic discharges containing high copper (7.95-17.6 mg/l), cadmium (223-1,510 ug/l), and zinc (20.6-78.0 mg/l) levels. The waste rock was extensive and slightly acidic (pH=6.1). Although the mineralogy information suggests otherwise, the waste rock appeared stable and was, therefore, not analyzed for metals.

Mammoth: Not visited but extensive information exists on the mine. The complex contains several adits discharging high copper (0.9-130 mg/l), zinc (1-172 mg/l), and cadmium (8-1000 ug/l) levels directly to Little Backbone Creek and Shoemaker Gulch. Adit plugging operations have been ongoing since 1981.

Rising Star: The mine is located on the other side of the hill from Bully Hill Mine and contains one main discharging adit that drains over waste rock to an ephemeral stream called Horse Creek. The acidic drainage contains high copper (3-19 mg/l), cadmium (140-510 ug/l), zinc (32-69 mg/l), and lead (45 ug/l) levels. The water flows several hundred feet before entering Shasta Lake. Extensive, reactive waste rock surrounds the mine complex positioned on steeply graded slopes. Waste rock was acidic (pH=2.8) and contained high arsenic (625 mg/kg), copper (1350 mg/kg), zinc (3500), and lead (105 mg/kg) levels.

Shasta King: Not visited but extensive data exists on the mine. The mine has 2 adits discharging low pH water with high cadmium (147-550 ug/l), copper (28-115 mg/l), zinc (27-100 mg/l), lead (100 ug/l) and arsenic (350 ug/l) levels. The water drains over waste rock piles to West Squaw Creek.

Sutro: Not visited but discharges coming from the site contain relatively moderate concentrations of cadmium (<5-20 ug/l), copper (<10-1,420 ug/l), and zinc (90-2,100 ug/l). The discharge drains to Little Backbone Creek.

SACRAMENTO RIVER, UPPER

The upper Sacramento River Watershed includes several mines with a wide range of extraction products (copper, zinc, silver, chromite, and gold), the largest of which is Iron Mt. mine. Several of the polymetallic mines that produce typical acid mine drainage (Afterthought, Iron Mt., Greenhorn, Stowell) have extensive monitoring databases. Abatement action at many of these mines has been ongoing for over 10 years. Rainfall in the area is moderate (ca 22 inches/year, Red Bluff) to high (40-80 inches/year, Redding).

Afterthought: The mine is located at the base of a mountain with several adits, shafts, and site locations. The main adit is the primary source of acid drainage and contains high levels of cadmium (0.3-1.23 mg/l), copper (10.6-48.9 mg/l), zinc (83.6-313 mg/l), lead (91 ug/l), and moderate levels of arsenic (125 ug/l) and nickel (32 ug/l). Adit discharges flow over waste rock directly into Little Cow Creek. The waste rock tested moderately acidic (pH=4.7) with high levels of copper (1090 mg/kg), lead (4000 mg/kg), zinc (4300 mg/kg), silver (28 mg/kg), and arsenic (500 mg/kg). The waste rock was extensive and composed several hundred feet of the Little Cow Creek streambank. **Gladstone:** The gold mine was located at the base of a large hill with a seep discharging neutral, clear water (Heiman, pers. comm.). The waste rock was extensive, slightly acidic (pH=5.1), and composed mostly of country rock fragments containing and moderate copper (179 mg/kg) and zinc (140 mg/kg) levels and high lead (76 mg/kg) and arsenic (800 mg/kg) levels. Cline Creek below the mine showed arsenic was present at 25 ug/l although any potential inputs were not bracketed.

Greenhorn: The mine complex contains an open pit area at the top of a large hill with several discharges at the hill's base which drain directly to Willow Creek and vary in pH (2.3-5.87) and metals content. The north adit discharge contains the highest levels of copper (61-138 mg/l), zinc (78-180 mg/l), cadmium (645-1510 ug/l), and moderate nickel (61-190 ug/l) and arsenic (39-170 ug/l) levels. Waste rock piles exist at both the upper and lower areas with a high erosion potential because of the steeply sloped terrain (60-80 degrees). The waste rock was extensively eroded and composed a portion of the Willow Creek stream bank. The moderately acidic waste rock (pH=3.8) was collected from the upper workings and contained only moderate levels of copper and zinc.

Iron Mt.: Not visited but extensive information exists on the mine. The complex is a major source of copper, zinc, cadmium to the Sacramento River and is presently under-going a variety of abatement measures including superfund (CERCLA) remediation (Heiman, pers. comm.). Several adits discharge highly acidic water with elevated levels of metals to Spring Creek. Spring Creek flows into Spring Creek Debris Dam (SCDD) and then to Keswick reservoir. Because of the many on-site discharges, concentrations were tabulated (and loads were calculated) at the point where Spring Creek enters the Sacramento River. One waste rock sample was collected at the ore loading site adjacent the Sacramento River above the confluence of Spring Creek. The waste rock material was highly acidic (pH=1.9) and contained moderate copper (480 mg/kg) and zinc (580 mg/kg) levels. The material appears to be a product of the beneficiation process and does not represent the characteristics of the other diverse waste rock piles.

JCL: Not visited.

Midas: The gold mine was located in a valley adjacent Harrison Creek. One shaft was seen but no discharges were observed. Water in Harrison Creek below the mine contained arsenic at slightly higher levels (4 ug/l) than water collected upstream the mine (<1 ug/l). The alkaline (pH=8) waste rock had been deposited on the hillside down to Harrison Creek and up in the surrounding hillsides on either side of the Creek.

Round Bottom: The chromite mine was located in a steeply sloped valley and contained an apparent caved adit which was seeping neutral neutral water with low nickel (54 ug/l) and cadmium (1.2 ug/l) levels. The seep disappeared into the ground several feet from the source. Waste rock was alkaline (pH=7.6) and vegetated to some extent.

Silver Falls: The silver mine was located at the base of a hill range in an ephemeral canyon and contained an adit with near-neutral, ponded water with near detection levels of metals. The waste rock was also near neutral (pH=6.7) and located approximately one-fourth mile from Andrews Creek.

Stowell: This site was not visited but extensive information exists on the mine. Located above Iron Mt. Mine in the Spring Creek watershed, it contributes around 1 percent of the total loads estimated to come from Spring Creek Debris Dam (Heiman, pers. comm.). Abatement projects are ongoing.

Thompson: The copper mine site was located in a flat watershed adjacent an ephemeral stream. There was some ponded water in the location of the shaft with nominal concentrations of analyzed metals. The soil material that appeared to be waste rock was moderately acidic (pH=3.9) and high copper (940 mg/kg) and moderate zinc (260 mg/kg) levels. The waste rock was graded flat around the caved shaft and made up a short length of the dry stream bank.

White Star: This silver mine was not visited.

Yankee John: This gold mine contained a single adit and shaft with no evidence of discharges to the nearby ephemeral stream. Waste rock tested neutral (pH=7.3) and appeared to be composed of non-friable, stable rock particles that were distributed over a large area.

STONY/ELDER CREEK

These chromite mines are located in a dry, steeply sloped watershed in the rainshadow effect of the western valley foothills. Many of the mines showed evidence of open pit excavations and all contained extensive, non-reactive, waste rock. The extensive surface extraction operations have resulted in massively scarred hillsides with a high potential for erosion. The landscape supports dry xeric vegitation with rainfall at Willows averaging around 16 inches/year.

Black Diamond: This chromite mine was located near the top of a mountain just above Grey Eagle Mine and was composed of an exposed open pit with waste rock that appeared non-reactive.

Grey Eagle: This large chromite mine consisted of an extensive open surface excavation operation with several observed adits. One large pond below the main adit was alkaline with just above detection levels of zinc and chromite. The very extensive waste rock piles that exist at the mine site were alkaline (pH=8.7) and spread into several steeply sloped, dry, canyons. Extracted ore was transported off-site via an aerial tramway.

Noble Electric: The mine extended over a large area on the side of a steeply sloped canyon wall. Neutral seepage from the area showed mostly non-detectable metal levels. Similar results were found in Elder Creek below the mine. The high EC in Elder Creek is apparently due to salt springs observed in the area (CSMB, 1916). Extensive erosion events are apparently occuring during rainy period. Much of the waste rock and erosional material had been carried down to the streamside. Waste rock tested alkaline (pH=8.7) with high nickel (2400 mg/kg) and chromium (400 mg/kg) levels. Some rock crushing equipment was observed at the site.

Grau: This chromite mine is located upstream the Noble Electric mine and exhibits similar erosional potential. No discharged was observed. Waste rock tested alkaline (pH=8.8).

CACHE CREEK WATERSHED

Mercury mines in the Cache Creek watershed all processed cinnabar ore at the site of extration using furnace/condensation equipment. The area is moderately wet (ca 27 inches/year, Lakeport) to dry (ca 15 inches/year, Williams). Most of the mines employed both underground and surface mining techniques. Several of the mines are eventually drained by Sulphur Creek which is largely ephemeral. Downstream of the Sulphur Creek mines, multi-colored seeps initiate stream flow which contains an extremely high salt content (EC > 10 mS/cm), occluding the detection of specific metals.

Central: One of five mines located in the Sulphur Creek valley. The mine site is characterized by a few buildings - any shaft or waste rock could not be distinguished from the surrounding vegetated landscape.

Elgin: Not visited.

Empire: Located in the Sulphur Creek valley, one dry adit and a large glory hole are present at the complex which was situated on the side of a large hill. The adit showed no evidence of any past discharges and the vegetated waste rock tested neutral (pH=7.2).

Manzanita: The mine is located in the Sulphur Creek valley with a combination of surface and underground mining scars. No evidence of a discharge was observed and the waste rock was, at places, indistinguishable from disturbed surface soils. The waste rock collected was alkaline (pH=7.9) with a high mercury content (785 mg/kg) and low levels of other metals.

Wide Awake: The mine consisted of several dry adits situated on a hillside located 100 feet above an ephemeral, erosion prone, gully. The waste rock was alkaline (pH=7.5) and containd a moderate concentration of mercury (13 mg/kg). The mine site included a very large furnace which apparently serviced other Sulphur Creek valley mines.

Abbott: Located on the side of a large and steep hillside, the mine workings consist of a shaft, surface mining scars, and furnace/condensation equipment. There was no history or evidence of discharges but the waste rock piles were extensive, extending 100-200 feet from the complex to the bottom of the Grizzly Gulch. The waste rock tested alkaline (pH=7.9) and contained a high mercury level (910 mg/kg).

Sulphur Bank: Not visited but extensive information exists on this mine. The mine is an open pit excavation covering approximately 2 acres directly adjacent Clear Lake. It was mined for mercury, sulfur, and borax. There is a large pit (Herman Pit) filled with low pH water (<3.0). Runoff from the site and erosion from a portion of the shoreline made up of tailings contributes to the lake's mercury loads (Walker, pers. comm.). There is a CDHS Health Advisory in effect for the lake against eating mercury tainted fish. The site is under consideration for various cleanup schemes.

Harrison: Not visited.

Reed: The mine site contains an adit located at the base of a large hill and at one time discharged a small volume (ca. 0.32 l/s) of slightly acidic water containing high nickel levels (1200 ug/l), moderate arsenic levels (59 ug/l), and low chromium (46 ug/l) and zinc (20 ug/l) levels. The adit discharges directly into Davis Creek above Davis Creek Reservoir and has caused, in the past, extensive iron floc buildup. The mine adit was plugged during this study reducing the discharge to a seep. Waste rock piles were deposited on the steeply sloped hillside and extend down to Davis Creek where it forms the streambank for several hundred feet. The waste rock was moderately acidic (pH=3.8) and contained high nickel (870 mg/kg) and chromium (440 mg/kg) levels, although halfway through this study, the waste rock was covered with imported soil and vegetated with barley. The mine site contained a rotary furnace and vapor condensation equipment. The study and reclamation of the mine site is conducted by a nearby active mining firm responsible for maintaining the quality of Davis Creek and Davis Creek Reservoir (Walker, pers. comm.).

Turkey Run: The small mine is located at the base of a large hill next to Abbott mine and a single adit discharges alkaline water with a nominal chromium concentration. Waste rock was extensive, composing the streambed of the gully draining the adit. The waste rock characteristics are probably similar to those at the Abbott mine due to their close proximity.

LAKE BERRYESSA/POPE CREEK

The James Creek watershed (a tributary of Pope Creek) remains impacted from several mercury mines located in the same watershed. Impacts occur from adit discharges, erosion, and mercury inputs into the food chain. James Creek is coated with an orange gelatinous floc extending up to 2 miles from Corona mine. The potential from erosion in the watershed is great due to past surface extraction operations, waste rock dumps, and the steep nature of the slopes. Because of the high content of cinnabar deposited in James Creek from the surrounding mines, the creek itself once supported a gravel washing operation during the early 1960's. Much of the historical information on these mines was recounted from Anthony A. Cerar, a past employee of several of the mining operations in the valley.

Corona: The mine complex contains an upper and lower workings which include several adits and a water release tunnel. The road from Oat Hill Mine was completed in 1894 with startup occuring soon after. In 1905-07 water from an uphill spring began infiltrating and flooding the mine tunnels. Mining was started in 1913 at the upper site and is located about

250 feet from the lower site. The lower site is about 500-600 feet above James Creek on a steeply sloped hillside. During 1925-27 a water release tunnel was blasted 1500 horizontal feet to the ledge of the main tunnel complex. The tunnel release is located directly adjacent to James Creek. The only other discharge comes from an adit at the lower site which was discharging only a seep although past monitoring and downstream iron staining indicated discharges could be substantial. The water release tunnel discharged the highest flows (3-21 l/s) which contained very high nickel (6-12 mg/l) and iron (150-620 mg/l) concentrations and high zinc (100-260 ug/l) levels. The high nickel content can be explained by mineralogical assays identifying nickel sulfide in approximately 5 percent of the surrounding orebody (CSMB, 1915). Secondary mineral formation at the adit release (prior to discharge to James Creek) was identified as iron oxide (HFeO2, FeO3) by the Sacramento Office of Mines and Geology (Walker, Pers. comm.). Waste rock piles were extensive around the site and were deeply gullied from upstream runoff. The waste rock was acidic (pH=2.6) and contained high mercury levels (1.37 g/kg) with low to moderate levels of other metals. Several mercury extraction operations were conducted on-site. A recent fish survey reported both trout and suckers as present inhabitants of the stream in the impacted area.

Twin Peaks: The mine became active in 1911 and at one time operated a rock crushing mill and a pipe furnace. The site is situated approximately 600 feet above Bateman Creek on a steep (ca 60 degrees) slope. Only one of the two adits that were drilled maintains a small discharge (0.2-0.3 l/s) containing high nickel (1.6-2 mg/l) and iron (14-16 mg/l) concentrations. The water was moderately acidic (pH=5-6) and flowed directly over a highly eroded waste rock pile. The waste rock was slightly acidic (pH=5.9) and contained low to moderate levels of all metals.

Oat Hill: This was the fifth largest mercury mine in the world at one time and produced over 800,000 flasks in its lifetime. Several adits were tunnelled starting in 1876 and during the mercury price rise (late 1950's), open pit mining techniques were used at several locations in the Valley's hillsides. No discharges were observed, although, seepage or releases had been observed at the base of the hill. Exposed soils and waste rock was slightly acidic (pH=5.8) and contained a high mercury content (590 mg/kg). No other compounds were analyzed.

Oat Hill Extension: The mine site once processed ore from other mines around the valley and consisted of a large vegetated waste rock pile and a large processing facility. The site was not sampled.

Aetna: The site is composed of several dry adits tunnelled into the side of a glory hole. The glory hole was highly eroded but the waste rock piles were apparently deposited in areas of housing construction. The waste rock was moderately acidic (pH=4.5) with a high mercury content (620 mg/kg) and low levels of several other compounds.

Aetna Extension: The mine is located above James Creek on the opposite side of the hill as the Aetna Mine. Several, dry, caved adits were observed among disturbed soils and waste rock which was largely vegetated. Several exposed waste rock piles tested alkaline (pH=7.6) and contained a relatively low mercury content (6.8 mg/kg). No other compounds were analyzed.

Grenada: The small site was located approximately 400 feet above James creek in moderately sloped terrain (40-60 degree incline). No mercury was ever produced from the tunnel which discharged a clear seep. The surrounding waste rock was alkaline (pH=7.9) and deeply gullied from upstream runoff in the ephemeral watercourse.

Toyon: The mine was located about 250 feet above the Grenada mine in a small, steeply sloped canyon. The small mine site apparently produced only 200 flasks in it's lifetime. The site contained a caved adit with a slight, clear seep and a smal brick retort. The alkaline waste rock (pH=8.2) contained moderately high mercury levels (86 mg/kg).

LAKE BERRYESSA/PUTAH CREEK WATERSHED

With the exception of Copper Prince Mine (a copper mine), the mines in this watershed were mined for their mercury containing ores. Precipitation in the area can be variable (ca 41 inches/year, Middletown). Most of the mines had no perennial discharge. Cinnabar extraction equipment was present or reported at all mercury mines in this watershed.

Anderson: Located near the town of Anderson Springs, the mine contains 2 known adits discharging near-neutral water with moderate to high levels of nickel (10-240 ug/l) and zinc (17-260 ug/l) and low levels of copper, chromium, and arsenic. Anderson Springs Creek water below the mine showed mostly below detection levels of these compounds. The west adit discharged water exhibiting reducing conditions (Eh=-65 to -105 mV). However, those reducing conditins only slightly affected the immediate downstream receiving water redox conditions. The extent of the waste rock piles appeared minimal and appeared non-reactive.

Big Chief: Located just above the Anderson Mine approximately 300-400 feet from Anderson Springs Creek, the site contained 2 dry adits. Waste rock was acidic (pH=2.5) and contained low levels of all metals analyzed with the exception of mercury (840 mg/kg).

Big Injun: No evidence of the mine workings exist since a-geothermal power generation plant was built over the site (Daniels, pers. comm.).

Copper Prince: Not visited.

Great Western: Extensive surface and underground operations occurred in two watersheds - the "new" mine was inspected for this study. A single adit discharging alkaline water contained nominal nickel, zinc, and chromium levels. Waste rock tested alkaline and was deposited at several locations around the watershed. St. Marys Creek below the mine site was alkaline with variable nickel levels (<5-120 ug/l). Extraction operations were extensive at the mine site according to observations and historical records.

Knoxville: The mercury mine was located in a flat valley with a single observed shaft and a tailings dam. No discharge was observed. The tailings dam contained dry, red, "soils", similar to dry ferric hydroxide and was fully contained within the dam structure.

Red Elephant: Located at the top of a local knoll, the surface/underground mercury mine contained one water filled shaft with no detectable metals. A gully extending from the shaft indicated past discharges. A large portion of the hillside had been excavated and the resultant unvegitated soil had formed deep erosional gullys. The landscape did not appear to receive much precipitation. The exposed soil tested near neutral (pH=7.3) and contained a high mercury content (240 mg/kg).

Manhattan: The original mine site has been converted to an active gold mining operation.

Table E-1. TRACE ELEMENT SURVEY OF SEVERAL SACRAMENTO VALLEY WATERBODIES.

SAMPLE LOCATION	COUNTY	DATE	EC	pH	TRACE METALS, UG/L (DETECTION LIMITS IN PARENTHESES) ARSENIC (1-2)	CADMIUM (0.1)	CHROMIUM (1)	COPPER (1)	NICKEL (4)	ZINC (5-10)	LEAD (5)	MERCURY (0.2)	SILVER (1)
NF Yuba River	Sierra	09JUN89											
at Hwy 49			78		1.6	ND	3.4	1.1	ND	ND	ND	ND	ND
at Downieville			38		1.3	ND	2.4	ND	ND	15			
at Bassett			36		1.1	ND	4.1	ND	ND	ND			
Kanaka Creek	Sierra	10JUN89											
above Kenton mine			88		18	ND	4.6	ND	5.9	20	ND	ND	ND
at M.F. Yuba River		14DEC89	182	6.86	25		2	ND	ND	ND	ND		
		13APR90	114	6.46	15		ND						
Howard Creek	Sierra	09JUN89											
at Bassett			24		10	ND	2.5	1.1	ND	25	ND	ND	ND
Camp Far West Res.	Yuba	08JUN89											
at base of dam			97		1.6	ND	3.8	2.9	ND	ND			
Rock Creek	Yuba	08JUN89											
trib. to Camp Far West			300		1.3	ND	2.8	1.4	ND	ND			
Dry Creek	Yuba	08JUN89											
trib. to Camp Far West			240		1.1	ND	5.3	2.8	ND	ND			
Yuba River	Nevada	08JUN89											
Englebright Res. release			70		1.5	ND	5.4	2.9	ND	ND			
Deer Creek	Nevada	08JUN89											
Lake Wildwood dam release			100		2.2	ND	2.6	1.6	ND	ND			
Squirrel Crk. next to dam	Nevada	08JUN89	160		1.9	ND	2.6	1.6	ND	ND			
Fiddle Creek	Sierra	09JUN89											
at Hwy 49			46		1.7	ND	2.8	ND	ND	ND			
Goodyears Creek	Sierra	09JUN89											
at Goodyear Crk Rd			142		1.8	ND	9.3	ND	ND	ND			
Downie River	Sierra	09JUN89											
at Hwy 49			87		2.1	ND	5.5	2.1	ND	ND			
Salmon Creek	Sierra	09JUN89											
at Hwy 49					1.2	ND	ND	ND	ND	ND			
MF Yuba River	Nevada	09JUN89											
at Hwy 49					2.9	ND	2.3	ND	ND	ND			
below Plumbago Mine			40		1.0	ND	2.5	ND	ND	ND			
above Kanaka Crk		13APR90	60.1	6.54	ND								
below Kanaka Crk		13APR90	65	6.77	ND								
SF Yuba River	Nevada	09JUN89											
at Hwy 49					ND	ND	2.5	ND	ND	ND			
Oregon Creek	Sierra	10JUN89											
at confl. MF Yuba			70		1.7	ND	2.6	1.2	ND	ND			
Unnamed stream	Sierra	09JUN89											
from Sierra Buttes					1.2	ND	3.0	ND	ND	ND			
Indian Creek	Plumas	27JUN89											
at Taylorsville			118		ND	ND	ND	2	ND	ND	ND	ND	ND
Lights Creek	Plumas	27JUN89											
at B.G. Rd. & Dia Mt. Rd.			134		3	ND	ND	12	ND	ND	ND	ND	ND
above China/Superior Gulch			120		ND	ND	ND	4	ND	ND	ND	0.4	ND
between Superior & Engel			98		ND	ND	ND	3	ND	ND	ND	0.3	ND
below Superior & Engel					ND	ND	ND	2	ND	ND	ND	0.3	ND
Wolf Creek	Nevada	13JUN89											
in Grass Valley			135		ND	ND	1	2	ND	5	ND	ND	ND
above Grass Valley					ND	ND	ND	2	ND	2	ND	0.4	ND
Malakoff Diggins	Nevada	14JUN89											
from Hillar Tunnel			117		ND	ND	ND	3	9	24	ND	0.3	ND
Humbug Creek u/s mine			82		ND	ND	ND	1	7	ND	ND	ND	ND
Shady Crk @ Hwy 49	Nevada	09JUN89			1.2	ND	4.8	1.0	ND	19.0	ND	ND	ND
Dry Fork	Shasta	27AUG89			ND	0.1	ND	ND	ND	ND	ND		
West Squaw Crk	Shasta	27AUG89			ND	6	ND	2800	ND	1000	ND		
Shoemaker Gulch	Shasta	27AUG89			3	22	1	2000	ND	3200	ND		
Little Backbone Crk	Shasta	27AUG89			16	63	4	7000	9	12000	23		
Big Backbone Crk	Shasta	27AUG89			ND	ND	ND	ND	ND	39	ND		
Shasta dam	Shasta	11JUL89	123		ND	ND	1	3	ND	7			
		12JUL89	123		ND	0.1	2	4	ND	10			
		12JUL89	120		ND	ND	2	11	ND	17			
		13JUL89	103		ND	ND	1	4	ND	9			
		14JUL89	118		ND	ND	2	3	ND	7			
		25JUL89			ND	ND	1	3	ND	7			
		27JUL89			ND	0.4	2	4	ND	18			
		03AUG89	100			ND	1	3	ND	8			
		04AUG89	100			ND	1	3	ND	13			

Table F-1. COMMON MINERALS IN CALIFORNIA CONTAINING METALS AND METALLOIDS OF CONCERN. 1/

CMD	MINERAL NAME	ASSOCIATED MINERALS	ELEMENTAL FORMULA	COMMENTS
As	Arsenopyrite			The primary arsenic mineral in CA; As content of most base-metal ores is below 1%
	Lollingite			
	Enargite			
	Tennantite			
	Realgar			
	Orpiment			
Cd	Greenockite			Chief Cd-bearing minerals, invariably occuring with sphalerite
	xanthochroite			Chief Cd-bearing minerals, invariably occuring with sphalerite; occurs as yellow coating on sphalerite
	cadmiumoxide			Present in the oxidized portion of zinc sulfide bodies
	otavite			Present in the oxidized portion of zinc sulfide bodies
Cr	Chromite		$Cr_2 O_3$	Primary source of chromium; serpentine and peridotite are the host rock
	Kammererite			Secondary source of chromite occuring as vienlets, stains, or incrustations in or on the ore
	Uvarovite			Secondary source of chromite occuring as vienlets, stains, or incrustations in or on the ore
Cu	Chalcopyrite	pyrite, pyrrhotite, sphalerite	$Cu Fe S_2$	Chief Cu mineral in CA; 34.5% Cu when pure. Sometimes called fool's gold.
	Chalcocite	are associated; galena,	$Cu_2 S$	Second most common Cu mineral in CA; 79.8% Cu when pure
	Bornite	magnetite, and ilmenite are	$Cu_5 Fe S_4$	Subordinate mineral; 63.3% Cu when pure
	Covellite	commonly also present; zinc	$Cu S$	
	Enargite	minerals not abundant in Plumas	$Cu_3 As_5 S_4$	
	Tetrahedrite	Co. deposits; all CA deposits	$Cu_8 Sb_2 S_7$	Subordinate mineral; commonly shows various amounts of Fe, An, and Ag
	Malachite	had to be concentrated prior to	$Cu CO_3 Cu(OH)_2$	
	Azurite	smelting	$2[Cu O_3 Cu(OH)_2]$	
	Cuprite		$Cu_2 O$	
Pb	Galena	Zn & Ag minerals commonly as-	$Pb S$	Chief source of lead
	Anglesite	sociated with Pb minerals in CA	$Pb SO_4$	Important secondary ore minerals
	Cerussite		$Pb CO_3$	Important secondary ore minerals
Ni	Pentlandite	nickeliferous material can consist	$(Ni, Fe) S$	By far the most important
	Polydymite	of primarily pyrrhotite with	$Ni_3 S_4$	
	Millerite	subordinate amts of pentlandite	$Ni S$	
	Niccolite		$Ni As$	
	Chloanthite		$Ni As_2$	
	Garnierite			
Fe	Pyrite	most common gangue mineral in metallic ore deposits; most massive	$Fe S_2$	By far the most important. Commonly called pyrite or fool's gold. 46.55% Fe and 53.45% S when when pure (pyrite and marcasite)
	Marcasite	sulfides contain minor amts of As,	$Fe S_2$	Not as common in metaliferous veins or crystalline rocks, orthorhombic form of pyrite.
	Pyrrhotite	Cu, Ag, Zn, & lime	$Fe[1-(0 to 0.2)]S$	Contains small amounts of Cu, Co, and Ni; commonly associated w/chalcopyrite, pyrite, magnetite, pendlantite and molybdenite
Zn	Sphalerite	Zn & Pb and Zn & Cu minerals ordinarily occur in close association	$Zn S$	67.0% Zn when pure; only important primary ore of zinc; present in nearly all types of sulfide deposits
	Marmatite		Ferriferous ZnS	Contains 10% or more Fe
	Smithsonite			Common oxidized product of ZnS
	Hememorphite			Less common oxidized product of ZnS

1/ Taken from CDMG, 1966 and DOM, 1957.

Table G-1. INPUT-OUTPUT CALCULATIONS OF METALS MOVING THROUGH SHASTA RESERVOIR.

MAIN SHASTA RESERVOIR INPUT	ANNUAL OUTFLOW (AC-FT)	SAMPLING PERIOD 1/	N 2/	COV	SOURCE *	CONC. (UG/L)	SAMPLING PERIOD 1/	N	COV	SOURCE *	LOADS (KG/YR)	STAND. ERROR (KG)
West Squaw Creek	4,712	1989-1992	4	0.383	A	1327	1989-1992	4	0.746	A	7,714	6,466
Little Backbone Creek	2,863	1989	2	0.11	A	5070	1989	2	0.38	A	17,907	7,084
Shoemaker Gulch	639	1989	1		A	2000	1989	1		A	1,577	
Big Backbone Creek	11,808	1989	1		A	0.6	1989	1		C	8.7	
Pit River	2,945,111	WY 1989	N.A.		B	0.240	1991	2	0.0589	D	872	51.4
upper Sacramento River	638,400	WY 1989	N.A.		B	0.270	1991	2	0.0524	D	213	11.1
McCloud River	411,400	WY 1989	N.A.		B	0.245	1991	2	0.664	D	124	82.3
TOTAL	4,014,933										28,416	9,592

CALCULATED AND ACTUAL COPPER CONCENTRATION IN SHASTA DAM RELEASE WATER, ANNUAL AVERAGE.

CONCENTRATION ORIGIN	SAMPLING PERIOD	N 2/	SOURCE	MEAN UG/L)	STANDARD ERROR (UG/L)
Expected using above data				5.74	1.94
Expected excluding mine drainage 3/				0.27	0.03
Actual data	7-89 to 8-89	9	Table E-1	4.2	2.6
Actual data	7-88 to 6-89	21	Heiman, 1989	4.2	1.9
Actual data	7-90 to 6-91	22	Heiman, 1991	2.4	1.1
Actual data	2-91 to 12-91	7	Connor, unpub.	2.601	0.866

1/ Single year indicates when data was collected and extrapolated for the year. WY=outflow measured during the water year.
2/ Number of samples taken to obtain the average.
3/ Calculated by substituting a copper concentration of 10.75 +- 13.50 ug/l into the above concentration columns for West Squaw Creek, Little Backbone Creek and Shoemaker Gulch. This was the average measured from 4 samples taken in West Squaw Creek above mine influence.

* SOURCE:
A: See source list corresponding to date and location in Table A-5.
B: U.S.GS Water Resources Data, California, Water Year 1983. Volume 4. U.S.GS Water-Data Report CA-89-4.
C: Nordstrom, et. al., 1977.
D: Connor, unpub.

Return to Mercury Home Page

County of Nevada
Department of Environmental Health

Press Release
Three County Environmental Health Agencies Issue Interim Public Health Notification on Mercury in Fish

A preliminary investigation of selected lakes and watercourses in Placer, Nevada, and Yuba counties has revealed elevated levels of mercury in certain fish populations. As part of an on-going investigation of mercury impacts from historic gold mining in the Bear River, South Yuba River, and Deer Creek watersheds, the United States Geological Survey (USGS) has conducted a screening study of mercury concentrations in several fish species in the three counties. While the mercury levels found are sufficient to warrant this Health Notification, the fish sample group in individual water bodies is limited and more study is needed.

Almost all fish, whether purchased commercially or caught as sport fish, contain some level of mercury. Mercury is a widespread contaminant in California lakes and streams. It occurs naturally in the rock formations of the Coast Range and a number of advisories have been issued in that region due to mercury levels in fish. Mercury was imported to the foothill counties as part of historic gold mining processes, where it was used to extract gold through several different processes. Mercury, in the form of methylmercury that is found in the fish, is a toxic metal that can cause damage to the nervous system, and in low levels can have an adverse effect on the neurological development of children.

The following lakes, reservoirs and watersheds were sampled by USGS: Camp Far West, Lake Combie, Rollins Reservoir, Bear River tributaries, South Yuba River tributaries, Lake Englebright, Scotts Flat Reservoir, and Deer Creek tributaries. Fish species tested were: black crappie, bluegill, brown trout, channel catfish, green sunfish, largemouth bass, rainbow trout, smallmouth bass, and spotted bass. Specifics on how many, which species of fish, what locations, and specific mercury levels can be found at the USGS website http://ca.water.usgs.gov/mercury.

The total number of legal-sized fish sampled throughout the three-county area was 150. This means that there were a limited number of samples of specific species tested, and it is difficult to make advisories based on small populations for specific lakes or streams. However, the Office of Environmental Health Hazard Assessment (OEHHA), a branch of the California Environmental Protection Agency, made an initial assessment of the information obtained from the USGS. From their analysis, several general conclusions can be made:
1. Levels of mercury in fish tend to increase further downstream.
2. The larger, older fish of a species tend to accumulate more mercury in the flesh. Among different species, the lowest levels were found in green sunfish, brown trout, rainbow trout, and bluegill. Higher levels were found in largemouth bass, smallmouth bass and spotted bass.
3. The average level of mercury encountered in the bass is below the federal Food & Drug Administration action level for commercially marketed fish of one part per million. But the level is high enough to warrant public health concern and the public needs to be informed of the condition.

Clearly, more study and testing are necessary to further define the extent of this problem, and to develop more definitive advice if indicated. Nationwide, there exist more than 2,500 fish consumption advisories, of which more then 1,900 are due to mercury. By following these interim guidelines, the public will be protected and able to catch and consume their favorite sport fish.

Nevada County is proactively pursuing State funding for a pilot study to further investigate this issue and assess the extent of mercury problems. It is expected that future studies will further define the extent and nature of this problem on a regional basis.

Interim Fish Consumption Notification for Placer, Nevada & Yuba Counties
Consumption Recommendations

- Eating sport fish in amounts slightly greater than what is recommended should not present a health hazard if only done occasionally, such as eating fish caught during an annual vacation.
- Nursing and pregnant women and young children may be more sensitive to the harmful effects of mercury and should be particularly careful about following the notification. Because contaminants accumulate over time, women who plan on becoming pregnant within a year, or are already pregnant, should exercise more caution than the recommendations below. The same is true for children under six years of age. In this way, the levels of chemicals stored in the body can be reduced over time.
- The limits given below for each species assume that no other contaminated fish is being eaten. If you consume several different listed species from the same area, or the same species from several areas, your total consumption still should not exceed the amount recommended for the fish with the fewest recommended meals. One should also realize that fish from other areas of the State may also be contaminated with mercury, and that the results of consuming all fish are cumulative. One simple approach is to just use the lowest recommended amount as a guideline to consumption. A meal for a person weighing approximately 150 pounds is assumed to be an eight-ounce serving; meal size should be adjusted according to body weight.

1 meal/month	1 meal/week
Spotted bass	**Bluegill**
Largemouth bass	**Green sunfish**
Smallmouth bass	**Brown trout**
	Rainbow trout
	Black crappie
	Channel catfish

If you have any further questions or concerns, please contact one of the following agencies:

Tracy Gidel, Nevada County (530) 265-1449

Dr. Richard Burton, Placer County (530) 889-7141

Tej Mann, Yuba County (530) 741-6251

California EPA, Office of Environmental Health Hazard Assessment (916) 324-7572

You may also visit the following websites for additional information:
http://www.co.nevada.ca.us/ehealth/hg
http://ca.water.usgs.gov/mercury/bear-yuba/

http://www.oehha.ca.gov/fish/general/99fish.html

Return to Environmental Health Home Page

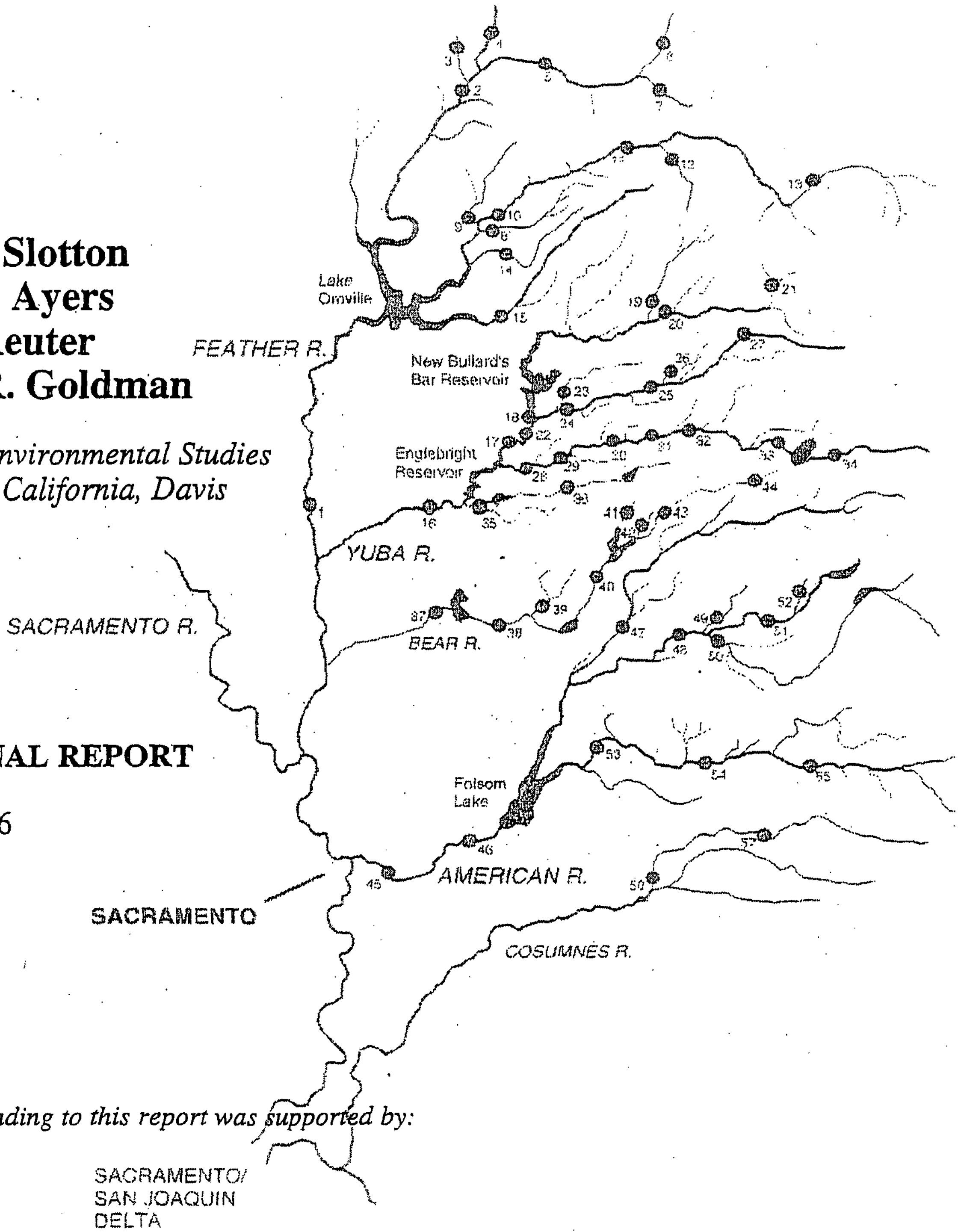
Last Updated On: Thursday, June 07, 2001 12:43:17
Please send questions or comments to tim@nccn.net

GOLD MINING IMPACTS ON FOOD CHAIN MERCURY IN NORTHWESTERN SIERRA NEVADA STREAMS (1996 REVISION)

By

Darell G. Slotton
Shaun M. Ayers
John E. Reuter
Charles R. Goldman

Division of Environmental Studies
University of California, Davis



DRAFT FINAL REPORT

Decmber 1996

The research leading to this report was supported by:

The University of California Water Resources Center
and
The Sacramento Sanitation District

ABSTRACT / EXECUTIVE SUMMARY

In this research, we investigated mercury levels in aquatic invertebrates and trout within the historic gold mining region of the northwestern Sierra Nevada, in order to determine the localized biological impacts of mining-derived mercury. These organisms were used as indicators of specifically the bioavailable fraction of mercury, that portion which can enter, transfer through, and be concentrated by the food web. The biota samples were used to determine relative "hot spots" of mercury contamination and to rank the various streams and rivers as to relative bioavailable mercury levels. Trout mercury was investigated also from a health perspective, for comparison with existing mercury guidelines.

Fifty-seven sites were sampled throughout the region during the three years of this study. A clear signature of mining-derived mercury was found, with notably elevated levels in the aquatic food webs of the South and Middle forks of the Yuba River, the mid-section of the Middle Fork of the Feather River, Deer Creek, the North Fork of the Cosumnes River, and tributaries throughout the Bear River drainage. Mercury was low throughout most of the American and Feather River watersheds and in many tributaries away from the most intensively mined stretches of rivers. Elevated mercury regions did not demonstrate a point source signature. Where biotic accumulations of mercury were elevated, this elevation was generally distributed across many miles of stream or river. The elevated bioavailable mercury regions could thus be localized to specific tributaries or series of river miles, but not to highly localized "hot spot" point sources. This is consistent with the historic widespread use of mercury throughout the gold mining region and its subsequent redistribution downstream.

Mercury concentrations in trout, while variable, were found to be uniformly below existing health standards, indicating the lack of a direct health hazard within the region itself. Foothill reservoirs were found to operate as interceptors of bioavailable mercury, in addition to trapping much of the sediment-associated inorganic load. Significantly lower bioaccumulated levels were found throughout the food web below several reservoirs, as compared to upstream. Concentrations of mercury in aquatic indicator organisms increased in a predictable pattern with increasing trophic feeding level. Aquatic invertebrate samples can be used to determine relative mercury presence and bioavailability, to predict mercury levels in co-occurring trout, and to integrate localized bioavailable mercury conditions over the lifetime of the respective organisms.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGMENTS

We are grateful to the many agency personnel who were generous with their time and conversation and who helped direct our site selection process in the early stages of the project. We also appreciate being provided access to several otherwise difficult to reach sites. In particular, we thank staff of: the Foresthill Ranger District in the American River watershed, the North Yuba Ranger Station in the Yuba River watershed, various stations in the Feather River area, the Yuba Water Agency, the University of California Agricultural Field Station at the lower Yuba River, the Central Valley Regional Water Quality Control Board, and the California Department of Fish and Game. The State Toxic Substances Monitoring Program supplied much parallel and related data and, in large part, provided the basis for this work. Special thanks go to our colleague, Dr. Michael Brett, who played an important role in the development of this project and who provided helpful suggestions throughout the data reduction and interpretation process.

INTRODUCTION: PROBLEM AND RESEARCH OBJECTIVES

Mercury pollution of aquatic systems is a major concern of researchers and regulatory agencies on both a regional and global scale. In its methylated form, mercury is readily concentrated and transferred through aquatic food chains, where it can become a significant neurological toxicant to higher trophic level consumers, including man. The primary pathway into humans is fish consumption. Much of the current mercury research is focused on the pervasive problem associated with low level atmospheric deposition of industrially-derived mercury across wide areas which have low pH and poorly buffered surface waters. In these regions, mercury can accumulate to dangerous levels in fish with even trace level inputs (e.g. the Northeast United States, Southeast Canada, Scandinavia and much of Western Europe). While the high alkalinity waters of the western U.S. render atmospheric sources of mercury relatively insignificant, California has historically been impacted by large-scale bulk contamination of mercury. This has been the result of extensive mercury mining in the Coast Range of Central California, the use of very large amounts of mercury in Sierra Nevada streams and rivers for gold mining, and the subsequent movement of mercury from both of these areas into downstream rivers and lakes, foothill reservoirs, and ultimately the Delta/Bay ecosystem. In this work, we investigated regional patterns of mercury accumulation in aquatic biota collected in the historic and current gold mining region of the northwestern Sierra Nevada. While some attention has been devoted to mercury accumulation in downstream sinks, little or no research has focused on probable upstream source regions associated with current and, primarily, historic use of mercury for gold mining. It has been estimated that over 3 million kilograms of mercury were lost into Sierra Nevada streams in the course of the California Gold Rush (CVRWQCB 1987).

Previous biological sampling efforts in these streams, as part of the State's Toxic Substances Monitoring Program (TSMP 1990, 1991, 1992), have been limited and most of this was done prior to the 1986 floods and the resurgence of small scale mining. Indeed, much of the routine sampling for the TSMP program is conducted on the lower reaches of the stem rivers and in foothill reservoirs. Mining, on the other hand, is concentrated along mid-elevation stretches of northern Sierra Nevada rivers, namely the forks of the upper Feather, Yuba, and American Rivers, the Bear River, Rubicon River, Cosumnes River, and the Mokelumne River. These rivers have been sampled sporadically by the Toxic Substances Monitoring Program (TSMP 1990, 1991, 1992). However, site selection and the species composition of the fish collected indicates that this work was generally carried out in regions well downstream of the reaches where gold mining is prevalent. We feel our data constitutes a valuable contribution to the Program's data base and its objective of identifying human health risks and major sources of toxic substances.

Small scale mining, suction dredging and panning for gold in the northwest region of the Sierra Nevada mountains has increased markedly during the last ten years. This is in part attributable to the recent series of flood runoff years in 1986, 1993, and 1995, which impacted the channel of many rivers in this region and, in the process, exposed new gold. The massive flows occurring at the time of this publication (December 1996 / January 1997) will undoubtedly continue this process. These high flows also exposed and mobilized old mercury. Additionally, current mining activity could potentially introduce additional mercury to the streams as well as disrupt formerly buried historic mercury. This project addresses the status of mercury contamination in northwestern Sierra Nevada gold mining streams, both in terms of on-site biotic mercury accumulation and as potentially ongoing sources of mercury contamination to downstream regions. The primary objectives of the project have been to:

- Determine levels of mercury in stream biota within the region most impacted by historic and current gold mining and demonstrate whether there is significant localized uptake of mercury into the stream food web in the vicinity of major historic and current mining operations.
- Produce data which will help to assess the importance of this region as an ongoing source of mercury to downstream rivers and reservoirs, and rank upstream tributaries in terms of mercury bioavailability.
- Determine whether a human or environmental health hazard exists in relation to trout mercury concentrations in the project area.
- Supplement mercury information collected from other areas of the state.

We believe that all of these objectives were achieved in this work, together with a number of other important scientific findings.

We chose mid-elevation sampling sites from among the main Sierra Nevada gold-mining rivers (Figure 1, Table 1). During the three years of the project reported here (1993-1995), we focused on the region between the Feather River watershed and the American River watershed, including the forks of the upper Feather, Yuba, Bear, and American Rivers. Special attention was given to those areas with high densities of active mining claims. These locations were determined by communication with agency and other personnel familiar with given stretches of river, and through our own reconnaissance. We soon determined that mercury distribution was very widespread throughout this region and the most effective sampling approach was to, as extensively as possible, sample throughout these rivers and their major tributaries. Where possible, samples were collected at or just below actively mined stretches of river, as well as at control sites upstream and/or along unmined stretches.

In this research, we utilized exclusively biotic samples. In-stream aquatic insect species were sampled as bioindicators of relative mercury bioavailability at each of the sites and as surrogates for fish, which were not available at many of the sites. The invertebrate mercury data also provided information on the transfer of mercury through the stream food web. Fish were of interest for their specific mercury concentrations, from a health perspective, as well as also being indicators of relative mercury availability. We chose rainbow trout as one focus of the survey because this species is the dominant vertebrate in many of these rivers, and because mercury bioaccumulation in this species represents perhaps the main vector of human exposure to mercury in this region. Other fish were sampled when available.

Sampled trout were generally representative of individuals taken by fishermen. While a range of sizes and ages were taken, the focus was on three year olds, typically 9-12 inches in length. Trout of this size class dominate angling catches, are the major contributors to in-stream reproductive success of this species, and are the group most heavily relied upon by the Department of Fish and Game in both research and policy making (Harry Rectenwald, Calif. Dept. of Fish and Game, personal communication). Stream aquatic insects were taken from a variety of trophic levels whenever possible, as described below in the methodology section.

The first two years of the work reported here were sponsored by the University of California Water Resources Center. Thirty-five individual sampling sites were studied in 1993 and 1994 and reported on in Slotton *et al.* 1995a. The Sacramento Sanitation District sponsored U.C. Davis follow-up work in 1995, sub-contracted through Larry Walker and Associates. As part of the 1995 continuation work, biota mercury was investigated at 22 additional sites, completing a comprehensive network of 55 sites throughout the Sierra Nevada drainage of the Sacramento River (plus 2 sites on the Cosumnes River of the San Joaquin drainage). The 1995 biological work was conducted in parallel with mercury mass balance and water quality studies which were performed by Larry Walker and Associates. The results of that project are presented in a separate report. The report that follows focuses specifically on the U.C. Davis biological mercury project that was conducted in the gold mining region of the nothwestern Sierra Nevada between 1993 and 1995. This report is a December 1996 revision of the original University of California Water Resources Center publication, including the additional (1995) data and new discussion as appropriate.

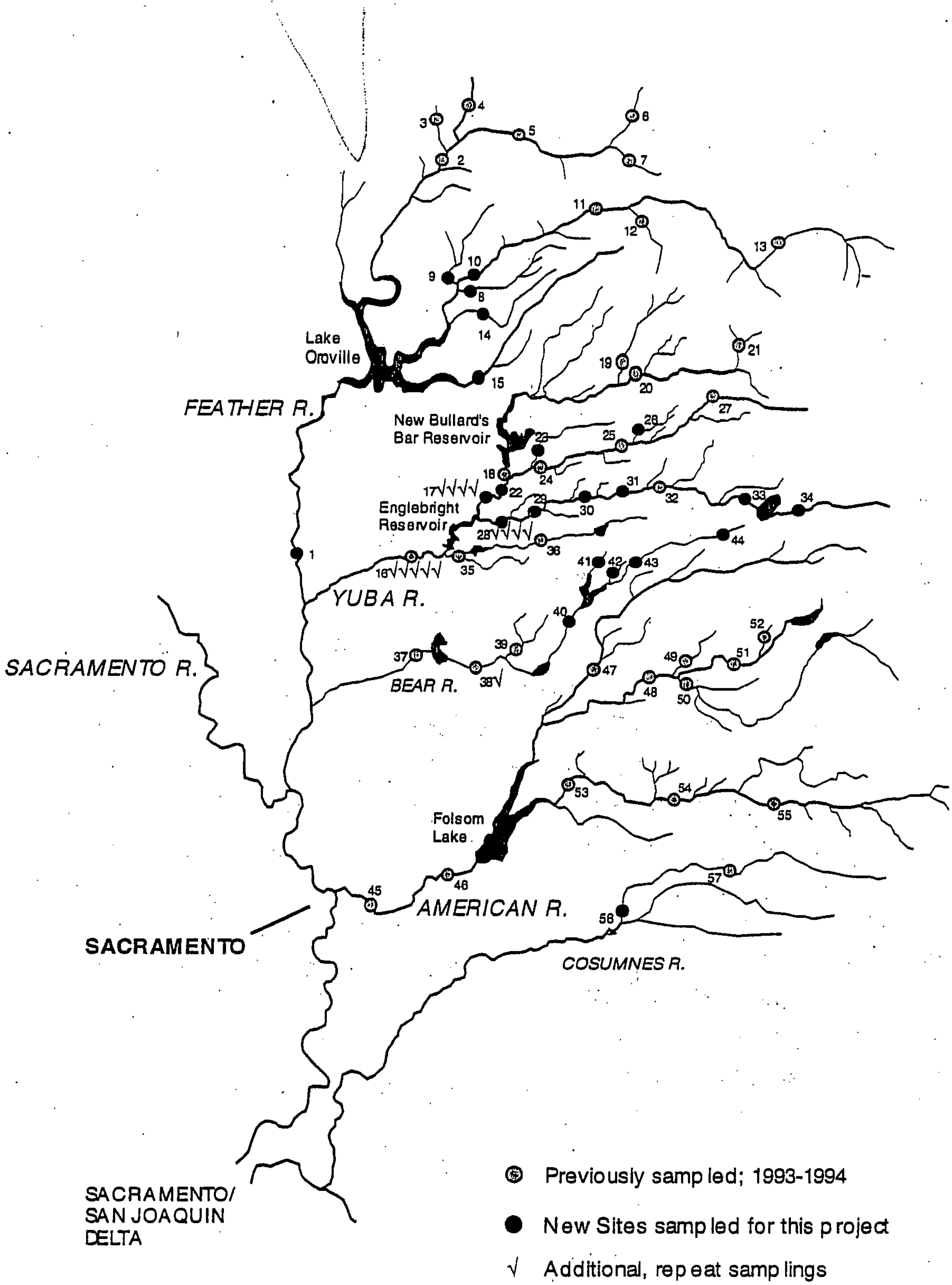


Fig. 1. U.C. Davis Northwest Sierra Nevada Biotic Sampling Sites, 1993-1995

Table 1. U.C. Davis Sierra Nevada Gold Region Biotic Mercury Sites

FEATHER RIVER DRAINAGE

1. Lower Feather River below Lake Oroville, near Live Oak (11/17/95).
2. North Fork Feather River at Belden (10/26/94).
3. Yellow Creek (tributary to N Fk Feather R), 2 miles above confluence (6/11/94).
4. Caribou Branch of North Fork Feather River, 4 miles above confluence (10/27/94).
5. East Branch of North Fork Feather River, 10 miles above confluence with Caribou Branch (10/26/94).
6. Indian Creek, tributary to E Branch N Fk Feather River, 7 miles above confluence (9/27/94).
7. Spanish Creek, tributary to E Branch N Fk Feather River, 2 miles above confluence (9/26/94).
8. South Branch Middle Fork Feather River, at M Fk Feather River (11/21/95).
9. Little North Fork Middle Fork Feather River, at M Fk Feather River (11/21/95).
10. Middle Fork Feather River, 15 miles upstream of Lake Oroville at Milsap Bar (11/21/95).
11. Middle Fork Feather River, 1 mile below Nelson Creek (9/22/94).
12. Nelson Creek, tributary to Middle Fork Feather River, 1 mile above confluence (9/21/94).
13. Upper Middle Fork Feather River, 3 miles upstream of Clio (9/23/94).
14. Fall River, tributary to lower Middle Fork Feather River, 3 miles above confluence (11/20/95).
15. South Fork Feather River above Lake Oroville (11/20/95).

YUBA RIVER DRAINAGE

16. Lower Yuba River below Englebright Reservoir, at University of California field station (12/16/93).
    * Additional, seasonal collections in 1995: (4/24/95, 6/30/95, 8/15/95, 11/16/95, 2/16/96).
17. Combined North and Middle Forks Yuba River, just above Englebright Reservoir.
    * 1995 seasonal collection site #2: (4/24/95, 6/30/95, 8/15/95; no inverts available 11/95 and 2/96).
18. North Fork Yuba River constrained (low) flow beneath New Bullard's Bar Reservoir (3/15/94).
19. Canyon Creek, tributary to N Fk Yuba, just above confluence (11/6/93).

Table 1. (continued)

20. North Fork Yuba River, 2 miles downstream of westmost Highway 49 crossing (11/5/93).

21. Downey Creek, tributary to N Fk Yuba, at Downieville (11/2/93).

22. Middle Fork Yuba River, upstream of Colgate Powerhouse inflow of N Fk Yuba water (11/16/95).

23. Oregon Creek (Middle Fork Yuba tributary) at Middle Fork Yuba (11/9/95).

24. Middle Fork Yuba River, just upstream of Oregon Creek and Highway 49 crossing (10/21/93).

25. Middle Fork Yuba River, 1 mile upstream of Tyler Foote crossing, near Kanaka Creek. (10/19/93).

26. Kanaka Creek (Middle Fork Yuba River tributary), at Middle Fork Yuba River (11/14/94).

27. Middle Fork Yuba River, 1 mile upstream of Plumbago Road (3/24/94).

28. South Fork Yuba River at Bridgeport, just above Englebright Reservoir.
    * 1995 seasonal collection site #3: (4/24/95, 6/30/95, 8/15/95, 11/16/95, 2/16/96).

29. South Fork Yuba River at Highway 49 crossing (11/10/95).

30. South Fork Yuba River at Purdon crossing (11/10/95).

31. South Fork Yuba River at Edward's crossing (10/4/95).

32. South Fork Yuba River 1 mile downstream of Washington (11/12/93).

33. South Fork Yuba River below Lake Spaulding (10/24/95).

34. South Fork Yuba River above Lake Spaulding (10/25/95).

35. Deer Creek below Lake Wildwood, at Mooney Flat Road (12/9/94).

36. Deer Creek at Bittney Spring Road (12/9/94).

BEAR RIVER DRAINAGE

37. Bear River below Camp Far West Reservoir (12/8/94).

38. Bear River between Camp Far West Res. and Wolf Ck confluence, at Hwy 49 (12/7/94, 11/10/95).

39. Wolf Creek, tributary to Bear River, 2 miles above confluence (12/7/94).

40. Bear River below Rollins Reservoir (10/12/95).

41. Greenhorn Creek (Bear River tributary), above Rollins Reservoir (10/13/95).

Table 1. (continued)

42. Steephollow Creek (Bear River tributary), above Rollins Reservoir (10/13/95).

43. Bear River above Rollins Reservoir and flow diversion from S Fk Yuba (10/13/95).

44. Bear River headwaters near Lake Spaulding (10/24/95).

AMERICAN RIVER DRAINAGE

45. Lower American River at Howe Avenue (12/16/94).

46. Lower American River 1 mile below Lake Natoma (12/16/94).

47. North Fork American River in vicinity of Humbug Bar (11/19/93).

48. Middle Fork American River below Oxbow Reservoir (2/25/94).

49. North Fork of the Middle Fork American River, 1 mile above confluence (3/2/94).

50. Rubicon River, tributary to Middle Fork American River, just above confluence (2/1/94).

51. Middle Fork American River at "End of the World" (2/1/94).

52. Duncan Creek, tributary to Middle Fork American River, 3 miles above confluence (11/16/93).

53. South Fork American River, above Folsom Lake (12/16/94).

54. South Fork American River, below Slab Creek Reservoir (12/20/93).

55. South Fork American River, 1 mile upstream of Pacific (4/11/94).

Additional Sites Outside the Sacramento River Drainage

56. North Fork Cosumnes River above M Fk Cosumnes confluence (7/30/95)

57. North Fork Cosumnes River at Mt Aukum Road (12/20/93).

METHODOLOGY

Site Selection

Sampling sites were chosen by a variety of methods. Likely high mercury regions were determined through conversations with employees of the Forest Service, California Department of Fish and Game, regional Water Quality Control Boards, and other agencies, as well as through our own reconnaissance and conversations with miners. Additional sites were chosen upstream and downstream of intensively mined stretches. Additional major tributaries were sampled as possible. Tributaries were sampled for trout ≥ 1 mile upstream of their confluences with main rivers, in order to minimize the importance of migration from downstream and other drainages. Stream invertebrates could be effectively sampled closer to a downstream confluence while remaining representative of the given tributary.

Collection Techniques

Stream invertebrates were taken from riffle habitat at each of the sites, i.e. from rapids or cobble bottomed stretches with maximal flow, where aquatic insects tend to be most concentrated among the rock interstices. Felt-soled boots were used to permit effective movement in this habitat. Neoprene waders were used when water temperatures were below ~12 °C. Stream invertebrates were collected primarily with the use of a kick screen. A 1.5 mm mesh size was used, trapping invertebrates thicker than this in cross section. One researcher spread and positioned the screen perpendicular to the flow, bracing the side dowels against the bottom, while the other researcher overturned boulders and cobble directly upstream of the screen. These rocks were hand scrubbed into the flow, dislodging any clinging biota. Following the removal of the larger rocks to the side of the stretch, the underlying cobble/pebble/gravel substrate was disrupted by shuffling the boots repeatedly. Invertebrates were washed into the screen by the current. The screen was then lifted out of the current and taken to the shore, where teflon coated forceps were used to pick macro-invertebrates from the screen into jars with teflon-lined caps. This process was repeated until a sufficient sample size of each taxon of interest was accumulated to permit future analysis for mercury. Whenever possible, we attempted to collect consistent samples from the following four invertebrate trophic levels: herbivores, drift feeders, small-item predators, and top insect predators. When present, we took Pteronarcyid stonefly nymphs or a variety of mayfly nymphs for the herbivore trophic level and Hydropsychid caddisfly nymphs for the drift feeding group. Medium to large Perlid stoneflies (either *Callineuria* or *Hesperoperla*) were taken wherever possible to represent the small-item predator insects, while hellgrammites (*Corydalus*) were the preferred top predator stream insect.

Several fish collection techniques were investigated initially, including gill netting, electroshocking, and angling. We determined that angling was the most effective method for taking a cross section of trout sizes from clear, fast moving Sierra foothill rivers and streams. To guard against potentially taking seasonal migrant fish from downstream reservoirs, fish sampling was largely confined to the months of August through December. Stocked individuals were rarely taken and were easily differentiated from native fish by their characteristic fused and bent fin rays. We sampled exclusively native fish for mercury content, with the emphasis on rainbow trout. The attempt was made to collect trout across a range of sizes and ages at each site, permitting the construction of site-specific fish size vs mercury regressions. These relationships were used to normalize trout mercury content at each site to a standard, inter-comparable size of trout. We chose a standard size of 250 g for normalization. This size was typical of 2-3 year old, 9-12 inch long trout which represent the majority of "keeper" fish taken by the angling public. Fish were weighed and measured in the field. At sites where stomach contents were assessed, this was also done in the field. Stomach contents were obtained with a stainless steel scalpel and were removed to an acid-cleaned jar with teflon-lined cap. Items were identified and percent volumes assessed, following standard fisheries sampling protocol.

Sample Preparatory Techniques

Stream insects were analyzed for mercury in homogenized composite samples of multiple whole individuals. Typically, ≥ 10 individuals were composited for each of the trophic levels through small-item predators (stoneflies), and 2-5 individuals of the top predator insect group such as hellgrammites, based on availability. Samples were pooled by taxa into separate jars. The insects were maintained live on ice. Within 24 hours of collection, the contents of each jar were carefully cleaned and sorted. This was accomplished by resuspending the jar contents in a tray of clean water and, with teflon-coated forceps, individually rinsing and shaking each individual insect in the clean water to remove any extraneous material. Insects were keyed to at least the family level, using a variety of aquatic insect texts and manuals (McCafferty 1981, Merrit and Cummins 1984, Pennak 1978, Thorp and Covich 1991) . Trophic feeding category of organisms was determined based on the recommendations of Merrit and Cummins (1984). In uncertain cases, the magnified examination of mouthparts was used to help make this determination. Cleaned insects were placed in well rinsed jars and frozen. At the onset of sample analysis, the jar contents were dried at 50-60 °C for 24 hours and then ground with teflon coated instruments or glass mortar and pestle to a homogeneous powder. The resulting powder was dried a second time to constant weight before analytical sub-samples were taken for digestion. All aquatic insect mercury analytical work was performed with dry powdered sample, both to ensure homogeneity of sample and to enhance mercury detection capacity. Percent moisture was determined on homogenized wet samples from several replicates of each major group, to permit the conversion between wet and dry concentrations.

In contrast to the dry, composite sample insect work, fish mercury was analyzed primarily in muscle tissue on a fresh (wet) weight basis, in accordance with standard practices which focus on the potential health risks of consuming mercury in filet meat (TSMP 1990). Muscle samples were taken from fresh fish at streamside. Fish muscle was sampled from the dorso-lateral (shoulder) region utilized by the California Department of Fish and Game. For each individual fish, the skin over the region was pulled back before the sample was taken with a stainless steel scalpel. Samples of approximately 0.2 g were rolled lightly over a laboratory tissue paper to remove extraneous surface moisture and then carefully placed into pre-weighed, acid-washed digestion tubes with teflon-lined caps. The precise weight of each muscle sample was later determined by re-weighing the digestion tubes with samples, together with empty "blank" tubes, on a balance accurate to 0.001 g. This direct sub-sampling technique reflects fresh weight muscle (filet) mercury concentrations, without introducing potential sources of error associated with homogenization techniques. We have found mercury concentration to be extremely uniform throughout the dorso-lateral region of muscle (Slotton 1991). Thus, direct sub-sampling accurately reflects overall muscle mercury concentration. For cases where liver mercury was also measured, identical procedures were followed. Wet/dry conversions were calculated for trout fillet tissue by determining percent moisture from 10 fillet samples from different fish. These were very similar and the mean value (78.2% ± 1.9%) was used to convert analyzed fresh weight parts per million mercury to a dry weight basis, for direct comparison with the invertebrate dry weight values.

Analytical Methodology

Mercury analytical methodology followed the protocols developed at U.C. Davis (Slotton 1991) and summarized in Slotton *et al.* (1995b). The method combines features of a number of previous techniques, and is notable for allowing excellent reproducibility, low detection levels, high numbers of samples per batch and thus room for high numbers of QA/QC samples, and the ability to re-analyze digests.

The method can be summarized as follows: digestion is performed in teflon-capped pyrex test tubes in a two stage process. Environmental samples are broken down in a 2:1 mixture of concentrated sulfuric acid to concentrated nitric acid, the digest mixture found to be most effective in a comparative study (Sadiq and Zaidi 1983). This first stage utilizes a temperature of 90-100 °C and pressure (sealed tubes) for 1.5 hrs, resulting in clear solutions. In the second stage, also 1.5

hrs, potassium permanganate is added for additional oxidation and digest stabilization. This portion of the digest procedure is performed at 80-95 °C with the tubes refluxing, uncapped. The resulting digests can be diluted or not, depending on the mercury concentrations and required level of detection, and are stable indefinitely, both before and following detection. Detection utilizes typical cold vapor atomic absorption techniques with a mercury lamp of 253.7 nm wavelength. The method differs from standard flow-through systems which reduce the entire digest in a one-time detection. A long path length, minimum volume gas cuvette and holder have been manufactured for positioning in the beam path and a specialized injection port allows direct introduction of reduced mercury in vapor. Reduction of digest mercury is performed inside a 12 cc calibrated syringe on a 2.0 cc aliquot of digest together with 2.0 cc of stannous chloride/hydroxylamine sulfate/sodium chloride reductant. A 6.00 cc airspace is utilized for partitioning of the volatile reduced mercury within the syringe and, after partitioning is complete, this airspace is injected directly into the low volume cuvette mounted in the beam path for detection. The amount of digest and, thus, proportion of sample detected is accurately determined through difference, with the digest tubes weighed to ± 0.001 g both before and immediately after removal of the analytical aliquot. Weight of total digest is initially determined by weighing the empty tube and then the full tube of digest. Level of detection was approximately 0.01 mg kg^{-1} (ppm).

QA/QC was quite extensive, with approximately 16 of the 40 tubes in each run dedicated to this purpose. QA/QC samples in each run included a set of 8 aqueous mercury standards, a minimum of 3 certified reference material samples in an appropriate matrix, and duplicate and spike recovery samples each at a ratio of approximately 10%. QA/QC samples passed through all phases of the digest and were treated identically to analytical samples. Replication was typically ≤ 5% difference between duplicates, recoveries of certified reference materials were uniformly within 20% of certified values, spike recoveries were within 20% of predicted concentrations, and standard curves generally had R^2 values in excess of 0.98.

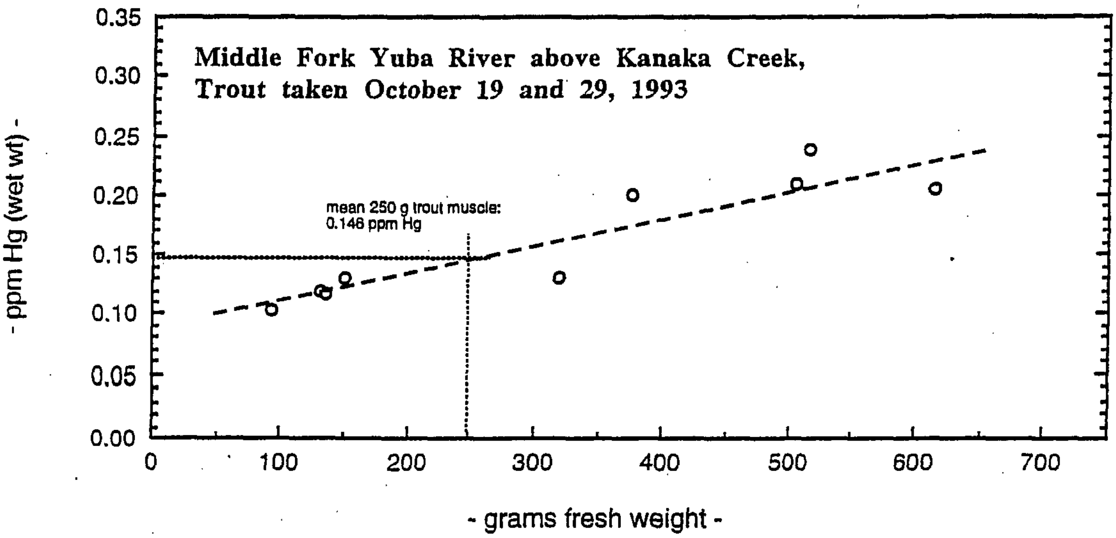
Data Reduction

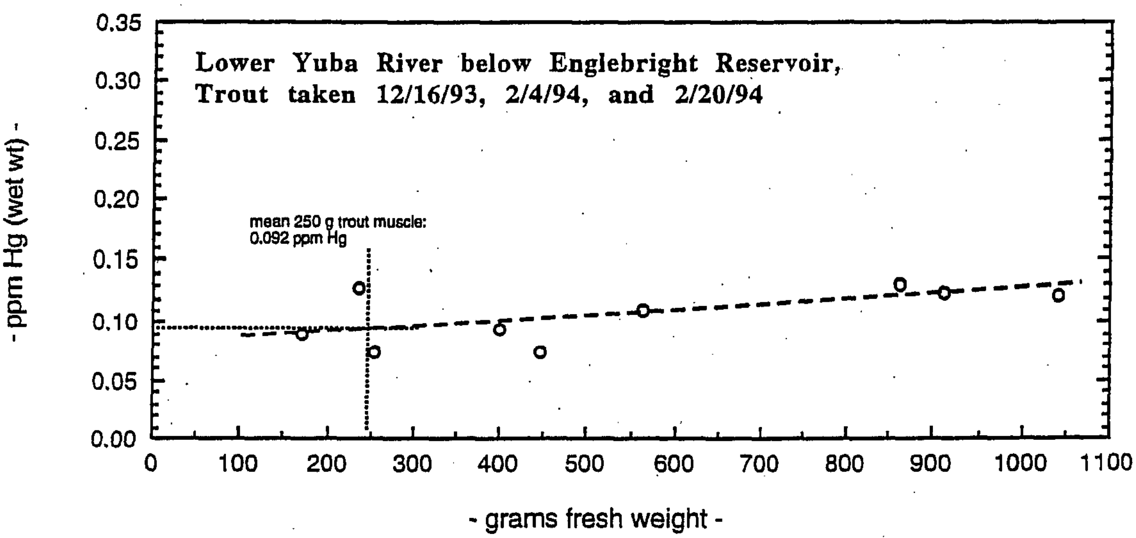
In order to reduce the fish muscle mercury concentration data to a single, inter-comparable number for each site, we developed trout size vs mercury concentration curves for the fish taken at each location. Data for fish weights and corresponding mercury concentrations were plotted for each sample set. Based on a visual line of best fit, a graphic relationship between trout size and mercury concentration was estimated for each site. This approach was taken for the following reasons: (1) obvious outlier individuals could be omitted when they were clearly of different origin than the rest of the fish in a set, typically due to recent migration from an adjoining stream with different mercury bioavailability, (2) fish size vs mercury concentration relations often follow a curvilinear rather than straight line function, and (3) standard polynomial function curve fitting routines tend to wrap the upper portion of these mercury curves, unnaturally, back down toward zero, rather than following the asymptotic, steadily increasing function typical in actual fish vs mercury relations. However, a straight line could generally be fitted to the trout data of most sample sets, within the range of sizes utilized. Examples of this normalization approach are presented in Fig. 2. Map figures for trout represent normalized 250 g rainbow trout filet muscle mercury concentrations. Only samples with sufficient individuals to derive a size:mercury relationship are displayed in the map figures (21 of 24 sites where trout were taken).

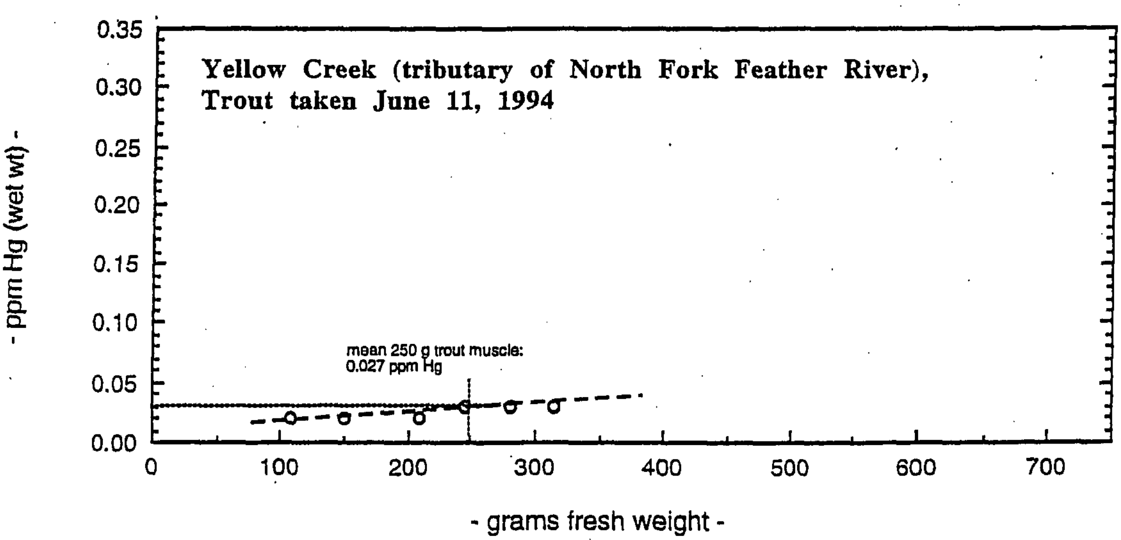
Among the invertebrate samples, some of the trophic levels were well represented by a single genus throughout the majority of sampling sites, while others were represented by different members of the trophic level at different locations. While mercury concentrations for all of the individual samples are presented in the data tables, the summary map figures utilize averaging techniques in several circumstances. In the herbivore trophic level, a distinction is made between consumers of allochthonous (terrestrially derived) vegetation ("shredders") and forms which graze autochthonous, within-stream algae and aquatic plants. The shredder sub-group was dominated by samples of Pteronarcyid stoneflies. Where other shredder groups were present rather than Pteronarcyids, the average mercury level among them is plotted. Grazers of within-stream vegetation are similarly averaged. For plots which utilize only a single value for "herbivores", the average of all shredder and grazer types is used for each site. The drift feeding omnivore trophic level is represented exclusively by Hydropsychid caddisfly larvae, which were widely represented among the sampling sites (44 of the 57 sites). The first order (small item) predator trophic level is represented by Perlid stoneflies at all but 4 of the 50 stations where first order predators were taken. At these 4 stations, the average of all available first order predator samples is used. The second order (large item) predator trophic level is represented most consistently, but not overwhelmingly, by Corydalid hellgrammites, which occurred at 24 of the 33 stations where second order predators were taken. In the second order predator figure, Corydalid hellgrammite mercury is plotted alone in addition to average values for all second order predators. For plots which utilize only a single value for "second order predators", the average of all second order predator types at each site is used.

In order to reduce the often voluminous and varied trophic mercury data to a single, inter-comparable value for each site, tissue concentrations were normalized to an intermediate trophic level for each sampling site. The selection of the specific intermediate trophic level for normalization was arbitrary and does not bias comparisons between sites. The data were normalized by trophic level for each site based on an ANCOVA model of the of tissue mercury concentration vs. relative trophic level and site factors. Additional manipulation of data consisted

Fig. 2. Examples of Fish Size vs Mercury Concentration Normalization







of adding back the model residuals to the trophic level-normalized data for each site. This allowed estimation and expression of the variability (standard deviation, confidence limits) of the trophic level-normalized estimates for each site. The average trophic level-normalized mercury concentration for each site (or drainage) was used as one of several tools in comparing relative biological accumulation of mercury between sites..

RESULTS

In the three years of this study, we were able to sample aquatic biota at a total of 57 different stream and river sites throughout the Sierra Nevada foothill gold region (Figure 1, Table 1). Of the 57 sites, all but the two Cosumnes River sites were within the Sierra Nevada watershed of the Sacramento River. Sampling was generally constrained to the months of September through December for a variety of reasons, including (1) prohibitively high flow in late winter through early summer and (2) frequently low invertebrate biomass at other times of year. In 1993, we focused our sampling efforts on tributaries of the Yuba and American River watersheds, while in the second year of the project we worked mainly in the Feather River, Bear River, and Deer Creek drainages. The third year of the project concentrated on more intensive sampling of higher mercury drainages identified previously. In Table 2, biota mercury data for all sites are displayed both numerically and graphically, on a dry weight basis. Fish data for individual trout are presented in Table 3. The biotic mercury data are also displayed on a regional map, with graphic representations of mercury levels in all main trophic levels superimposed in Figure 3 and the approximated normalized mercury values for the 57 sites shown in Figure 4. Mercury trends within individual trophic categories are displayed in Figures 5-10.

Trout

Trout were sampled in sufficient numbers for statistical analysis at 21 of the 24 stream sites where fish were taken, with a total of 134 fish collected and analyzed for filet muscle mercury. This included 120 native rainbow trout, 11 small brown trout, 1 large brown trout, and 2 mid-sized squawfish. Data for individual fish are presented in Table 3 and are displayed on a regional basis in Figures 9 (dry weight ppm Hg) and 10 (wet weight ppm Hg). On a wet weight (fresh) basis, normalized filet muscle mercury concentrations in 250 g trout varied between 0.03 mg kg^{-1} (ppm) and 0.21 mg kg^{-1}. The normalized values represent the synthesis of data from 4-13 fish from each site. Trout from all sites demonstrated a generally positive size vs mercury concentration relationship, with largest fish typically having the highest concentrations. Highest trout mercury was found at sites along the Middle and South Forks of the Yuba River, and the mid

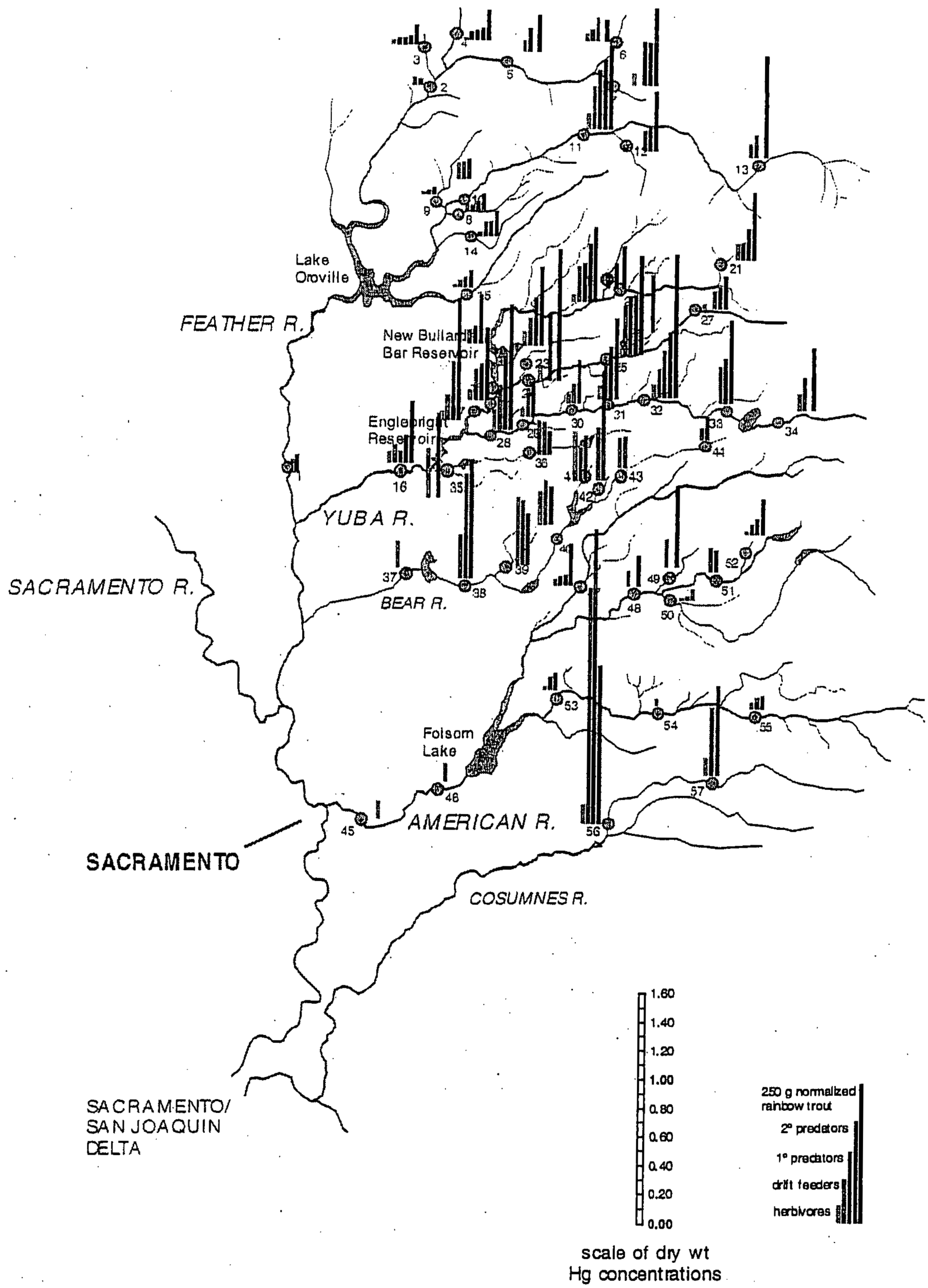


Fig. 3. Superimposed Sierra Nevada biotic mercury data for all major trophic categories

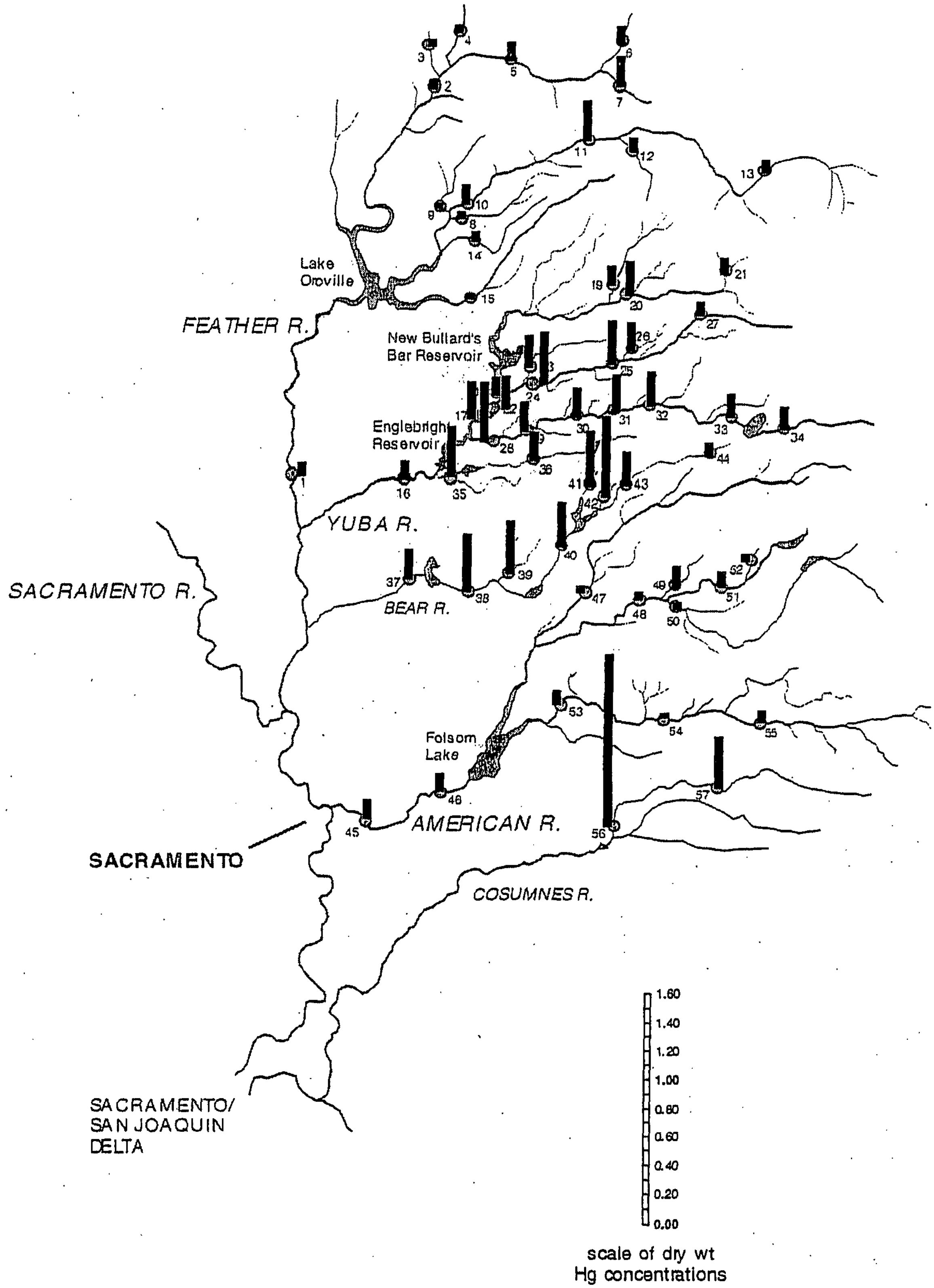


Fig. 4. Trophically Averaged Relative Mercury Levels, For Inter-Site Comparison

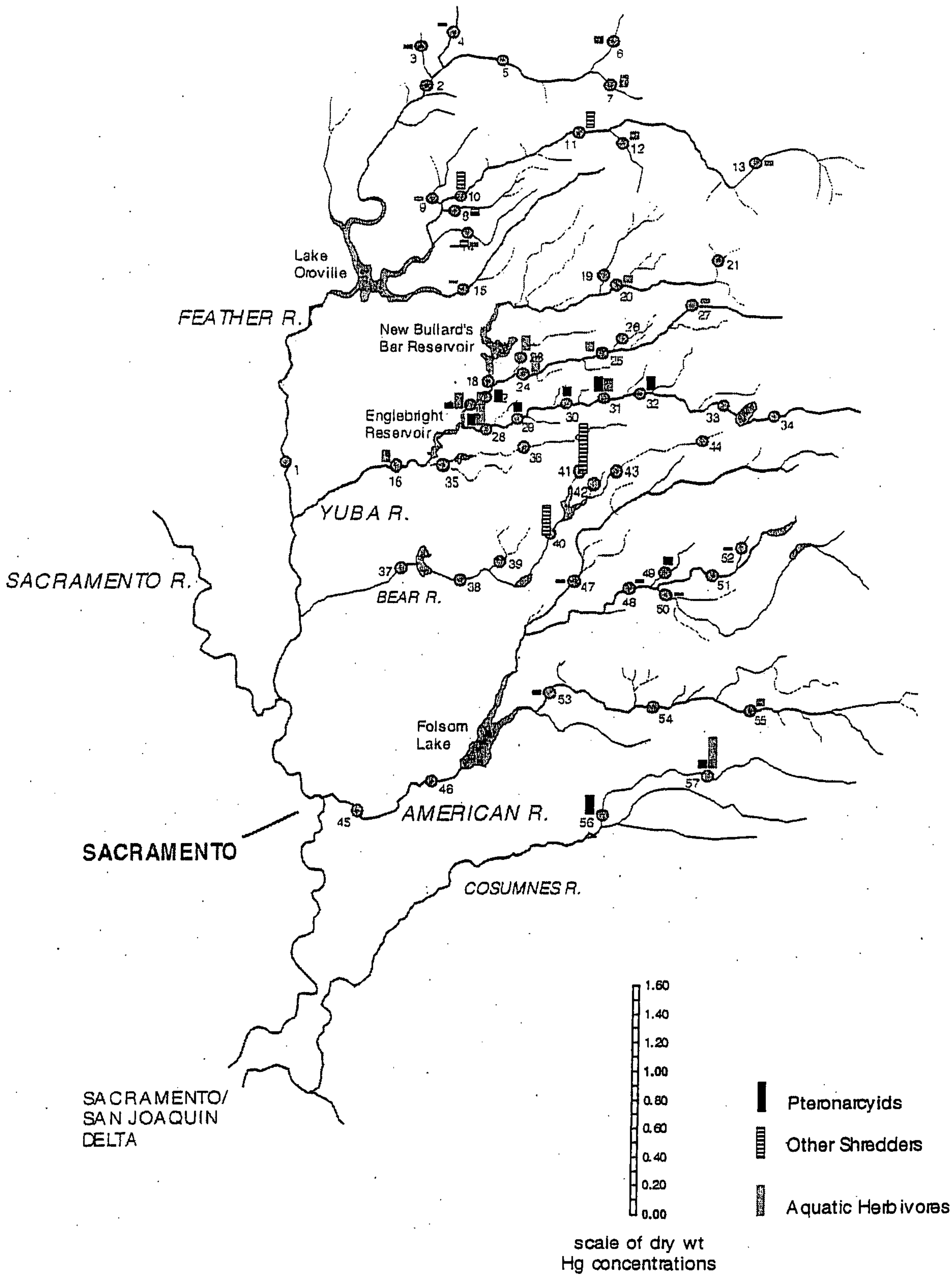


Fig. 5. **Mercury in Herbivorous Stream Invertebrates** (dry weight ppm)
(Shredders of terrestrial vegetation vs consumers of aquatic plants and algae)

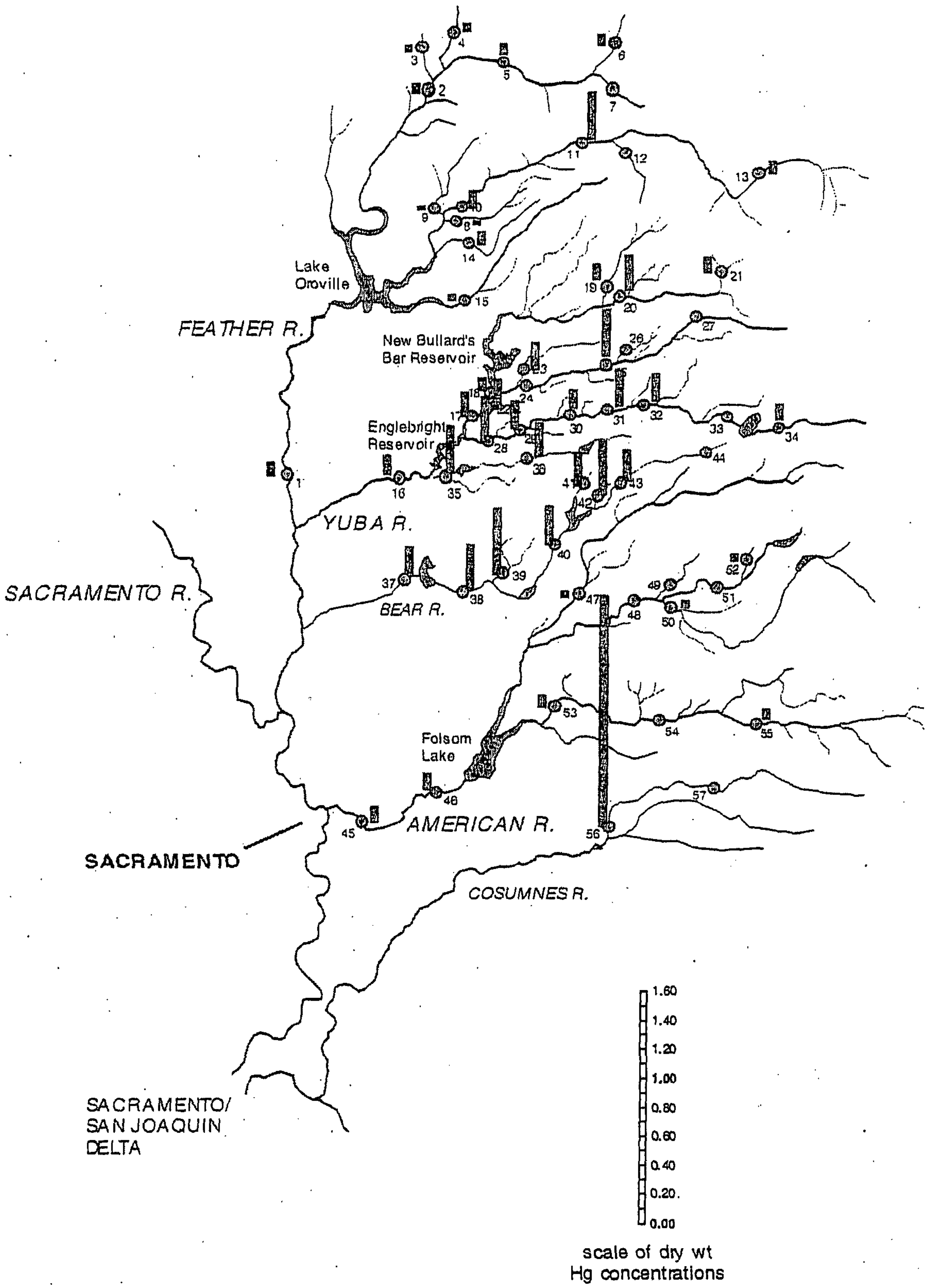


Fig. 6. Mercury in Hydropsychid Caddisfly Larvae (dry weight ppm)
(Net-utilizing drift feeders)

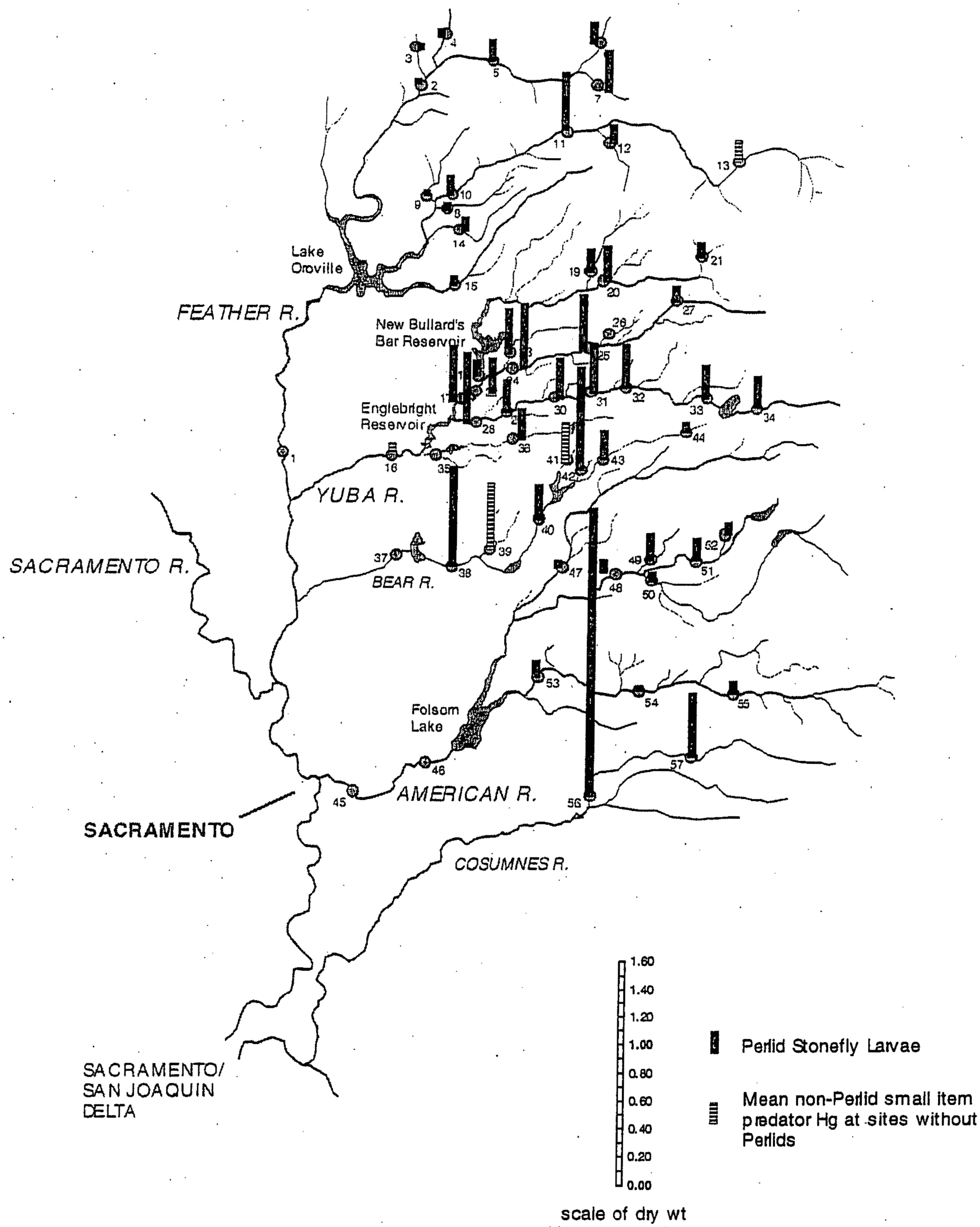


Fig. 7. Mercury in Perlid Stonefly and Other Small Item Predator Larvae
(dry weight ppm)

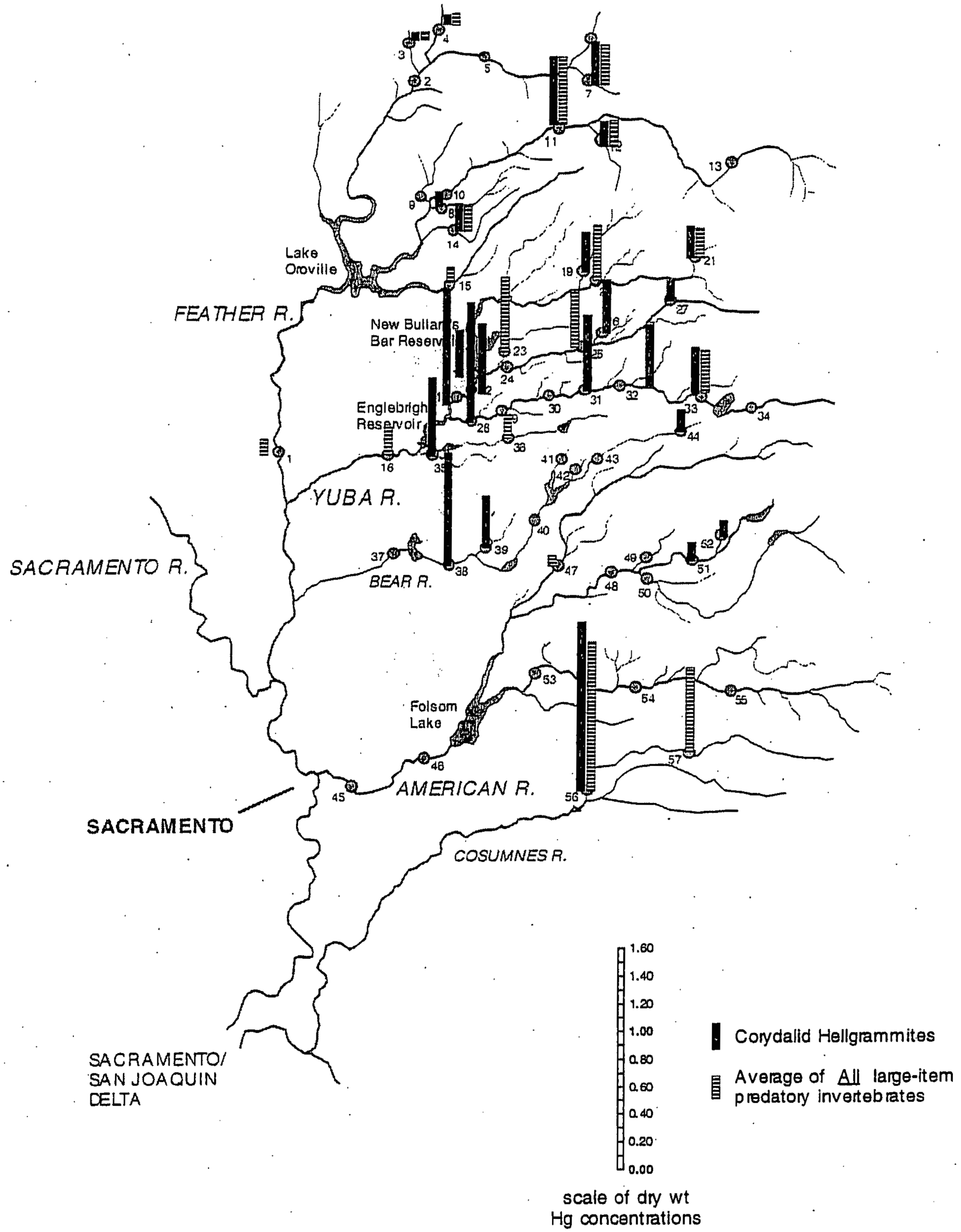


Fig. 8. Mercury in Corydalid Hellgrammite Larvae and Other Large Item Predatory Invertebrates (dry weight ppm)

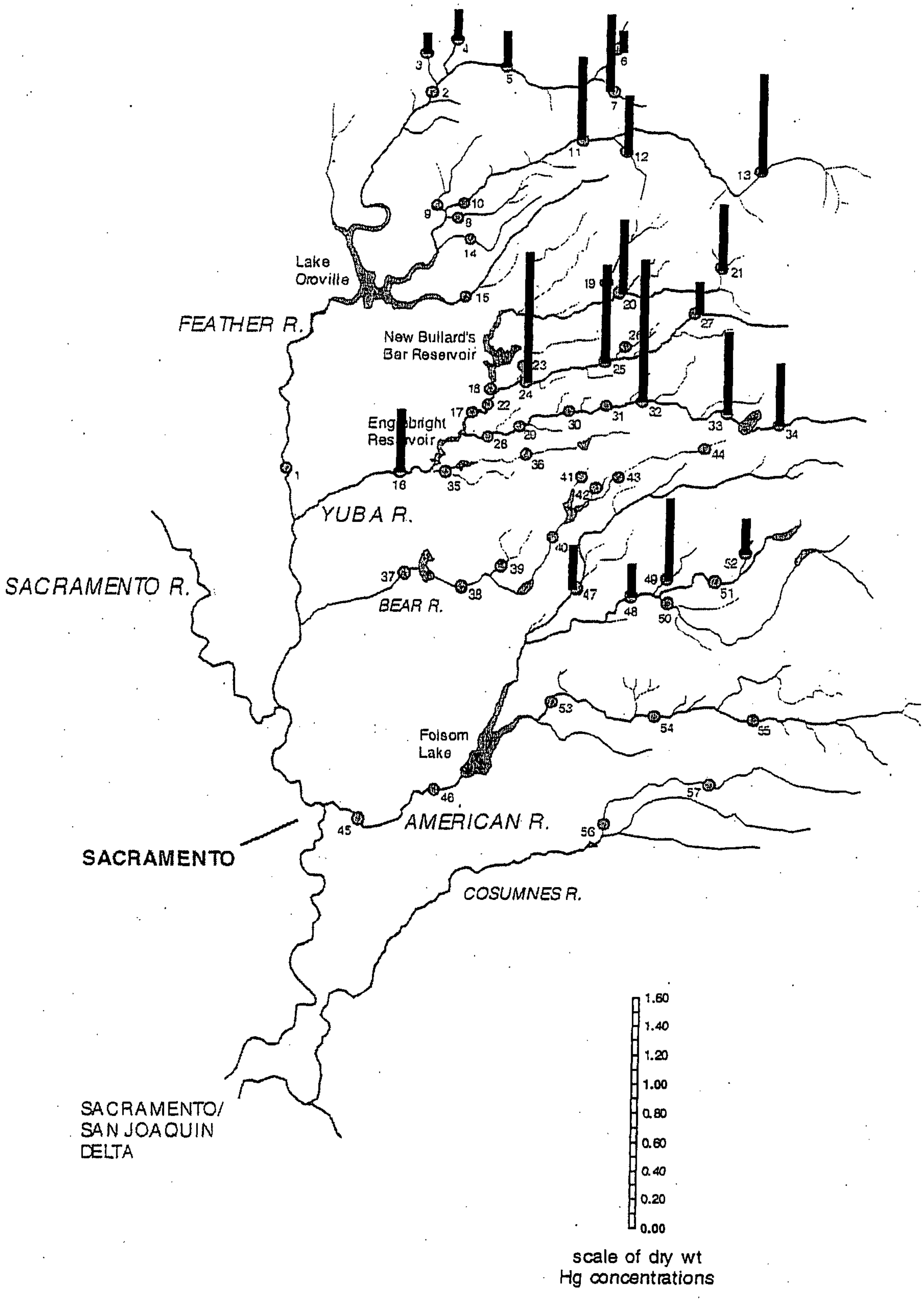


Fig. 9. Mercury in Normalized 250 g Rainbow Trout Muscle
(dry weight ppm, comparable to dry wt invertebrate data)

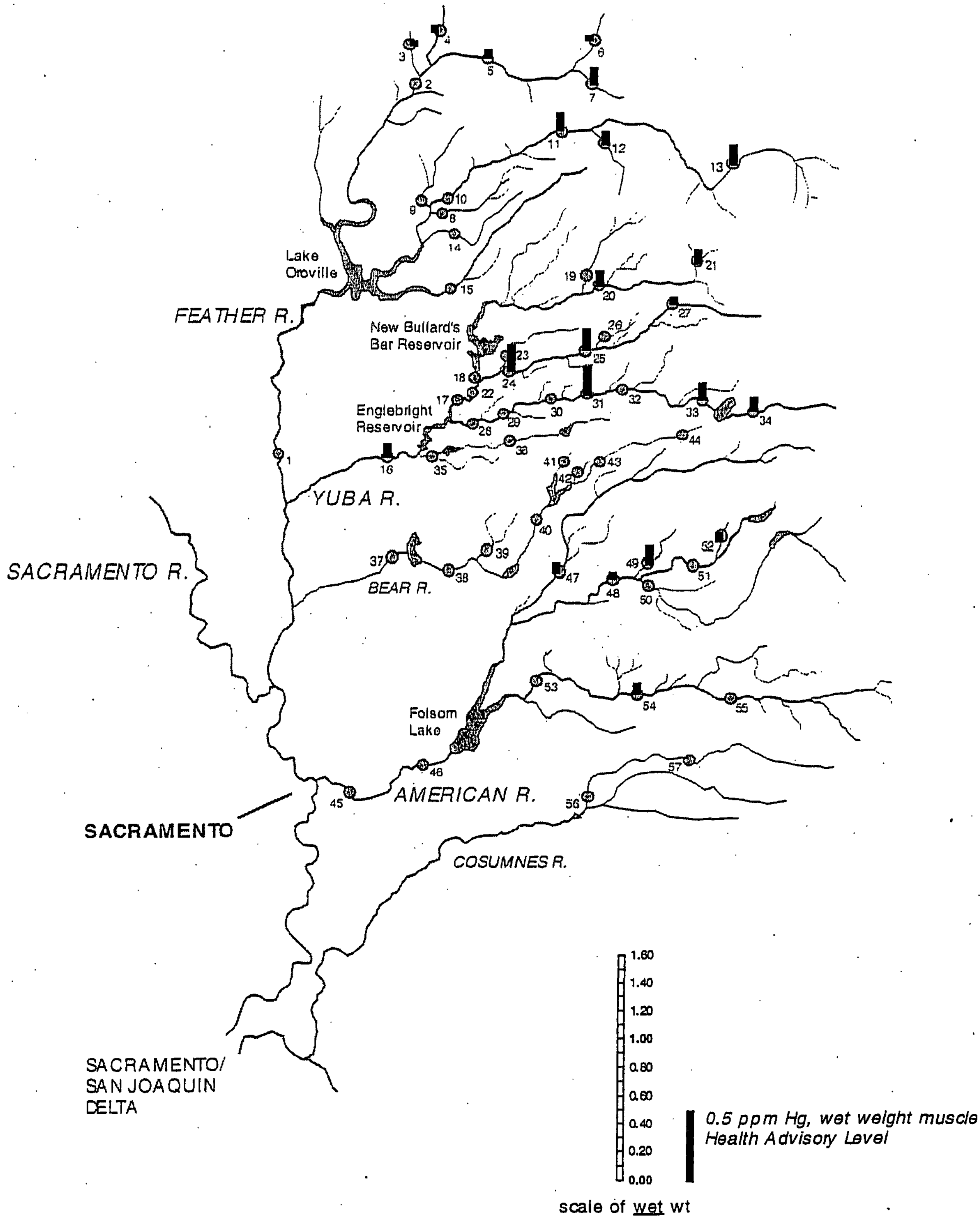


Fig. 10. Mercury in Normalized 250 g Rainbow Trout Filet Muscle
(wet weight ppm, in relation to 0.5 ppm wet weight health advisory level)

Table 2. Biota Mercury Data For All Northwe[illegible] Sierra Nevada Project Sites (all as dry wt ppm)

identification	trophic level	Hg
1. Lower Feather River at Live Oak. (11/17/95)		
Hydropsychidae (net caddis)	drift feeder	0.08
Gomphidae (dragonfly nymph)	large predator	0.10
2. North Fork Feather River at Belden. (10/26/94)		
Hydropsychidae (net caddis)	drift feeder	0.05
Perlidae-Gold sp (Callineuria)	small predator	0.04
3. Yellow Creek (trib. of North Fk Feather R.), 2 miles above confluence. (6/11/94)		
(Large Mayflies)	herbivore	0.03
Hydropsychidae (net caddis)	drift feeder	0.04
Rhyacophyllidae (pred. caddis)	small predator	0.04
Perlidae (golden stonefly)	small predator	0.03
Corydallidae (hellgrammite)	large predator	0.05
Tipulidae (cranefly)	large predator	0.06
Mean 250 g Trout (dry ppm)	*(insect predator)*	*0.12*
(trout diet)	(trout diet)	0.05
4. Caribou Branch North Fork Feather River, 4 miles above confluence. (10/27/94)		
Pteronarcyidae	leaf shredder	0.02
Hydropsychidae (net caddis)	drift feeder	0.05
Perlidae-Dark sp (Hesperoperla)	small predator	0.06
Gomphidae (dragonfly)	large predator	0.08
Corydallidae (hellgrammite)	large predator	0.07
Tipulidae (cranefly)	large predator	0.09
Mean 250 g Trout (dry ppm)	*(insect predator)*	*0.20*
(trout diet)	(trout diet)	0.06

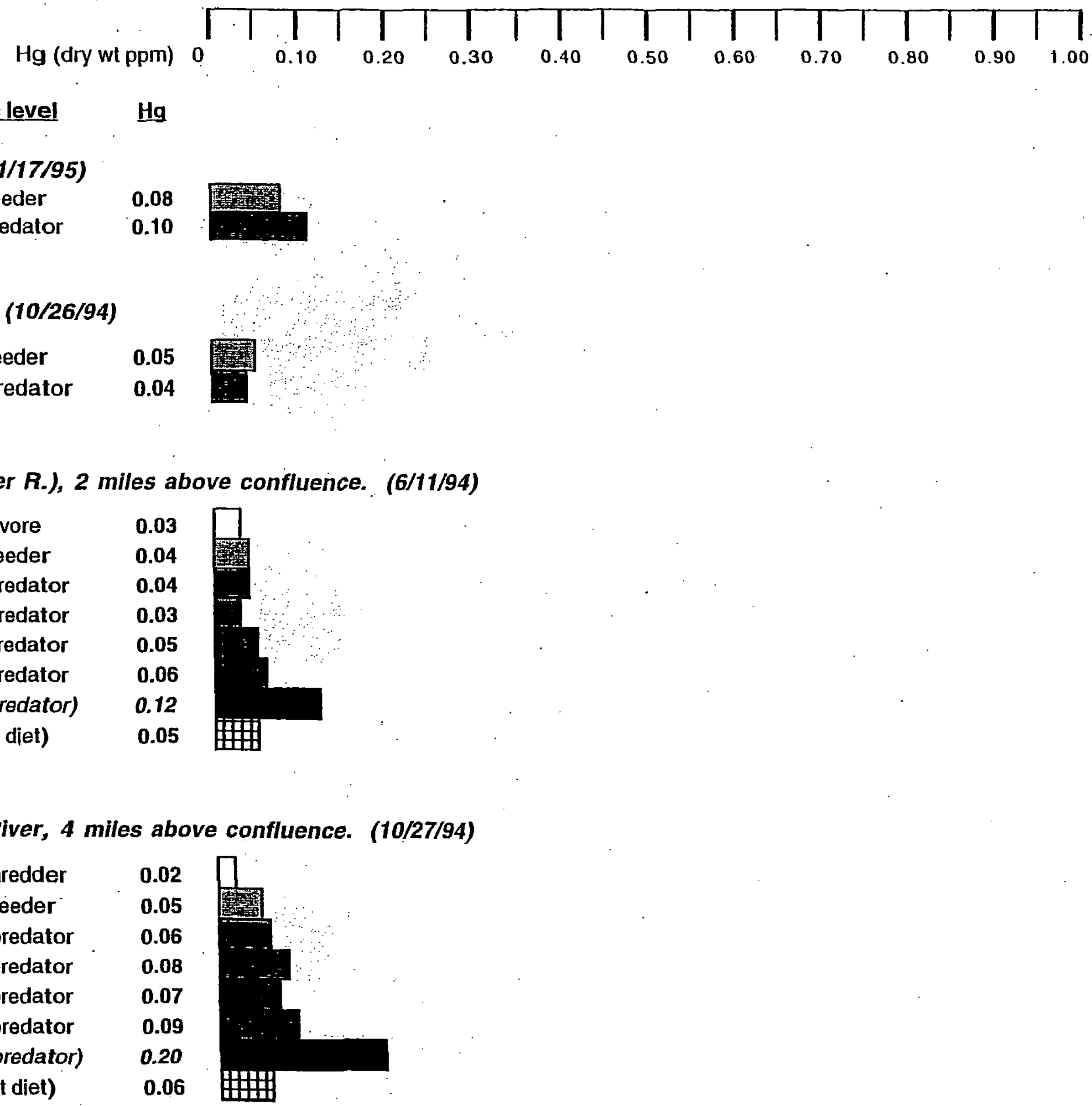


Table 2. (continued)

Hg (dry wt ppm) scale: 0, 0.10, 0.20, 0.30, 0.40, 0.50, 0.60, 0.70, 0.80, 0.90, 1.00

5. East Branch of North Fork Feather River,10 miles above confluence with Caribou Branch. (10/26/94)

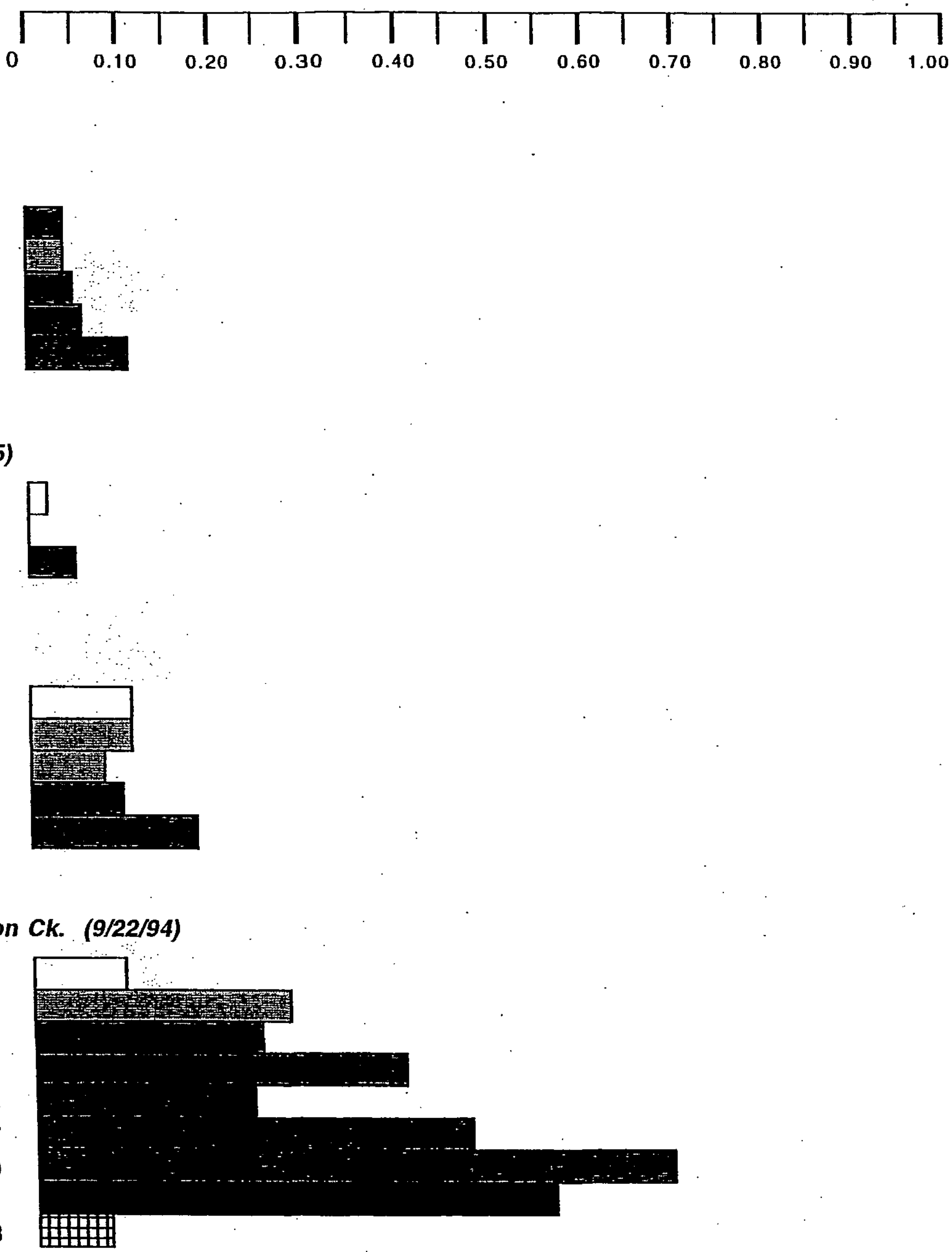
identification	trophic level	Hg
Hydropsychidae (net caddis)	drift feeder	0.07
Rhyacophyllidae (pred. caddis)	small predator	0.15
Perlidae-Dark sp (Hesperoperla)	small predator	0.15
Mean 250 g Trout (dry ppm)	*(insect predator)*	*0.24*
(trout diet)	(trout diet)	0.05

6. Indian Creek, tributary to E Branch N Fk Feather River, 7 miles above confluence. (9/27/94)

identification	trophic level	Hg
Oligoneuriidae (mayfly)	herbivore	0.05
Hydropsychidae (net caddis)	drift feeder	0.07
Damsefly nymphs	small predator	0.08
Perlidae (golden stonefly)	small predator	0.15
Rhyacophyllidae (pred. caddis)	small predator	0.18
Mean 250 g Trout (dry ppm)	*(insect predator)*	*0.14*
(trout diet)	(trout diet)	0.04

7. Spanish Creek, tributary to E Branch N Fk Feather River, 2 miles above confluence. (8/26/94)

identification	trophic level	Hg
Ptilodactyllidae (lg aq beetle nymph)	herbivore	0.08
Rhyacophyllidae (pred. caddis)	small predator	0.20
Damsefly nymphs	small predator	0.28
Perlidae (golden stonefly)	small predator	0.35
Gomphidae (dragonfly)	large predator	0.24
Corydallidae (hellgrammite)	large predator	0.30
Mean 250 g Trout (dry ppm)	*(insect predator)*	*0.51*
(trout diet)	(trout diet)	0.10



identification	trophic level	Hg
8. S Branch M Fk Feather at M Fk Feather. (11/21/95)		
Peltoperlidae (lg/giant)	herb/detritiv	**0.04**
Hydropsychidae (giant)	drift feeder	**0.03**
Perlidae--Callineuria (med/Lg)	small predator	**0.05**
Perlidae--Hesperoperla (lg)	small predator	**0.06**
Hellgrammite (med/lg)	large predator	**0.11**
9. Little N Fk M Fk Feather at M Fk Feather R. (11/21/95)		
Peltoperlidae (med/lg/giant)	herb/detritiv	**0.02**
Hydropsychidae (giant)	drift feeder	**0.00**
Perlidae (lg/giant)	small predator	**0.05**
10. M Fk Feather River at Milsap Bar. (11/21/95)		
Peltoperlidae (med/lg)	herb/detritiv	**0.11**
Hydropsychidae (med)	drift feeder	**0.11**
Hydropsychidae (giant)	drift feeder	**0.08**
Perlidae--Callineuria (lg)	small predator	**0.10**
Perlidae--Hesperoperla (lg)	small predator	**0.18**
11. Middle Fork Feather River, 1 mile below below Nelson Ck. (9/22/94)		
Pteronarcyidae	leaf shredder	**0.10**
Hydropsychidae (net caddis)	drift feeder	**0.28**
Rhyacophyllidae (pred. caddis)	small predator	**0.25**
Perlidae (golden stonefly)	small predator	**0.40**
Gomphidae (dragonfly)	large predator	**0.24**
Corydallidae (hellgrammite)	large predator	**0.47**
Tipulidae (cranefly)	large predator	**0.69**
Mean 250 g Trout (dry ppm)	*(insect predator)*	***0.56***
(trout diet)	(trout diet)	**0.08**

Table 2. (continued)

Hg (dry wt ppm) 0 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

12. Nelson Creek, tributary to Middle Fork Feather River, 1 mile above confluence. (9/21/94)

identification	trophic level	Hg
Limnephilidae (stone case caddis)	herbivore	0.05
Perlidae (golden stonefly)	small predator	0.13
Corydallidae (hellgrammite)	large predator	0.15
Tipulidae (cranefly)	large predator	0.16
Mean 250 g Trout (dry ppm)	*(insect predator)*	*0.40*
(trout diet)	(trout diet)	0.05

13. Upper Middle Fork Feather River, 3 miles upstream of Clio. (9/23/94)

identification	trophic level	Hg
Oligoneuriidae (mayfly)	herbivore	0.03
Hydropsychidae (net caddis)	drift feeder	0.08
Damselfly Nymphs	small predator	0.13
Rhyacophyllidae (pred. caddis)	small predator	0.16
Mean 250 g Trout (dry ppm)	*(insect predator)*	*0.68*
(trout diet)	(trout diet)	0.07

14. Fall River (Feather River trib). (11/20/95)

identification	trophic level	Hg
Pteronarcyidae (med/Lg)	leaf shredder	0.01
Mixed Mayflies (lg)	herbivore	0.03
Peltoperlidae (lg/giant)	herb/detritiv	0.05
Hydropsychidae (giant)	drift feeder	0.09
Perlidae-Callineuria (lg/giant)	small predator	0.09
Gomphidae (lg)	large predator	0.13
Hellgrammite (sm)	large predator	0.25
Hellgrammite (med/lg)	large predator	0.11

identification	trophic level	Hg
15. South Fk Feather River. (11/20/95)		
Mayflies (lg)	herbivore	0.02
Hydropsychidae (giant)	drift feeder	0.00
Peltoperlidae (giant)	herb/detritiv	0.04
Perlidae-Callineuria (lg)	small predator	0.06
Perlidae-Callineuria (giant)	small predator	0.07
Perlidae-Hesperoperla (lg)	small predator	0.06
Hellgrammite (sm)	large predator	0.12
Hellgrammite (med)	large predator	0.09
16. Lower Yuba River below Englebright Reservoir, at University of California field station. (12/16/93)		
Ephemerellidae (mayfly)	herbivore	0.07
Hydropsychidae (net caddis)	drift feeder	0.12
Perlodidae (stonefly)	small predator	0.07
Tipulidae (cranefly)	large predator	0.18
Mean 250 g Trout (dry ppm)	*(insect predator)*	*0.42*
17. North Fk / Middle Fk Yuba River below Colgate inflow. (4/24/95)		
Pteronarcyidae-sm	leaf shredder	0.04
Mayflies	herbivore	0.10
Hydropsychidae	drift feeder	0.16
Perlodidae-sm	small predator	0.13
Perlidae-lg	small predator	0.39
Hellgrammites-lg	large predator	0.97
Hellgrammites-giant	large predator	0.68

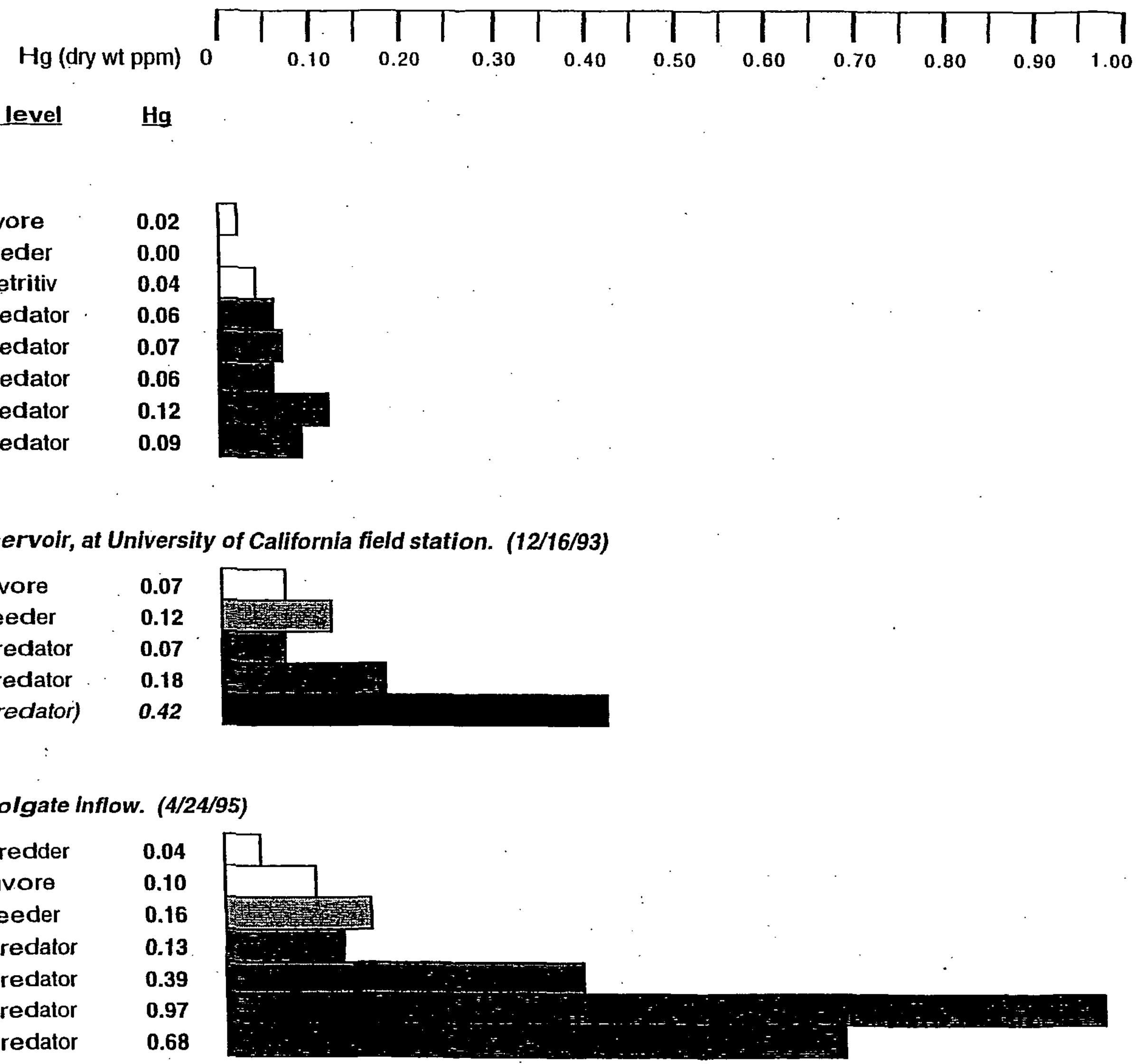


Table 2. (continued)

Hg (dry wt ppm) 0 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

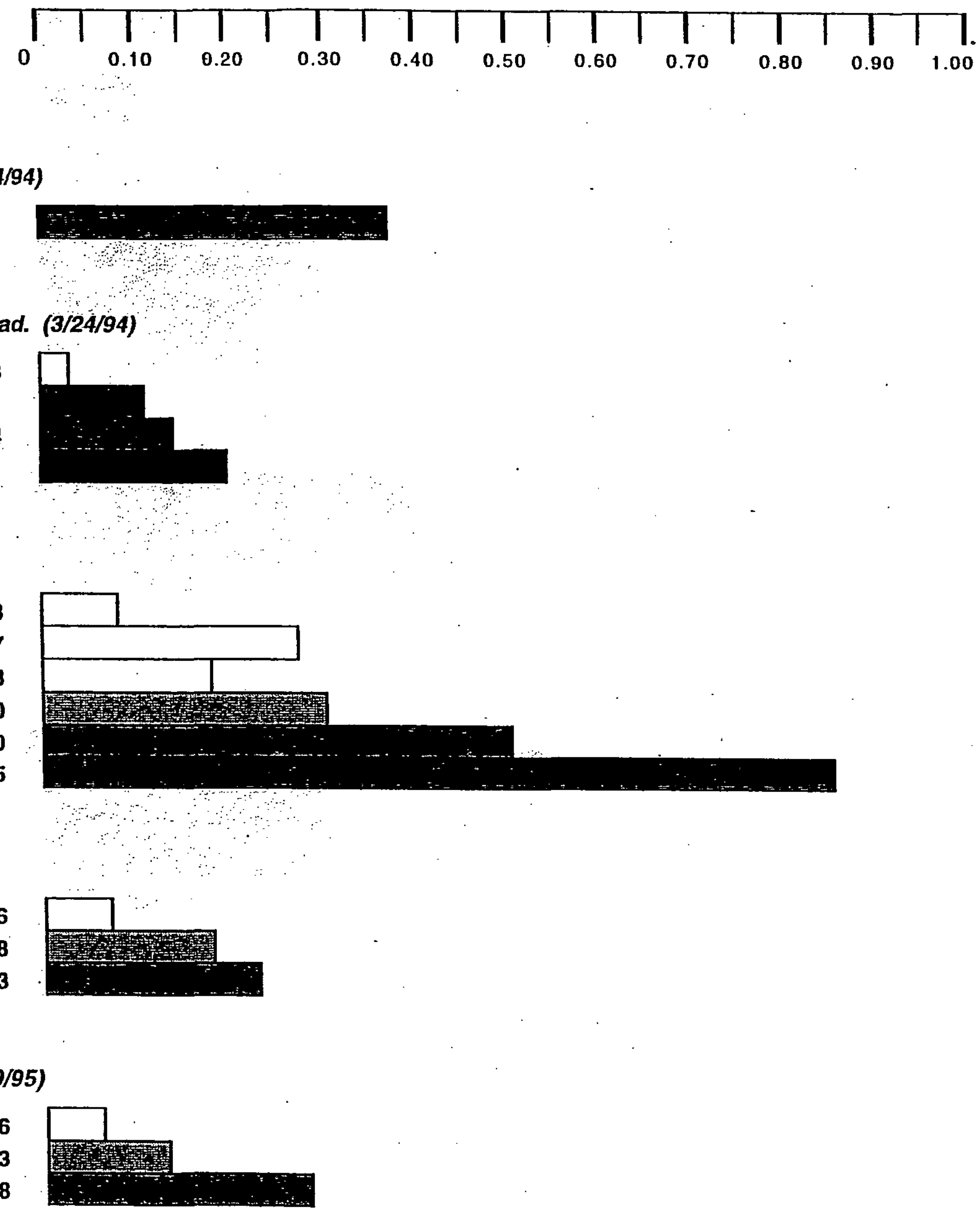
identification	trophic level	Hg
18. North Fork Yuba River constrained (low) flow below New Bullard's Bar Reservoir. (3/15/94)		
Hydropsychidae (net caddis)	drift feeder	**0.08**
Perlidae (golden stonefly)	small predator	**0.11**
Corydallidae (hellgrammite)	large predator	**0.33**
19. Canyon Creek, tributary to N Fk Yuba, just above confluence. (11/6/93)		
Hydropsychidae (net caddis)	drift feeder	**0.10**
Perlidae (golden stonefly)	small predator	**0.16**
Corydallidae (hellgrammite)	large predator	**0.27**
20. North Fork Yuba River, 2 miles downstream of westmost Highway 49 crossing. (11/5/93)		
Pteronarcyidae (giant stonefly)	leaf shredder	**0.05**
Hydropsychidae (net caddis)	drift feeder	**0.24**
Perlidae (golden stonefly)	small predator	**0.25**
Tipulidae	large predator	**0.38**
Mean 250 g Trout (dry ppm)	*(insect predator)*	***0.50***
21. Downie River, tributary to N FK Yuba, at Downieville. (11/2/93)		
Hydropsychidae (net caddis)	drift feeder	**0.10**
Perlodidae (stonefly)	small predator	**0.11**
Perlidae (golden stonefly)	small predator	**0.11**
Tipulidae (cranefly)	large predator	**0.19**
Corydallidae (hellgrammite)	large predator	**0.22**
Mean 250 g Trout (dry ppm)	*(insect predator)*	***0.45***

Table 2. (continued)

Hg (dry wt ppm) 0 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

identification	trophic level	Hg
22. Middle Fork Yuba River, just upstream of Colgate inflow. (11/16/95)		
Pteronarcyidae (sm)	leaf shredder	0.04
Pteronarcyidae (Lg)	leaf shredder	0.11
Hydropsychidae	drift feeder	0.20
Perlodidae (med/Lg)	small predator	0.18
Perlidae (Lg)	small predator	0.25
Damsel nymphs	small predator	0.27
Hellgrammites (sm/Med)	large predator	0.57
Hellgrammites (Lg/giant)	large predator	0.41
23. Oregon Creek at Middle Fk Yuba. (11/9/95)		
Ptilodactylidae (lg)	herbivore	0.09
Hydropsychidae	drift feeder	0.17
Perlidae-Callineuria (med/Lg)	small predator	0.32
Tipulidae (lg)	large predator	0.53
24. Middle Fork Yuba River, just upstream of Oregon Creek and Highway 49 crossing. (10/21/93)		
Pteronarcyidae (giant stonefly)	leaf shredder	0.10
Perlidae (golden stonefly)	small predator	0.45
Mean 250 g Trout (dry ppm)	*(insect predator)*	*0.87*
Mean 250 g Squawfish	*(fish predator)*	*1.87*
25. Middle Fork Yuba River, 1 mile upstream of Tyler Foote crossing. (10/19/93)		
Pteronarcyidae (giant stonefly),1 yr	leaf shredder	0.05
Pteronarcyidae; large (2 yr)	leaf shredder	0.06
Hydropsychidae (net caddis)	drift feeder	0.33
Perlidae (golden stonefly)	small predator	0.38
Gomphidae (dragonfly)	large predator	0.39
Mean 250 g Trout (dry ppm)	*(insect predator)*	*0.66*

Table 2. (continued)



identification	trophic level	Hg
26. Kanaka Ck (Middle Fork Yuba trib) near M Fk Yuba. (10/14/94)		
Corydalidae	large predator	**0.37**
27. Middle Fork Yuba River, 1 mile upstream of Plumbago Road. (3/24/94)		
Peltoperlidae (stonefly)	herbivore	**0.03**
Perlidae (golden stonefly)	small predator	**0.11**
Corydallidae (hellgrammite)	large predator	**0.14**
Mean 250 g Trout (dry ppm)	*(insect predator)*	***0.20***
28. South Fork Yuba River at Bridgeport. (4/24/95)		
Pteronarcyidae-sm	leaf shredder	**0.08**
Mayflies	herbivore	**0.27**
Ptilodactylidae	herbivore	**0.18**
Hydropsychidae	drift feeder	**0.30**
Perlidae	small predator	**0.50**
Hellgrammites-lg	large predator	**0.85**
29. South Fork Yuba River at Hwy 49. (11/10/95)		
Pteronarcyidae (sm/med)	leaf shredder	**0.06**
Hydropsychidae	drift feeder	**0.18**
Perlidae (med/Lg)	small predator	**0.23**
30. South Fork Yuba River at Purdon Crossing. (11/10/95)		
Pteronarcyidae (lg)	leaf shredder	**0.06**
Hydropsychidae	drift feeder	**0.13**
Perlidae-Callineuria (med/lg)	small predator	**0.28**

Table 2. (continued)

Hg (dry wt ppm) 0 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

31. South Fork Yuba River at Edward's Crossing. (10/4/95)

identification	trophic level	Hg
Mayflies	herbivore	0.08
Pteronarcyidae-sm	leaf shredder	0.09
Pteronarcyidae-lg	leaf shredder	0.09
Hydropsychidae-sm/med	drift feeder	0.25
Perlidae-sm	small predator	0.28
Perlidae-med	small predator	0.32
Perlidae-large	small predator	0.37
Hellgrammite-med	large predator	0.55

32. South Fork Yuba River, 1 mile downstream of Washington. (11/12/93)

identification	trophic level	Hg
Pteronarcyidae (giant stonefly)	leaf shredder	0.08
Hydropsychidae (net caddis)	drift feeder	0.18
Perlidae (golden stonefly)	small predator	0.30
Corydallidae (hellgrammite)	large predator	0.44
Mean 250 g Trout (dry ppm)	*(insect predator)*	*0.94*

33. South Fork Yuba River below Lake Spaulding. (10/24/95)

identification	trophic level	Hg
Perlidae (m/Lg)	small predator	0.24
Gomphidae (med)	large predator	0.24
Tipulidae (med/lg)	large predator	0.31
Hellgrammites (sm/med)	large predator	0.32

34. South Fork Yuba River 2 miles above Lake Spaulding. (10/25/95)

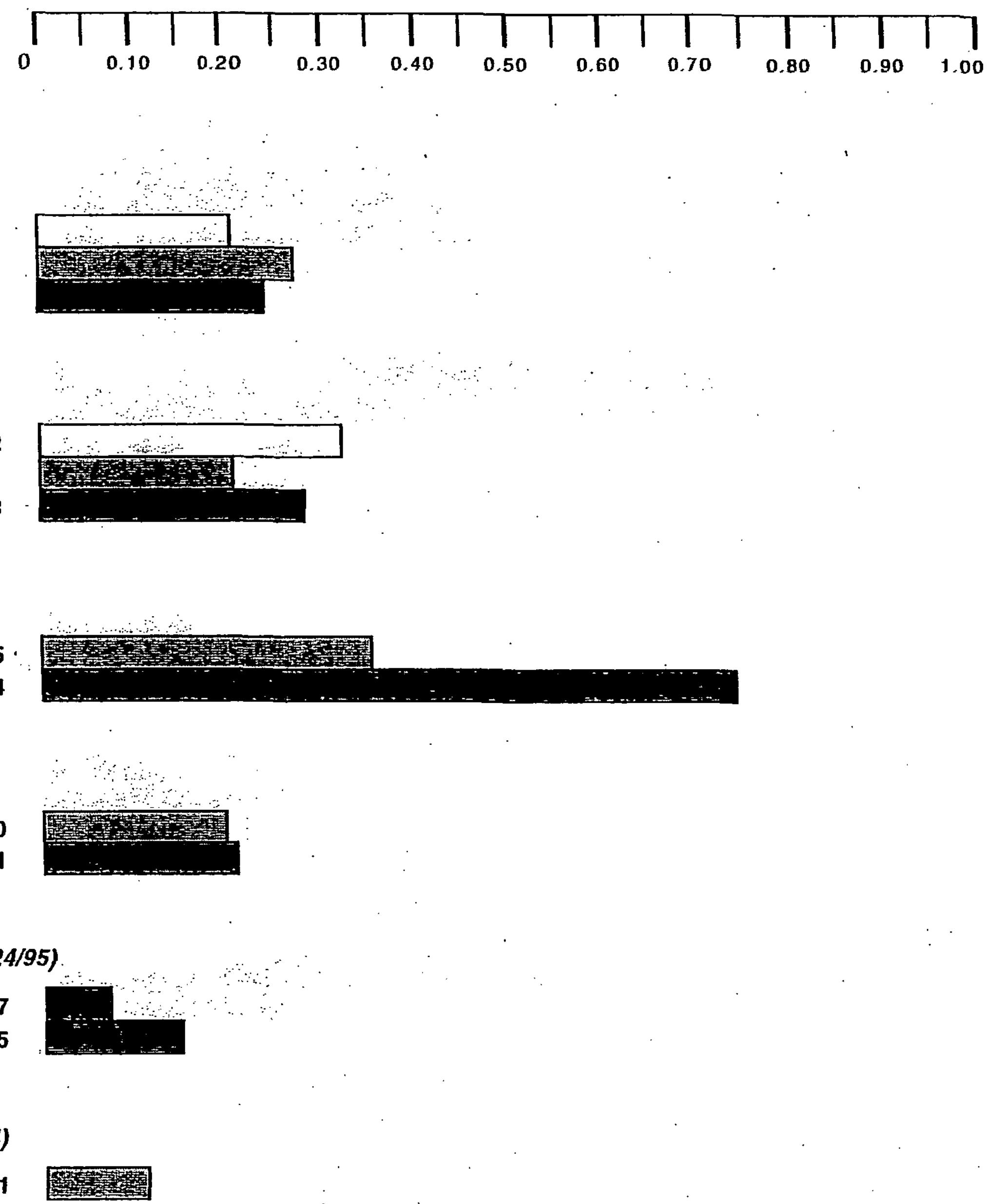
identification	trophic level	Hg
Hydropsychidae (giant)	drift feeder	0.11
Perlidae (med/lg)	small predator	0.22

Table 2. (continued)

Hg (dry wt ppm) 0 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

identification	trophic level	Hg
35. Deer Creek below Lake Wildwood, at Mooney Flat Road. (12/9/94)		
Hydropsychidae (net caddis)	drift feeder	0.30
Corydallidae (hellgrammite)	large predator	0.55
36. Deer Creek at Bittney Spring Road. (12/9/94)		
Hydropsychidae (net caddis)	drift feeder	0.23
Perlidae (golden stonefly)	small predator	0.22
Tipulidae (cranefly)	large predator	0.16
37. Bear River below Camp Far West Reservoir. (12/8/94)		
Hydropsychidae (net caddis)	net collector	0.17
38. Bear River at Highway 49 crossing. (12/7/94)		
Hydropsychidae (net caddis)	drift feeder	0.29
Rhyacophyllidae (pred. caddis)	small predator	0.34
Perlidae-Dark sp (Hesperoperla)	smallpredator	0.69
Corydallidae (hellgrammite)	large predator	0.77
39. Wolf Creek, tributary to Bear River, 2 miles above confluence. (12/7/94)		
Hydropsychidae (net caddis)	drift feeder	0.46
Perlodidae (stonefly)	small predator	0.44
Tipulidae (cranefly)	large predator	0.35

Table 2. (continued)



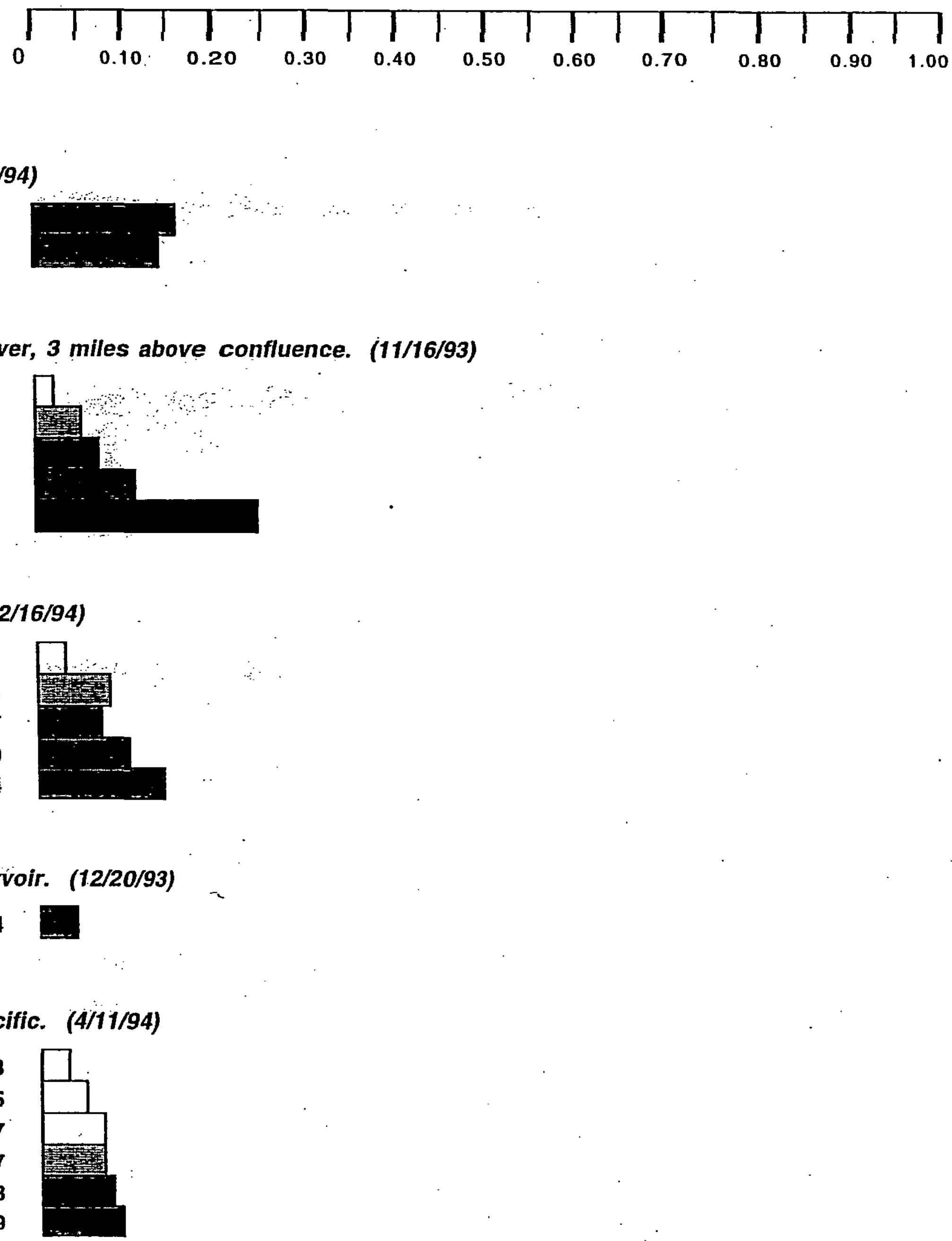
identification	trophic level	Hg
40. Bear River below Rollins Reservoir. (10/12/95)		
Peltoperlidae (med/lg)	small predator	0.21
Hydropsychidae	drift feeder	0.27
Perlidae-Hesperoperla (Med/lg)	small predator	0.24
41. Greenhorn Creek (Bear River trib). (10/13/95)		
Peltoperlidae (med/lg)	small predator	0.32
Hydropsychidae	drift feeder	0.21
Damselfly Nymphs	small predator	0.28
42. Steephollow Creek (Bear River trib). (10/13/95)		
Hydropsychidae	drift feeder	0.35
Perlidae (med/lg)	small predator	0.74
43. Bear River above Rollins Reservoir. (10/13/95)		
Hydropsychidae	drift feeder	0.20
Perlidae-Callineuria (med/Lg)	small predator	0.21
44. Bear River headwaters near Lake Spaulding. (10/24/95)		
Perlidae (med/Lg)	small predator	0.07
Hellgrammites (lg)	large predator	0.15
45. Lower American River at Howe Avenue. (12/16/94)		
Hydropsychidae (net caddis)	drift feeder	0.11

Table 2. (continued)

Scale: Hg (dry wt ppm) 0, 0.10, 0.20, 0.30, 0.40, 0.50, 0.60, 0.70, 0.80, 0.90, 1.00

identification	trophic level	Hg
46. Lower American River, 1 mile below Lake Natoma. (12/16/94)		
Hydropsychidae (net caddis)	drift feeder	**0.11**
47. North Fork American River in vicinity of Humbug Bar. (11/19/93)		
Pteronarcyidae (giant stonefly)	leaf shredder	**0.02**
Hydropsychidae (net caddis)	drift feeder	**0.04**
Perlidae-Gold sp (Callineuria)	small predator	**0.05**
Perlidae-Dark sp (Hesperoperla)	small predator	**0.06**
Gomphidae (dragonfly)	large predator	**0.07**
Mean 250 g Trout (dry ppm)	*(insect predator)*	***0.27***
48. Middle Fork American River below Oxbow Reservoir. (2/25/94)		
Pteronarcyidae (giant stonefly)	leaf shredder	**0.02**
Perlodidae (stonefly)	herbivore	**0.05**
Perlidae (golden stonefly)	small predator	**0.09**
Mean 250 g Trout (dry ppm)	*(insect predator)*	***0.20***
950 g Brown Trout (dry ppm)	*(fish predator)*	***1.68***
49. North Fork of the Middle Fk American River, 1 mile above confluence. (3/2/94)		
Pteronarcyidae (giant stonefly)	leaf shredder	**0.05**
Perlidae (golden stonefly)	small predator	**0.18**
Mean 250 g Trout (dry ppm)	*(insect predator)*	***0.55***
50. Rubicon River, tributary to Middle Fork American River, just above confluence. (2/1/94)		
Pteronarcyidae (giant stonefly)	leaf shredder	**0.02**
Perlodidae (stonefly)	herbivore	**0.03**
Hydropsychidae (net caddis)	drift feeder	**0.05**
Perlidae (golden stonefly)	small predator	**0.07**

Table 2. (continued)



identification	trophic level	Hg
51. Middle Fork American River at "End of World". (2/1/94)		
Perlidae (golden stonefly)	small predator	**0.16**
Corydallidae (hellgrammite)	large predator	**0.14**
52. Duncan Creek, tributary to Middle Fork American River, 3 miles above confluence. (11/16/93)		
Peltoperlidae (stonefly)	herbivore	**0.02**
Hydropsychidae (net caddis)	drift feeder	**0.05**
Perlidae (golden stonefly)	small predator	**0.07**
Corydallidae (hellgrammite)	large predator	**0.11**
Mean 250 g Trout (dry ppm)	*(insect predator)*	***0.24***
53. South Fork American River above Folsom Lake. (12/16/94)		
Pteronarcyidae	leaf shredder	**0.03**
Hydropsychidae (net caddis)	drift feeder	**0.08**
Perlodidae- Osobenus	small predator	**0.07**
Perlidae-Gold sp (Callineuria)	small predator	**0.10**
Perlidae-Dark sp (Hesperoperla)	small predator	**0.14**
54. South Fork American River below Slab Creek Reservoir. (12/20/93)		
Perlidae (golden stonefly)	small predator	**0.04**
55. South Fork American River, 1 mile upstream of Pacific. (4/11/94)		
Heptageneidae (mayfly)	herbivore	**0.03**
Ephemerellidae (mayfly)	herbivore	**0.05**
Ptilodactylidae (lg aq beetle nymph)	herbivore	**0.07**
Hydropsychidae (net caddis)	drift feeder	**0.07**
Perlidae-Gold sp (Callineuria)	small predator	**0.08**
Perlidae-Dark sp (Hesperoperla)	small predator	**0.09**

Table [illegible] (continued)

Hg (dry wt ppm) 0 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

56. North Fork Cosumnes River just above M Fk confluence. (7/30/95)

identification	trophic level	Hg
Pteronarcyidae-sm	leaf shredder	0.12
Hydropsychidae-med	drift feeder	1.62
Perlidae-med	small predator	2.02
Gomphidae	large predator	0.90
Hellgrammite-sm	large predator	1.23

57. North Fork Cosumnes River at Mt. Aukum Rd. (12/20/93)

identification	trophic level	Hg
Pteronarcyidae (giant stonefly)	leaf shredder	0.05
Ptilodactylidae (lg aq beetle nymph)	herbivore	0.20
Perlodidae (stonefly)	herbivore	0.21
Perlidae-Dark sp (Hesperoperla)	small predator	0.38
Perlidae-Gold sp (Callineuria)	small predator	0.52
Gomphidae (dragonfly)	large predator	0.60

TABLE 3. Mercury Data From Individual Fish

wt (g)	Length (mm)	Sex	Muscle ppm Hg	Liver ppm Hg
2. Yellow Ck (off N Fk Feather River), 6/11/94				
107 g	197	f	0.02	
150 g	230	m	0.02	
210 g	257	f	0.02	
245 g	270	f	0.03	
280 g	285	f	0.03	
280 g	288	m	0.03	
315 g	297	f	0.03	
normalized 250 g trout muscle (wet wt ppm Hg):			*0.03*	
normalized 250 g trout muscle (dry wt ppm Hg):			*0.12*	
3. Caribou N Fk Feather River, 10/27/94				
75 g	190	m	0.03	
115 g	223	f	0.03	
120 g	223	m	0.02	
210 g	266	m	0.04	
240 g	274	m	0.04	
normalized 250 g trout muscle (wet wt ppm Hg):			*0.04*	
normalized 250 g trout muscle (dry wt ppm Hg):			*0.20*	
4. E Branch N Fk Feather River, 10/26/94				
75 g	193	m	0.04	
160 g	248	m	0.03	
207 g	266	f	0.04	
423 g	348	m	0.05	
515 g	370	f	0.07	
627 g	385	f	0.12	
normalized 250 g trout muscle (wet wt ppm Hg):			*0.05*	
normalized 250 g trout muscle (dry wt ppm Hg):			*0.24*	
5. Indian Ck (Trib, E Branch N Fk Feather River), 9/27/94				
151 g	242	f	0.03	
153 g	243	f	0.02	
335 g	304	m	0.03	
normalized 250 g trout muscle (wet wt ppm Hg):			*0.03*	
normalized 250 g trout muscle (dry wt ppm Hg):			*0.14*	

TABLE 3. (continued)

wt (g)	Length (mm)	Sex	Muscle ppm Hg	Liver ppm Hg
6. Spanish Ck (Trib, E Branch N Fk Feather River), 9/26/94				
139 g	241	f	0.10	
133 g	238	m	0.13	
164 g	250	f	0.06	
185 g	258	f	0.09	
285 g	298	f	0.06	
normalized 250 g trout muscle (wet wt ppm Hg):			*0.11*	
normalized 250 g trout muscle (dry wt ppm Hg):			*0.51*	
11. Middle Fk Feather River (Below Nelson Ck), 9/22/94				
74 g	195	m	0.12	
109 g	223	?	0.09	
137 g	238	m	0.10	
170 g	245	m	0.17	
273 g	294	m	0.09	
normalized 250 g trout muscle (wet wt ppm Hg):			*0.12*	
normalized 250 g trout muscle (dry wt ppm Hg):			*0.56*	
12. Nelson Ck (Tributary to M Fk Feather River), 9/21/94				
60 g	185	?	0.07	
160 g	245	m	0.07	
230 g	292	f	0.09	
305 g	304	f	0.10	
340 g	325	m	0.23	
430 g	338	f	0.06	
normalized 250 g trout muscle (wet wt ppm Hg):			*0.09*	
normalized 250 g trout muscle (dry wt ppm Hg):			*0.40*	
13. Upper Middle Fk Feather River, Above Clio, 9/23/94				
70 g	176	m	0.09	
112 g	210	m	0.08	
144 g	222	f	0.10	
137 g	224	f	0.14	
174 g	245	f	0.17	
normalized 250 g trout muscle (wet wt ppm Hg):			*0.15*	
normalized 250 g trout muscle (dry wt ppm Hg):			*0.68*	

TABLE 3. (continued)

wt (g)	Length (mm)	Sex	Muscle ppm Hg	Liver ppm Hg
16. Lower Yuba below Engelbright Reservoir, 12/16/93				
170 g	235	f	0.09	0.11
235 g	274	m	0.13	0.09
255 g	272	f	0.07	0.08
400 g	314	f	0.10	0.09
440 g	329	m	0.07	0.08
565 g	370	m	0.11	0.06
860 g	408	f	0.13	0.09
910 g	417	m	0.12	0.08
1040 g	434	m	0.12	0.07
normalized 250 g trout muscle (wet wt ppm Hg):			*0.09*	
normalized 250 g trout muscle (dry wt ppm Hg):			*0.42*	
20. North Fork Yuba River Near Canyon Creek, 11/5/93				
145 g	236	f	0.14	0.16
200 g	270	f	0.09	0.08
300 g	306	f	0.10	0.10
320 g	314	f	0.11	0.13
340 g	311	m	0.10	0.07
normalized 250 g trout muscle (wet wt ppm Hg):			*0.11*	
normalized 250 g trout muscle (dry wt ppm Hg):			*0.50*	
19. Canyon Creek at N Fk Yuba, 11/6/93				
305 g	294	m	0.11	0.10
21. Downie River (tributary of N Fk Yuba), 11/2/93				
55 g	176	m	0.04	0.04
85 g	195	m	0.06	0.04
150 g	239	f	0.08	0.06
155 g	243	m	0.06	0.05
410 g	356	f	0.15	0.13
465 g	348	m	0.07	0.06
normalized 250 g trout muscle (wet wt ppm Hg):			*0.10*	
normalized 250 g trout muscle (dry wt ppm Hg):			*0.45*	

wt (g)	Length (mm)	Sex	Muscle ppm Hg	Liver ppm Hg
24. Middle Fork Yuba above Oregon Creek, 10/21/93				
Rainbow Trout				
100 g	204	f	**0.15**	0.12
260 g	260	m	**0.21**	0.19
250 g	278	f	**0.17**	0.20
normalized 250 g trout muscle (wet wt ppm Hg):			***0.19***	
normalized 250 g trout muscle (dry wt ppm Hg):			***0.87***	
Squawfish				
370 g	321	m	**0.56**	0.33
480 g	339	f	**0.81**	0.42
25. Middle Fork Yuba above Kanaka Creek, 10/93				
94 g	210	m	**0.10**	0.09
130 g	235	f	**0.12**	0.10
135 g	237	m	**0.12**	0.09
150 g	240	m	**0.13**	0.12
320 g	298	m	**0.13**	0.19
375 g	320	f	**0.20**	0.17
505 g	368	m	**0.21**	(Lost Liver)
515 g	363	m	**0.24**	0.30
615 g	387	m	**0.21**	0.19
normalized 250 g trout muscle (wet wt ppm Hg):			***0.15***	
normalized 250 g trout muscle (dry wt ppm Hg):			***0.66***	
27. Middle Fork Yuba above Plumbago Rd, 3/24/94				
270 g	292	f	**0.05**	0.04
380 g	346	f	**0.06**	0.06
580 g	385	m	**0.12**	0.08
710 g	391	f	**0.12**	0.09
730 g	415	f	**0.19**	0.20
normalized 250 g trout muscle (wet wt ppm Hg):			***0.05***	
normalized 250 g trout muscle (dry wt ppm Hg):			***0.20***	

TABLE 3. (continued)

wt (g)	Length (mm)	Sex	Muscle ppm Hg	Liver ppm Hg
32. South Fork Yuba at Washington, 11/12/93				
20 g	112	?	0.14	(not analyzed)
70 g	183	f	0.13	0.11
70 g	186	?	0.12	0.14
85 g	195	?	0.12	0.15
90 g	200	m	0.11	0.13
90 g	201	?	0.11	0.13
90 g	207	f	0.12	0.16
100 g	205	?	0.11	0.12
135 g	234	m	0.10	0.12
140 g	230	m	0.13	0.15
150 g	237	f	0.11	0.13
230 g	274	f	0.22	0.22
310 g	305	f	0.26	0.35
450 g	345	f	0.30	0.48
normalized 250 g trout muscle (wet wt ppm Hg):			*0.21*	
normalized 250 g trout muscle (dry wt ppm Hg):			*0.94*	
33. South Fork Yuba below Lake Spaulding, 10/24/95				
Rainbow Trout				
22 g	131		0.04	
75 g	180		0.06	
85 g	190		0.08	
130 g	228		0.11	
normalized 250 g trout muscle (wet wt ppm Hg):			*0.12*	
normalized 250 g trout muscle (dry wt ppm Hg):			*0.56*	
Brown Trout				
125 g	224		0.07	
190 g	248		0.07	
34. South Fork Yuba above Lake Spaulding, 10/24/95				
Brown Trout				
99 g	208	f	0.06	
101 g	211	f	0.09	
155 g	247	f	0.08	
189 g	264	f	0.06	
normalized 250 g trout muscle (wet wt ppm Hg):			*0.09*	
normalized 250 g trout muscle (dry wt ppm Hg):			*0.43*	
40. Bear River below Rollins Reservoir, 10/13/95				
101 g	209		0.16	

TABLE 3. (continued)

wt (g)	Length (mm)	Sex	Muscle ppm Hg	Liver ppm Hg
47. North Fork American River above Humbug Bar, 11/19/93				
110 g	216	f	0.03	0.02
140 g	237	f	0.05	0.03
150 g	245	m	0.03	0.03
595 g	384	m	0.15	0.14
normalized 250 g trout muscle (wet wt ppm Hg):			*0.06*	
normalized 250 g trout muscle (dry wt ppm Hg):			*0.27*	
48. Middle Fk American River Below Oxbow Reservoir, 2/25/94				
Rainbow Trout				
295 g	297	f	0.05	0.04
330 g	308	f	0.06	0.05
335 g	313	f	0.06	0.05
385 g	327	f	0.06	0.05
385 g	332	f	0.04	0.05
400 g	334	m	0.07	0.05
normalized 250 g trout muscle (wet wt ppm Hg):			*0.04*	
normalized 250 g trout muscle (dry wt ppm Hg):			*0.20*	
Brown Trout				
965 g	452	f	0.37	0.67
49. N Fk Middle Fk American River--Middle Fk up to Skunk Ck, 3/2/94				
90 g	211	f	0.11	0.08
120 g	227	f	0.10	0.08
160 g	247	f	0.11	0.07
normalized 250 g trout muscle (wet wt ppm Hg):			*0.12*	
normalized 250 g trout muscle (dry wt ppm Hg):			*0.55*	

section of the Middle Fork of the Feather River (Site 11). These sites were among those noted in the course of the study as having the greatest current mining activity. They also include some of the historically most intensively mined regions. Low mercury concentrations (≤ 0.06 mg kg^{-1}, normalized) were found in trout from many tributaries of the Feather and American rivers, as well as upstream of the major mining activity along the Middle Fork of the Yuba River. Fish from the North Fork of the Middle Fork of the American River (Site 49) and Spanish Creek (Site 7), a tributary to the North Fork Feather River, were relatively higher in mercury as compared to adjacent sites in their watersheds. When converted to units of dry weight parts per million, the 250 g normalized trout mercury concentrations of this study range from a low of 0.14 mg kg^{-1} to a high of 0.94 mg kg^{-1}. These data are used in Table 2 for comparison with the invertebrate data, which are reported on a dry weight basis.

Several collections of piscivorous squawfish and adult brown trout were made during the course of the study. Being largely fish eaters, these species feed at a higher trophic level, as compared to mid-sized rainbow trout which feed primarily on a mix of aquatic and terrestrial insects. The piscivorous fish contained significantly higher concentrations of mercury than rainbow trout from the same locations (Table 3). At the Middle Fork Yuba River site near Oregon Creek, squawfish contained 0.41 mg kg^{-1} muscle mercury in same sized fish, as compared to rainbow trout which had 0.19 mg kg^{-1} (both on a wet weight basis). At the Middle Fork American River Site below Oxbow Reservoir, a large (965 g) brown trout was taken which had muscle mercury at 0.37 mg kg^{-1}, while a comprehensive sample of rainbow trout from the same river stretch had muscle mercury at only 0.05 mg kg^{-1}. The correlation between trophic feeding level and mercury concentration is also apparent in the data from Duncan Creek (Site 52), the South Fork American River at Slab Creek Reservoir (Site 54), and Sites 33 and 34 on the upper section of the South Fork Yuba River (Table 3). At these sites, samples of small (< 250 g) rainbow and brown trout were taken together. At these sizes, the species are both insectivorous. Mercury concentrations were found to be identical at these sites between the two species.

The relationship between muscle mercury and liver mercury was investigated in the first year of the study. The data are presented together with muscle mercury data in Table 3. Generally, the liver mercury concentrations in these fish were very similar to corresponding muscle mercury levels. Mean liver mercury from 77 rainbow and small brown trout was 97.9% of corresponding muscle mercury concentrations, with a standard deviation of 23.5%. We have found, in other research, that liver mercury is frequently 150-200% of muscle mercury in extremely polluted sites, such as Coast Range lakes and reservoirs in the historic mercury mining district of California (Slotton 1991). These liver data, together with the lower absolute tissue mercury concentrations, indicate a relatively more moderate level of mercury bioavailability in the Sierra gold district as compared to the Coast Range mercury mining districts.

Trout stomach contents were analyzed for mercury at a subset of the sampling sites. These data are displayed in Table 2 together with other trophic mercury data for each site. The food item mercury data was generally reflective of corresponding stream invertebrate mercury levels. In the several cases where food item mercury was considerably lower than corresponding stream invertebrate mercury, it was noted that terrestrial insects dominated the stomach contents. The diets of insectivorous rainbow trout and young brown trout naturally demonstrate temporal shifts in the percentage of terrestrial forms, in conjunction with changes in availability.

Stream Invertebrates

Aquatic invertebrates were taken at each of the 57 sites. Approximately 250 separate invertebrate composite samples were collected, identified, processed, and analyzed for mercury in the research reported here. The sites varied considerably in invertebrate diversity and types present. The most consistently available groups were drift feeding caddisfly nymphs of the family Hydropsychidae (omnivores), stonefly nymphs of the family Perlidae (small-item predators), and hellgrammites of the family Corydalidae (large-item predators). The lowest trophic feeding level of stream invertebrates taken, herbivorous species, were represented by a variety of families, with Pteronarcyid stoneflies being the most frequently taken. A variety of mayfly species represented this trophic level at a number of sites. Additional herbivores included large beetle larvae of the family Ptilodactylidae. The omnivore/drift collector feeding level was represented exclusively by Hydropsychid caddis nymphs, which were widespread throughout much of the region. The invertebrate small-item predator trophic level included Rhyacophyllid caddis nymphs, Perlodid stoneflies, and damselfly nymphs in addition to the Perlid stoneflies which were most generally available. In addition to Corydalid hellgrammite nymphs, the larger-item invertebrate predator trophic level also included large predaceous dipteran larvae of the family Tipulidae and Gomphid dragonfly nymphs.

The invertebrate mercury data are presented in Table 2 and Figures 5-8. The table includes data from each of the samples, while averaging techniques were utilized to derive single trophic level values in the map figures. The averaging methods used are described above in the Methods section. Mercury was detected at ≥ 0.01 mg kg^{-1} (ppm) in all invertebrate samples taken throughout the Sierra Nevada gold country. Inter-site mercury differences were generally consistent among all invertebrate (and trout) trophic levels, with low mercury sites demonstrating low biotic Hg levels throughout the food web and sites with high biotic Hg in one group typically having elevated Hg levels in all co-occurring organisms.

Similar to the trout results, notably elevated mercury in stream invertebrates was found at sites along the Middle and South Forks of the Yuba River, and the Middle Fork of the Feather

River. Also as found for trout, invertebrates from the mid section of the Middle Fork Feather River (Site 11), the North Fork of the Middle Fork of the American River (Site 49) and Spanish Creek (Site 7), a tributary to the North Fork Feather River, were relatively higher in mercury as compared to adjacent sites in their watersheds. Relatively low mercury concentrations (≤ 0.15 mg kg^{-1}, dry weight) were found in all trophic levels of invertebrates from most tributaries of the Feather and American rivers, as well as upstream of the major mining activity along the Middle and South Forks of the Yuba River, similar to co-occurring trout.

Invertebrates were also sampled exclusively at 36 sites where trout were not present in sufficient quantities for adequate collections. These invertebrate-only collections identified a number of additional notably elevated mercury streams, including sites throughout the Bear River watershed mining region (Sites 38-42), the Cosumnes River (Sites 56 and 57), and Deer Creek (Site 35). Other invertebrate-only collections indicated relatively low mercury bioavailability at sites where trout were not present or readily collectable, including the Feather River downstream of Lake Oroville (Site 1), several additional tributaries of the Feather River (Sites 8, 9, 14, 15), the lower American River below Folsom Lake (Sites 45 and 46), the South Fork of the American River (sites 53-55), the Rubicon River (site 50), and the Bear River below Camp Far West Reservoir (site 37). Similar to the reduced mercury results found in fish above the gold mining stretches of the forks of the Yuba River, benthic invertebrate samples of all types from the relatively pristine headwaters sample on the Bear River (Site 44) were far lower in mercury concentration than corresponding samples taken from within and below the major mining elevations (Sites 38-42).

Notably lower invertebrate mercury concentrations were found below many of the foothill reservoirs, as compared to concentrations in similar biota upstream. Specifically, the invertebrates below New Bullard's Bar Reservoir (station 18) were considerably lower in mercury than those collected upstream of the reservoir on the North Fork of the Yuba River (station 20). Hydropsychid net caddis nymphs were 0.08 ppm in their dry weight mercury concentration below the dam, as compared to 0.24 ppm upstream of the reservoir. Perlid stoneflies were 0.11 ppm below, 0.25 ppm above, and Corydalid hellgrammites were 0.33 below vs 0.50 above. Similarly, the invertebrates collected below Englebright Reservoir (station 16) were consistently far lower in mercury than samples collected upstream of the reservoir on the Middle and South Forks of the Yuba River (sites 22, 24, 25, 28-32). On the Bear River, Hydropsychid net caddis larvae ranged from 0.21 to 0.46 ppm Hg (mean = 0.32 ppm) at sites in the mining region above Camp Far West Reservoir (sites 38-42), as compared to 0.17 ppm in extensive, replicate collections from below the dam.

Collections from the Feather River valley site below Lake Oroville (Site 1) and the American River below Folsom Lake (Sites 45 and 46) were similar to samples taken upstream in these relatively low mercury watersheds. Deer Creek was unique in demonstrating significantly higher biotic mercury accumulation below a reservoir (Lake Wildwood) as compared to above (Site 35 vs 36). While both sites were relatively elevated, the higher levels found below Lake Wildwood may result from historic downstream movement of gold mining mercury in this small drainage. The lack of significant modern barriers to downstream mercury migration may be of particular concern on the Cosumnes River (Sites 56 and 57), where the very highest levels of biotic mercury accumulation were observed.

Trophic level relationships to mercury accumulation

A pattern of increasing mercury concentrations in progressively higher trophic levels was found at the majority of sites (Figure 3, Table 2). In Figures 11 and 12 we summarize the food-chain mercury data from 19 sites where trout were sampled, normalized to 250 g rainbow trout muscle concentrations at each of the sites. In Figure 11, the normalized invertebrate data are plotted with 95% confidence intervals for trophic guilds vs trout, and in Figure 12 the dominant single family or genus of each guild is used. The means and confidence intervals are similar with either analysis.

A relatively predictable pattern results, with the highest trophic level stream invertebrates having mercury concentrations approximately half those seen in normalized 250 g trout from the same sites. Among the invertebrates, herbivorous species as a group consistently had the lowest mercury concentrations (averaging 14% of those found in co-existing trout). Low mercury levels in herbivore species was not a function of age and, thus, time of exposure. Similar low concentrations were found in Pteronarcyid stoneflies up to three years old, as well as in annual mayflies. Predaceous invertebrates accumulated considerably higher concentrations. Relatively small predators such as nymphs of Perlid stoneflies, Rhyacophyllid caddisflies, and damselflies had mercury concentrations averaging 38% of the concentrations in corresponding normalized trout muscle, while the largest invertebrate predators, characterized by the large-jawed hellgrammites, averaged 47% of trout concentrations. Hydropsychid caddis nymphs, which were an important component of the invertebrate biomass at many of the sites, averaged 31% of corresponding trout in their mercury levels. This was lower than that of the larger invertebrate predators but considerably higher than the mercury concentrations seen in herbivores, suggesting that these nymphs, which feed by capturing drift in their nets, consume primarily other invertebrates rather than algal material. We believe that relative mercury concentrations in aquatic species may offer a useful tool for determining relative, time-integrated trophic feeding level.

In Figures 13-19, mercury concentrations in different trophic categories and types of invertebrates are plotted against corresponding trout mercury to determine relative correlations.

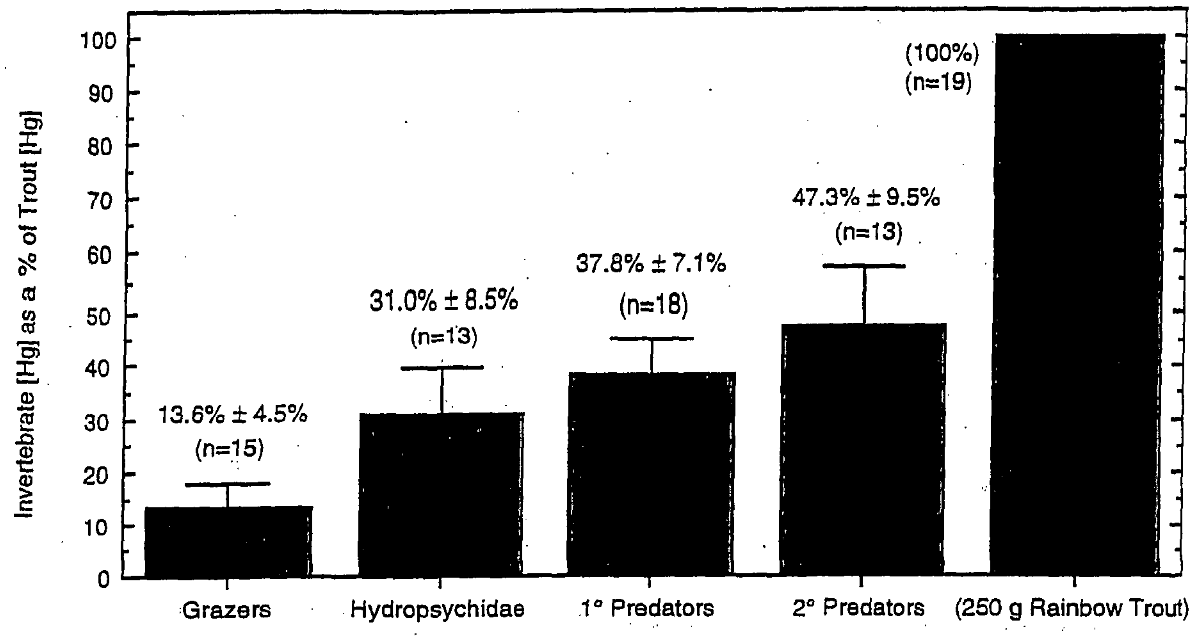


Fig. 11. Mercury in Invertebrate Trophic Groups--As a Proportion of Corresponding Fish Mercury, Among Sites With Sampled Fish

In units of dry wt parts per million Hg, together with 95% confidence intervals

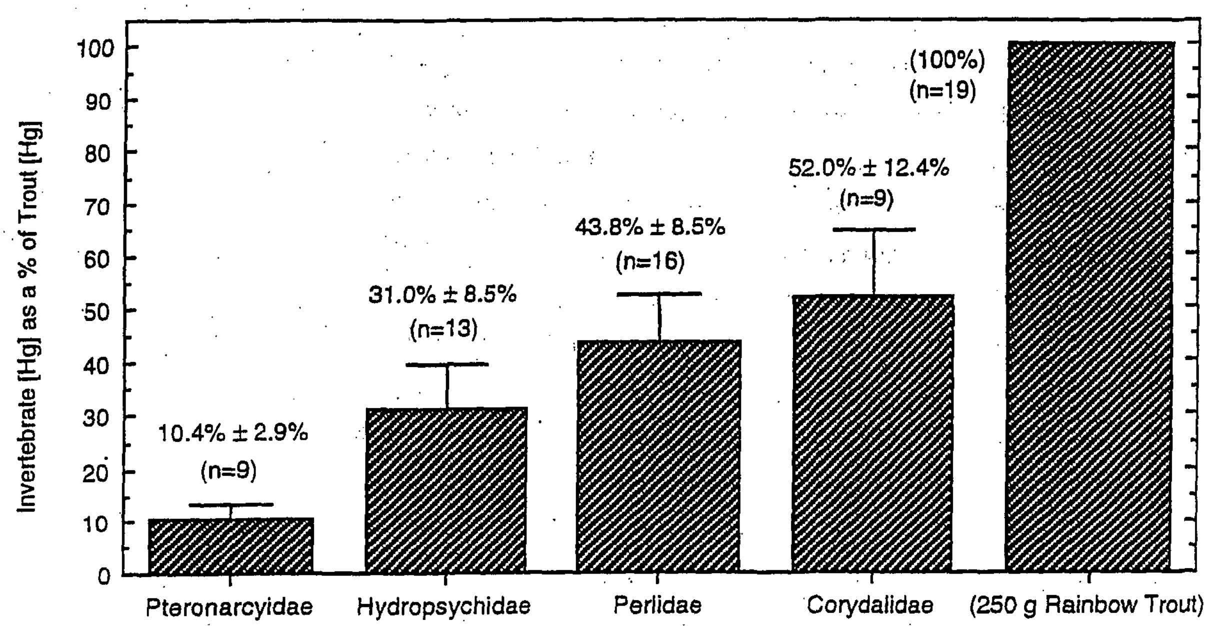


Fig. 12. Mercury in Individual Invertebrate Families--As a Proportion of Corresponding Fish Mercury, Among Sites With Sampled Fish

In units of dry wt parts per million Hg, together with 95% confidence intervals

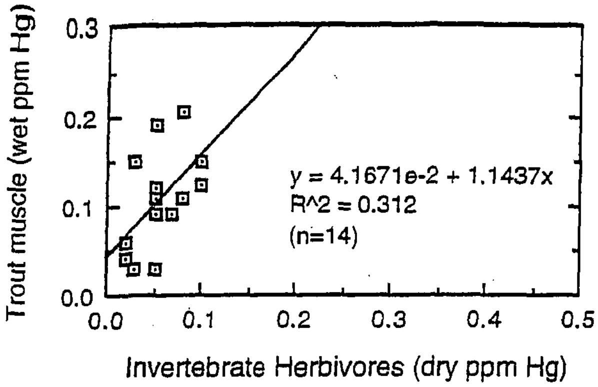


Fig. 13. Invertebrate Herbivores vs Trout

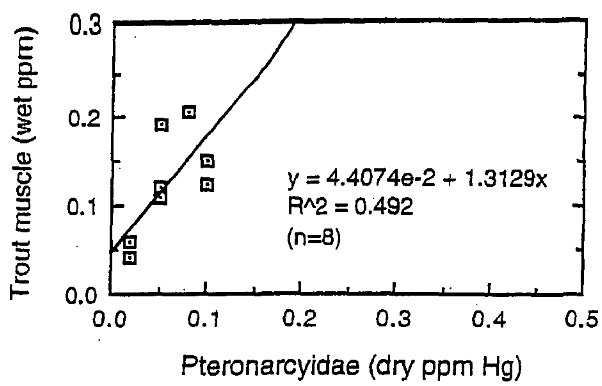


Fig. 14. Pteronarcyidae (Giant Herbivorous Stoneflies) vs Trout

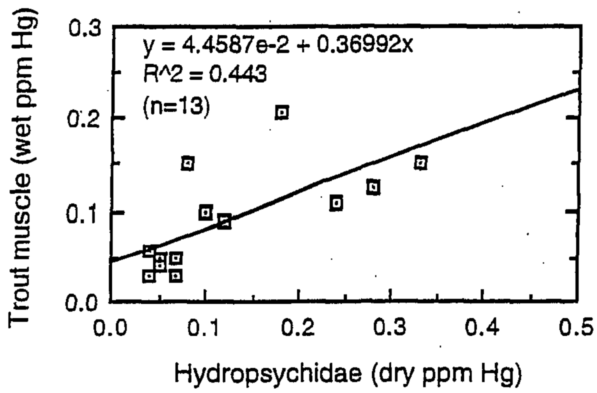


Fig. 15. Hydropsychidae (Net Collector Caddis) vs Trout

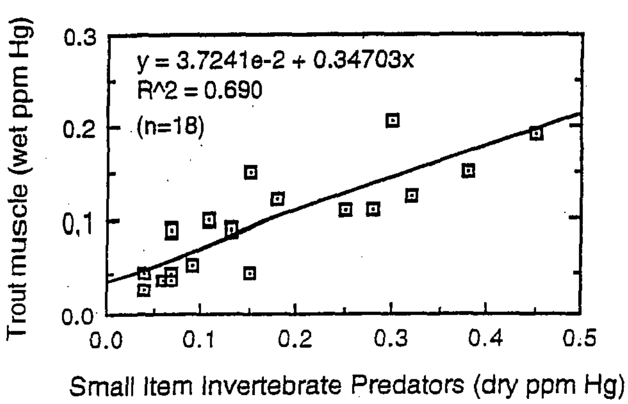


Fig. 16. Small Item Invertebrate Predators (Perlid Stoneflies, etc.) vs Trout

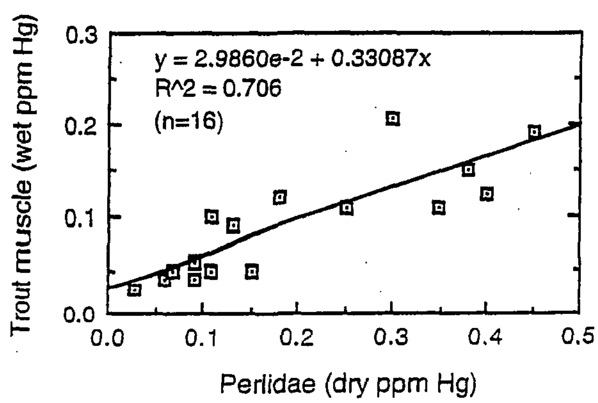


Fig. 17. Perlid Stoneflies vs Trout

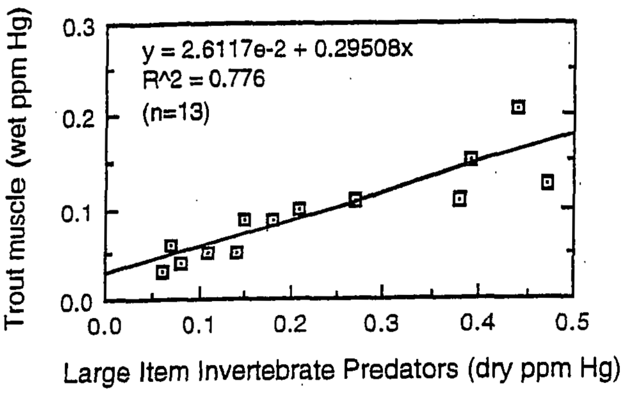


Fig. 18. Large Item Invertebrate Predators (Hellgrammites, etc.) vs Trout

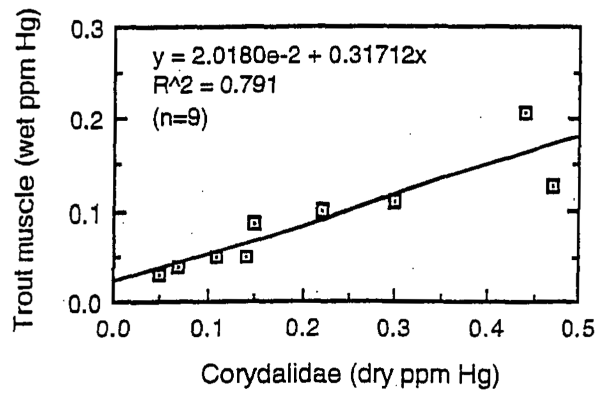


Fig. 19. Corydalid Hellgrammites vs Trout

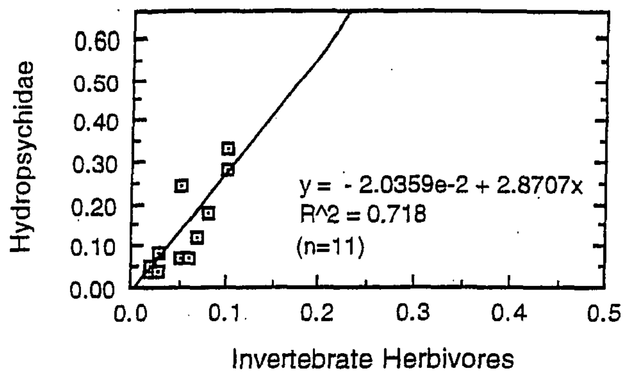


Fig. 20. Invertebrate Herbivores vs Hydropsychidae (Net Collector Caddis)

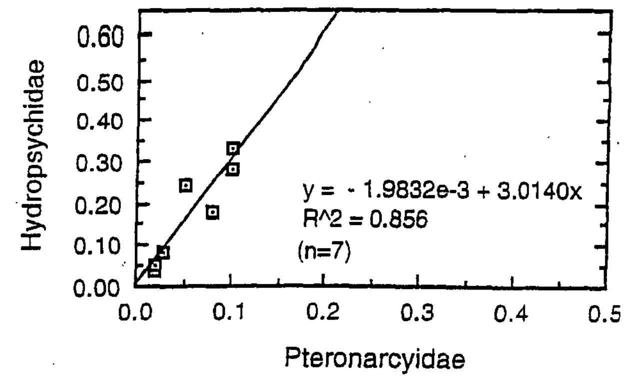


Fig. 21. Pteronarcyidae (Giant Herbivorous Stoneflies) vs Hydropsychidae (Net Collector Caddis

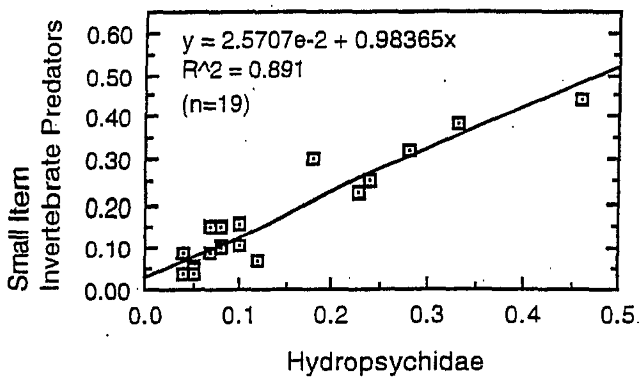


Fig. 22. Hydropsychidae (Net Collector Caddis) vs Small Item Predators (Perlid Stoneflies, etc.)

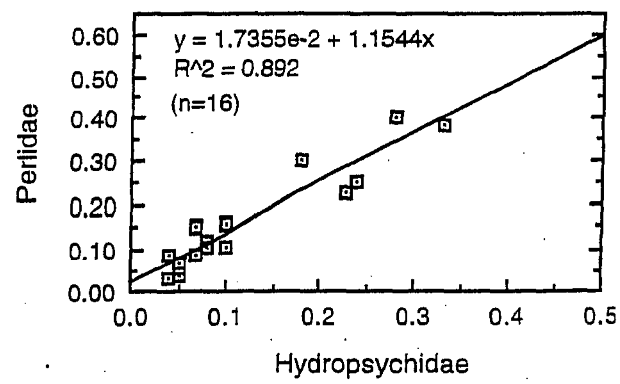


Fig. 23. Hydropsychidae (Net Collector Caddis) vs Perlidae (Predaceous Golden Stoneflies)

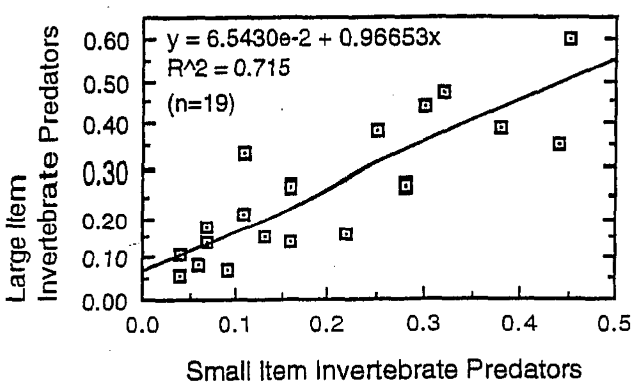


Fig. 24. Invertebrate Small Item Predators (Perlid Stoneflies, etc.) vs Large Item Predators (Hellgrammites, etc.)

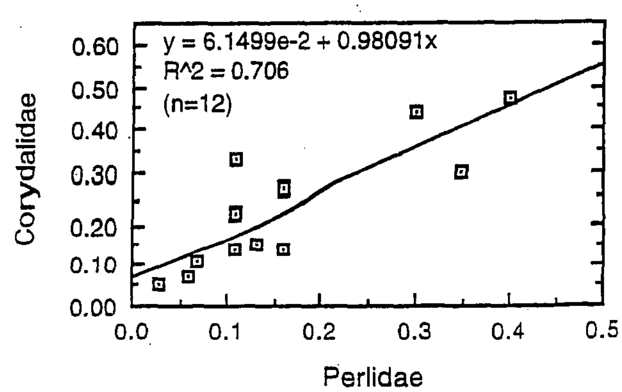


Fig. 25. Perlid Stoneflies vs Corydalid Hellgrammites

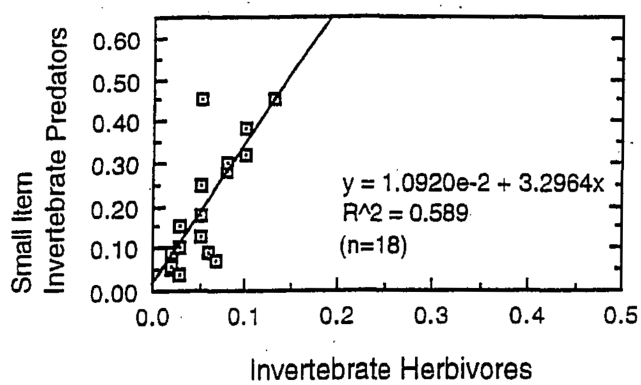


Fig. 26. Invertebrate Herbivores vs Small Item Predators (Perlid Stoneflies, etc.)

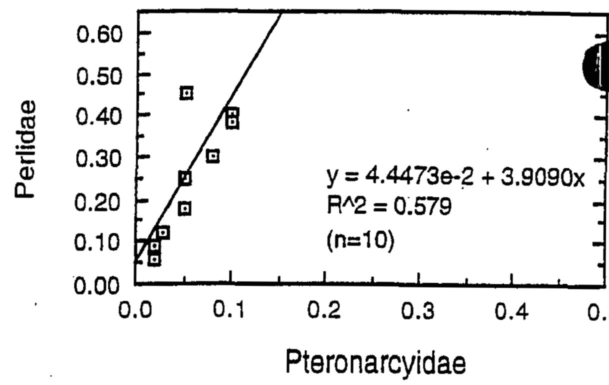


Fig. 27. Pteronarcyidae (Giant Herbivorous Stoneflies) vs Perlidae (Predaceous Golden Stoneflies)

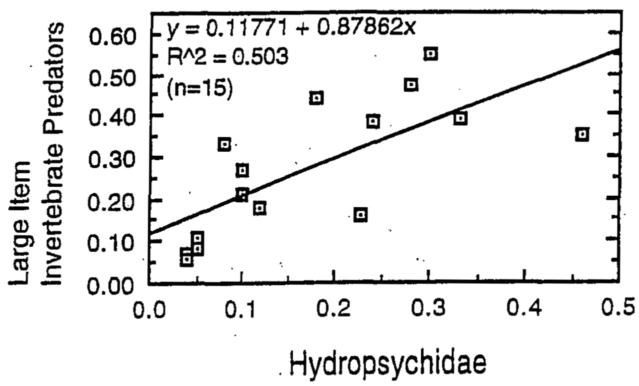


Fig. 28. Hydropsychidae (Net Collector Caddis) vs Large Item Invertebrate Predators (Hellgrammites, etc.)

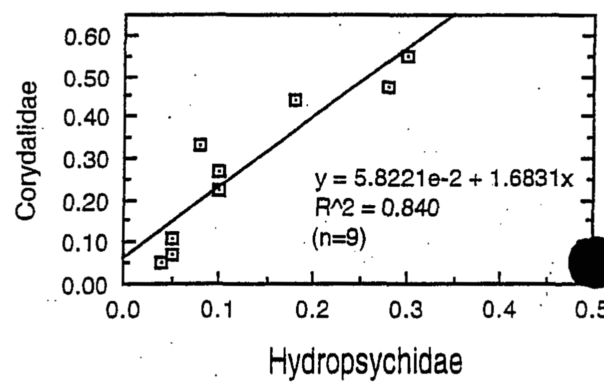


Fig. 29. Hydropsychidae (Net Collector Caddis) vs Corydalidae (Hellgrammites)

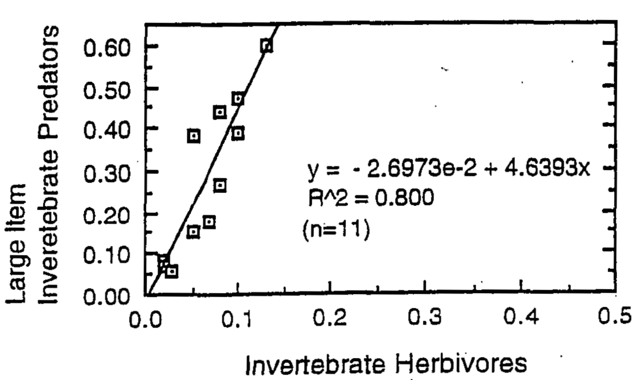


Fig. 30. Invertebrate Herbivores vs Large Item Predators (Hellgrammites, etc.)

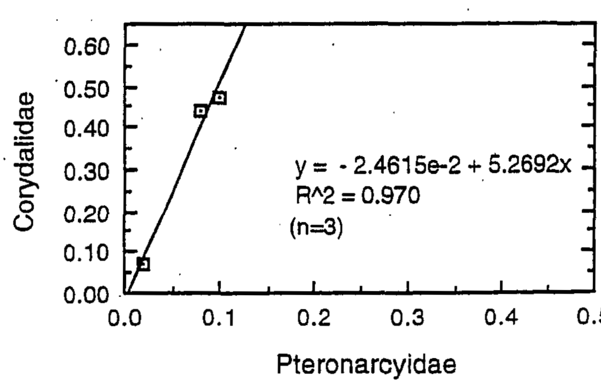


Fig. 31. Pteronarcyidae (Giant Herbivorous Stoneflies) vs Corydalidae (Hellgrammites)

Interestingly, the R^2 correlation coefficients between invertebrates and trout taken from the same sites increased steadily with increasing invertebrate trophic feeding level. Herbivores, as a group, demonstrated the weakest correlation with corresponding trout ($R^2 = 0.31$). Hydropsychid caddis nymphs had a stronger correlation ($R^2 = 0.44$). Small predaceous invertebrates such as Perlid stoneflies had considerably tighter correlations with trout ($R^2 = 0.69$), while the highest trophic level invertebrates, characterized by Corydalid hellgrammites, demonstrated the strongest correlations with corresponding trout ($R^2 = 0.78$). Correlations between individual invertebrate family or genus and trout (figures 11, 14, and 16) were generally not significantly stronger than those using grouped trophic guild members, though this may be partially a function of lower sample size for particular invertebrates.

In Figures 20-31, correlations in mercury concentration between invertebrates are plotted, first between adjacent trophic feeding levels (Figures 20-25) and finally between more distantly separated groups (Figures 26-31). As a set, these inter-invertebrate correlations were all quite high. R^2 correlation coefficients of 0.72-0.98 were found between adjacent trophic levels (Figures 20-25) and coefficients of 0.50-0.97 were found between non-adjacent but co-occurring trophic levels (Figures 26-31).

Biotic time series data

A series of 5 separate collections were made throughout 1995 and early 1996 at 3 index stations, to address the question of potential seasonal shifts in biotic mercury accumulation. Data are presented in Table 4. These sites corresponded to those also used for the intensive temporal series of water collections by Larry Walker and Associates, and were all adjacent to Englebright Reservoir. One site was located below the reservoir on the Lower Yuba River (Site 16), while the other two were situated immediately above the reservoir along the two major inflowing tributaries. Site 17 was an index station located just below the Colgate powerhouse on the Middle Fork Yuba River. The Colgate powerhouse is where the majority of flow from the North Fork Yuba River is diverted into the Middle Fork, piped from the bottom of New Bullards Bar Reservoir. The North Fork flow typically dominates the total flow at this point, though releases can be erratic. The final index station (Site 28) was located along the South Fork Yuba River at Bridgeport, just above Englebright Reservoir.

Sampling for this temporal series of invertebrate bioindicator collections occurred on April 24, June 30, August 15, and November 16 in 1995, and February 16, 1996. Composite collections of 3-7 different types of benthic invertebrates were made on each of the five dates at the lower Yuba site (16) and the site on the South Fork Yuba (28). However, at Site 17 below the Colgate powerhouse, only Hydropsychid caddisfly larvae were present on the August sampling

Table 4. Biota Mercury Data For Time Series Samplings at Above/Below Englebright Reservoir Index Stations

identification	trophic level	Hg (dry wt ppm)
16. Lower Yuba River at UC field station --1993 (12/16/93)		
Ephemerellidae (mayfly)	herbivore	0.07
Hydropsychidae (net caddis)	drift feeder	0.12
Perlodidae (stonefly)	small predator	0.07
Tipulidae (cranefly)	large predator	0.18
Mean 250 g Trout (dry ppm)	*(insect predator)*	*0.42*
16*. Lower Yuba River at UC field station. (4/24/95)		
Mixed Mayflies	herbivore	0.050
Hydropsychidae	drift feeder	0.140
Perlodidae-sm	small predator	0.113
Perlidae-giant	small predator	0.132
Tipulidae-lg	large predator	0.490
16**. Lower Yuba River at UC field station. (6/30/95)		
Mayflies	herbivore	0.018
Hydropsychidae	drift feeder	0.082
Perlodidae-tiny	Tiny Stoneflies	*(<0.01)*
Hellgrammite	large predator	0.231
16. Lower Yuba River at UC field station. (8/15/95)***		
Mayflies	herbivore	0.080
Hydropsychidae-sm/med	drift feeder	0.122
Hydropsychidae-lg	drift feeder	0.129
Beetle larvae	small predator	0.082
Perlodidae-sm/med	small predator	0.095
Perlidae-Callineuria-lg	small predator	0.108
Hellgrammite-med	large predator	0.273

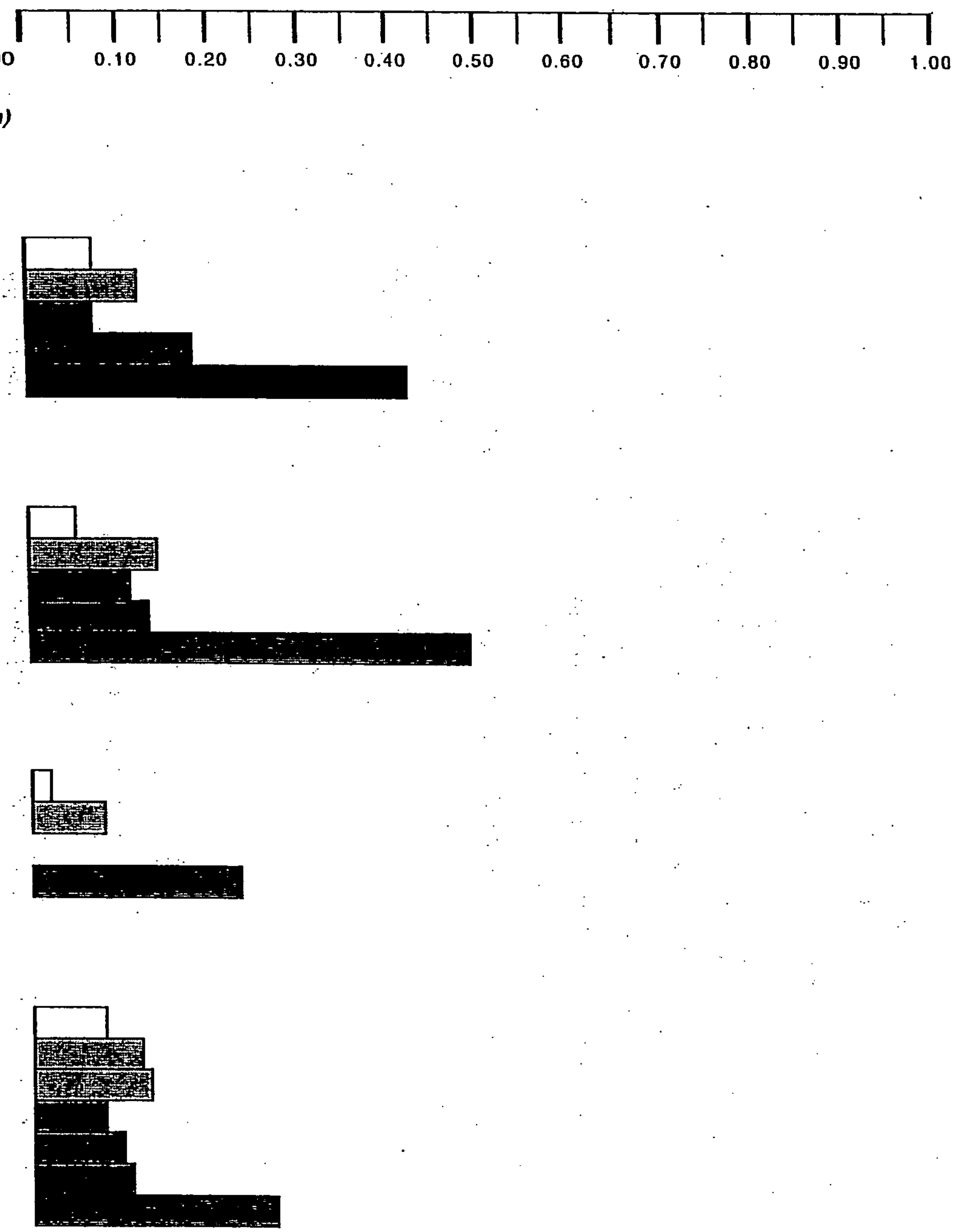
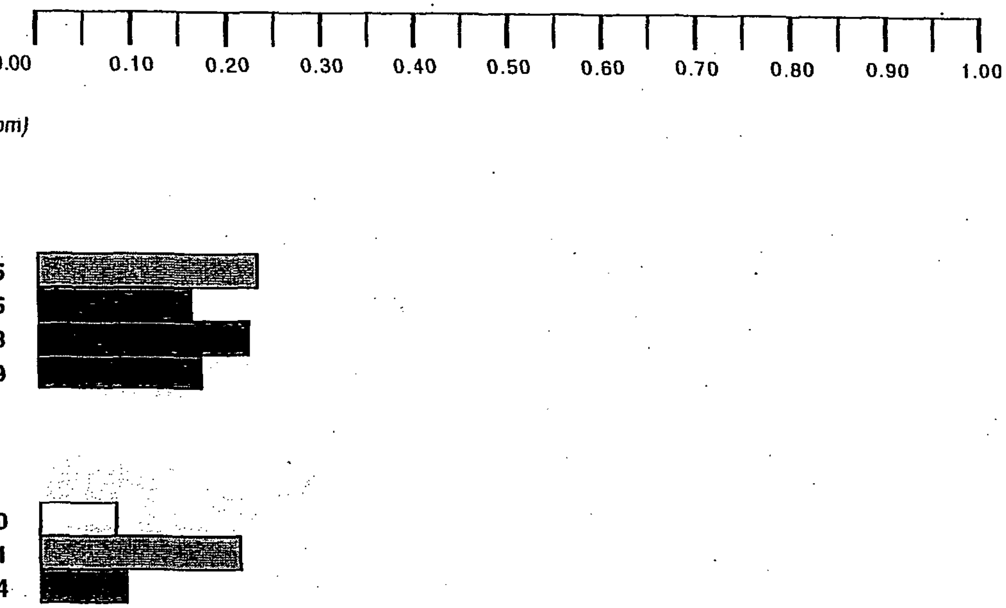


Table 4. (continued)



*16****. Lower Yuba River at UC field station. (11/16/95)*

identification	trophic level	Hg (dry wt ppm)
Hydropsychidae	drift feeder	0.225
Perlodidae-med/Lg	small predator	0.155
Perlidae-Hesperoperla-med/Lg	small predator	0.218
Perlidae-Hesperoperla-giant-2 yr	small predator	0.169

*16*****. Lower Yuba River at UC field station. (2/16/96)*

identification	trophic level	Hg (dry wt ppm)
Mixed Mayflies	herbivore	0.080
Hydropsychidae-med/lg	drift feeder	0.211
Perlodidae	small predator	0.094

Table 4. (continued)

Identification	trophic level	Hg (dry wt ppm)
17. N Fk / M Fk Yuba River below Colgate inflow. (4/24/95)		
Pteronarcyidae-sm	leaf shredder	0.040
Mayflies	herbivore	0.099
Hydropsychidae	drift feeder	0.163
Perlodidae-sm	small predator	0.130
Perlidae-lg	small predator	0.390
Hellgrammites-lg	large predator	0.970
Hellgrammites-giant	large predator	0.680
17*. N Fk / M Fk Yuba River below Colgate inflow. (6/30/95)		
Mayflies	herbivore	0.006
Hydropsychidae	drift feeder	0.094
Perlidae-sm	small predator	0.073
Perlidae-lg	small predator	0.031
Perlidae-giant	small predator	0.224
Hellgrammites-sm	large predator	0.314
Hellgrammites-lg	large predator	0.577
17**. N Fk / M Fk Yuba River below Colgate inflow. (8/15/95)		
Hydropsychidae	drift feeder	0.078

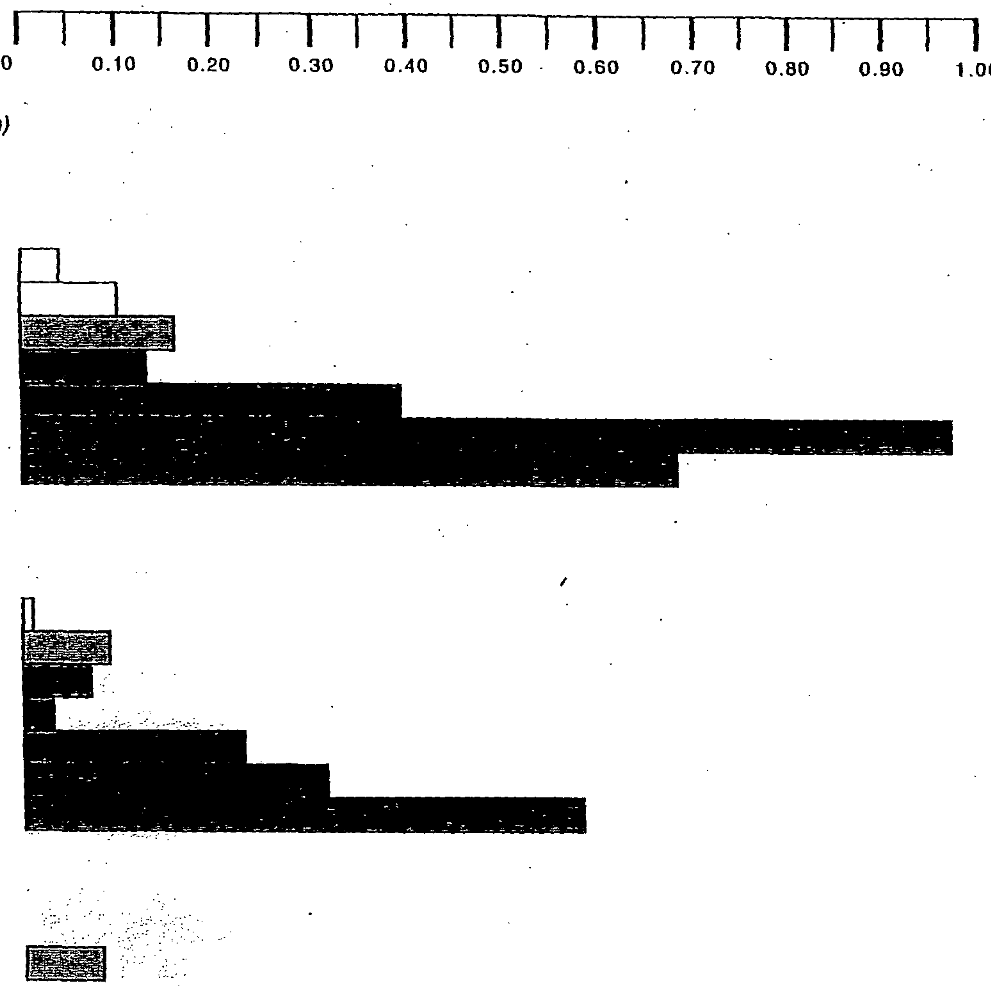
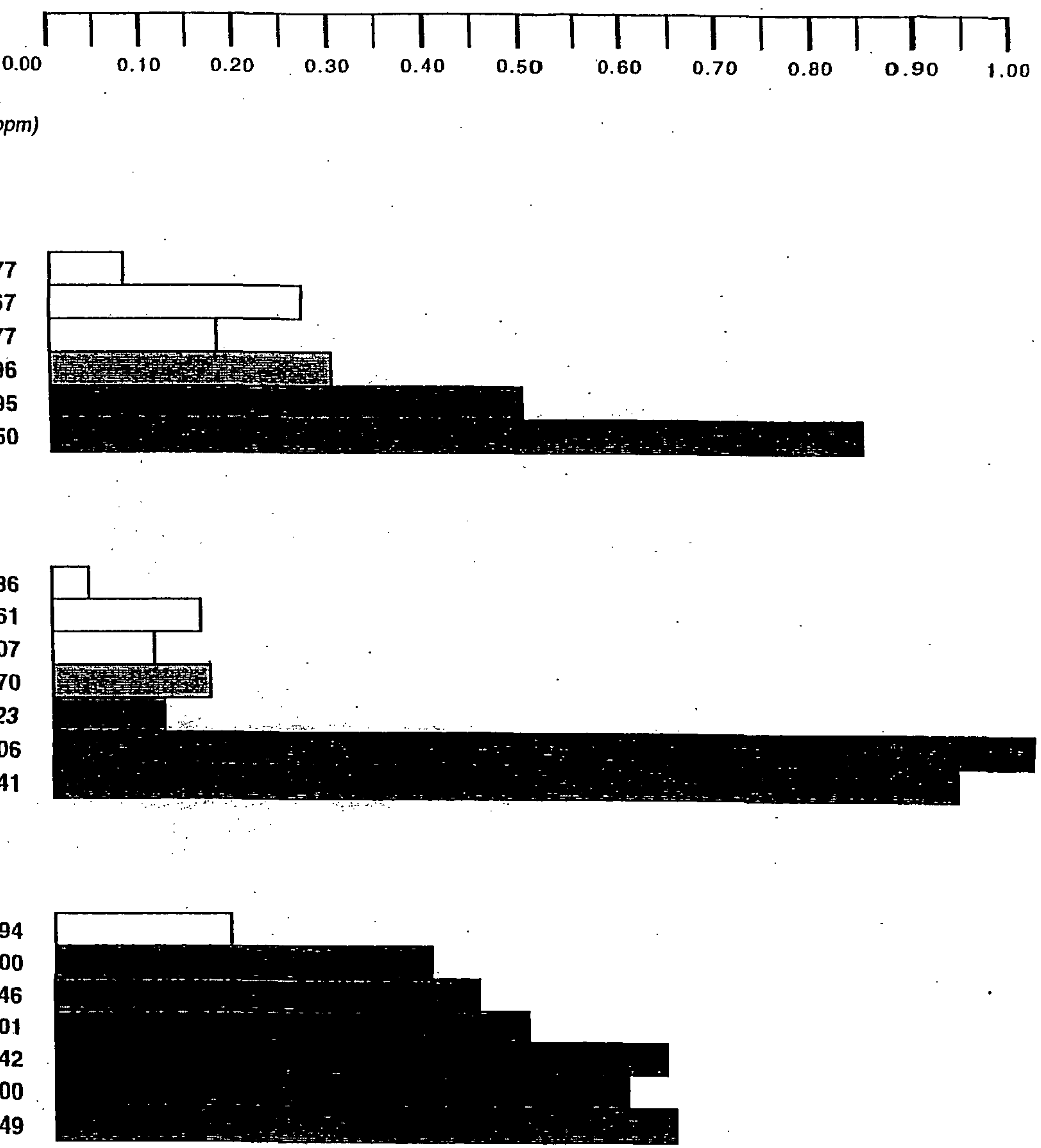
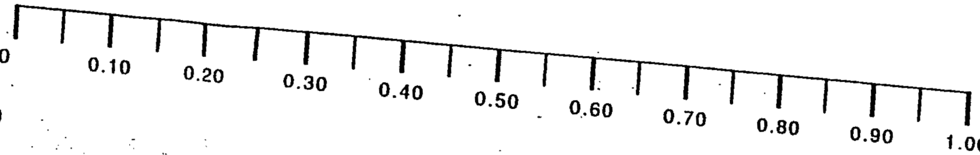


Table 4. (continued)



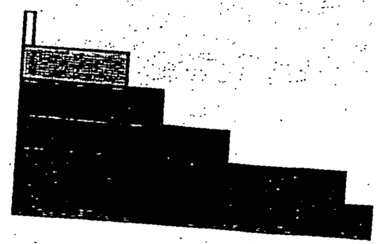
Identification	trophic level	Hg (dry wt ppm)
28. South Fork Yuba River at Bridgeport. (4/24/95)		
Pteronarcyidae-sm	leaf shredder	0.077
Mayflies	herbivore	0.267
Ptilodactylidae	herbivore	0.177
Hydropsychidae	drift feeder	0.296
Perlidae	small predator	0.495
Hellgrammites-lg	large predator	0.850
28*. South Fork Yuba River at Bridgeport. (6/30/95)		
Pteronarcyidae	leaf shredder	0.036
Mayflies	herbivore	0.161
Ptilodactylidae	herbivore	0.107
Hydropsychidae	drift feeder	0.170
Perlodidae-sm	Sm. Stoneflies	*0.123*
Hellgrammites-lg	large predator	1.306
Hellgrammites-giant	large predator	0.941
28**. South Fork Yuba River at Bridgeport. (8/15/95)		
Mixed Grazers	herbivore	0.194
Perlidae-sm/med	small predator	0.400
Perlidae-Heperoperla-med/lg	small predator	0.446
Perlidae-Heperoperla-lg/giant	small predator	0.501
Hellgrammites-sm/med	large predator	0.642
Hellgrammites-med/lg	large predator	0.600
Hellgrammites-lg/giant	large predator	0.649

Table 4. (continued)



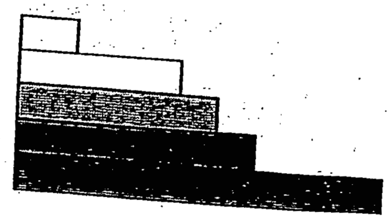
28*. South Fork Yuba River at Bridgeport. (11/16/95)**

identification	trophic level	Hg (dry wt ppm)
Pteronarcyidae	leaf shredder	0.007
Hydropsychidae	drift feeder	0.113
Perlodidae-med/Lg	small predator	0.149
Perlidae-Lg	small predator	0.216
Hellgrammites-sm	large predator	0.344
Hellgrammites-sm	large predator	0.369



28**. South Fork Yuba River at Bridgeport. (2/16/96)**

identification	trophic level	Hg (dry wt ppm)
Pteronarcyidae-sm/med	leaf shredder	0.056
Mixed Mayflies	herbivore	0.172
Hydropsychidae-med/lg	drift feeder	0.213
Perlidae	small predator	0.248
Hellgrammite-giant	large predator	0.375



date and, on subsequent samplings, the site was essentially barren. We attributed this to the unnatural mid-summer releases of very cold North Fork Yuba water from the base of New Bullards Bar Reservoir and the erratic flow regime, which varied between zero and very high flows from this cold source. When the flows from New Bullards Bar Reservoir were high, the water beneath the Colgate powerhouse was very swift and cold; when that source was shut down, the flow returned to that of the relatively warm, low flow Middle Fork Yuba. Our unsuccessful collection attempts (despite considerable sampling effort) from mid-summer through the winter indicate that the conditions at this site were too erratic to maintain a diverse community of typical benthic invertebrate fauna.

Comparing the entire data sets for each site, it is apparent that the below-reservoir site on the Yuba River (Site 16) was consistent in demonstrating significantly lower levels of mercury accumulation, throughout the trophic levels, than the sites above the reservoir. Because of a shift in species present at this site over time, it is difficult to draw conclusions with regard to potential seasonal changes in mercury accumulation here. Hydropsychid caddisfly larvae, which were present in all Lower Yuba collections, suggest a possible increase in mercury accumulation at the Lower Yuba site in the fall and winter, as integrated by the November 1995 and February 1996 samples (0.21-0.23 ppm Hg Nov-Feb vs 0.08-0.14 ppm Hg Apr-Aug). However, other sampled species did not follow any particular trend. Except for a single somewhat anomalous data point for Tipulid dipteran larvae in June 1995 (0.49 ppm), all Lower Yuba benthic invertebrate indicator samples contained ≤ 0.27 ppm mercury.

In contrast, composite samples of benthic invertebrates from the inflowing tributaries to the reservoir consistently demonstrated significantly elevated levels of mercury accumulation in most trophic levels. All samples of second order predatory invertebrates from these sites were found to contain more than 0.30 ppm mercury, with individual composites ranging to over 1.30 ppm. Comparative trout were not present at the reservoir inflow sites, though trout collected below the reservoir were far lower in mercury than were trout taken at sites where they were present further up the Forks of the Yuba within the historic gold mining region.

After seeing firsthand the large variation in flow conditions, we hesitate to form conclusions on potential temporal trends for the North Fork/Middle Fork Yuba reservoir inflow site below the Colgate powerhouse (17). Diverse samples were only available for the first two collections (April and June), during which time mercury levels appeared to drop fairly uniformly. However, because of the unique conditions at this site brought on by flow manipulations, it is unclear whether this apparent trend might be a function of different proportions of Middle Fork Yuba water being present at different times or if the invertebrates taken below the powerhouse on one or both of the significant collections might actually represent drift from the Middle Fork.

The samples from the South Fork inflow, however, indicate an interesting trend of apparent reduced mercury accumulation in fall and winter as compared to earlier collections. This was particularly the case for the predatory trophic levels. Corydalid hellgrammite composites from April through August averaged a very high 0.83 ppm mercury, as compared to 0.36 ppm in November and February. Perlid stoneflies averaged 0.46 ppm in April-August collections, as compared to 0.23 ppm in November and February. This indicates that, at this representative site and this sampling year, less bioavailable mercury moved into the food web later in the year as compared to earlier. This could be a function of changes in bulk mercury presence, changes in mercury methylation within the stream, or a combination of the two.

One conclusion to be drawn from the temporal collections is that comparative sampling of benthic invertebrate indicator samples between sites should be done within a relatively similar time frame, as levels can change fairly significantly across periods on the order of 6 months. Fortunately, the great majority of collections made for the survey work occurred between the months of September and December in each of the years.

Methyl mercury split data

Splits of a subset of the total samples were sent to Frontier Geosciences Laboratory in Washington state for analysis of methyl mercury. Results from split and duplicate samples indicated that this particular assay was limited in accuracy to a range of approximately ± 25%, as compared to the total mercury analysis which has a variability closer to ± 10%. Because of the fairly high level of analytical variation, temporal trends in methyl mercury content cannot be ascertained. Methyl fractions varied fairly erratically and within a range generally less than or equal to the analytical range of variation. However, the general methyl mercury results provide some useful information.

Reduced methyl mercury data are presented in Table 5, together with corresponding total mercury results and the calculated methyl mercury percentage for each sample. Except for a single lower point, all of the data that passed QA/QC controls varied somewhat erratically in the general range of 55-100% methyl mercury. In approximately 10% of the samples that were near the respective limits of detection, impossible results of 110-500+% methyl mercury were obtained, presumably through analytical error at the bottom end of the scale. These data are not shown in the table.

Pteronarcyid stoneflies, which are shredders of primarily terrestrial leaf fall, had methyl mercury percentages which varied between 64% and 100%, with a mean of 76.2% ± 14.5%. Herbivorous mayflies ranged from 60% to 79% methyl mercury, with a mean of 69.4% ± 12.8%. Hydropsychid caddisfly larvae ranged between 36% and 94%, with a mean value of 68.8% ±

Table 5. Methyl Mercury / Total Mercury Split Data (dry weight ppm Hg)

ENGLEBRIGHT SERIES

	Mayflies			Pteronarcyids			Hydropsyche			Perlodids			Perlids			Hellgrammites		
	MeHg	THg	%	MeHg	THg	%	MeHg	THg	%	MeHg	THg	%	MeHg	THg	%	MeHg	THg	%
4/24/95																		
Lower Yuba	.032	.054	60.3%				.050	.141	35.5%	.085	.113	75.4%						
Colgate							.106	.163	65.0%							0.821	0.971	84.6%
S Fk Yuba				.051	.077	66.0%	.172	.296	58.0%				.442	.495	89.2%	0.611	0.848	72.0%
6/30/95																		
Lower Yuba							.077	.082	94.2%									
Colgate							.070	.094	74.5%									
S Fk Yuba																1.096	1.306	83.9%
8/15/95																		
Lower Yuba	.063	.080	78.5%				.118	.129	91.9%							0.190	0.273	69.6%
Colgate							.052	.078	66.4%									
S Fk Yuba																0.346	0.600	57.6%
11/16/95																		
Lower Yuba							.144	.225	63.8%	.154	.155	99.2%	.189	.218	86.6%			
Colgate																		
S Fk Yuba										.110	.149	73.9%	.192	.216	88.5%	0.336	0.369	91.1%
M Fk Yuba				.114	.115	99.6%	.128	.204	62.8%	.177	.177	100.4%	.239	.246	97.4%	0.311	0.411	75.6%

Table 5. (continued)

INTER-ANNUAL SERIES (Middle Fk Yuba at Tyler Foote Crossing)

	Mayflies			Pteronarcyids			Hydropsyche			Perlodids			Perlids			Hellgrammites		
	MeHg	THg	%	MeHg	THg	%	MeHg	THg	%	MeHg	THg	%	MeHg	THg	%	MeHg	THg	%
Oct-93				.066	.103	63.6%							.270	.325	82.9%			
Oct-94				.177	.220	80.3%	.308	.543	56.7%				.806	.797	101.2%	0.415	0.593	69.9%
Oct-95				.043	.060	71.7%	.125	.222	56.4%				.241	.244	99.0%	0.187	0.215	87.1%

ABOVE/BELOW CAMP FAR WEST RESERVOIR

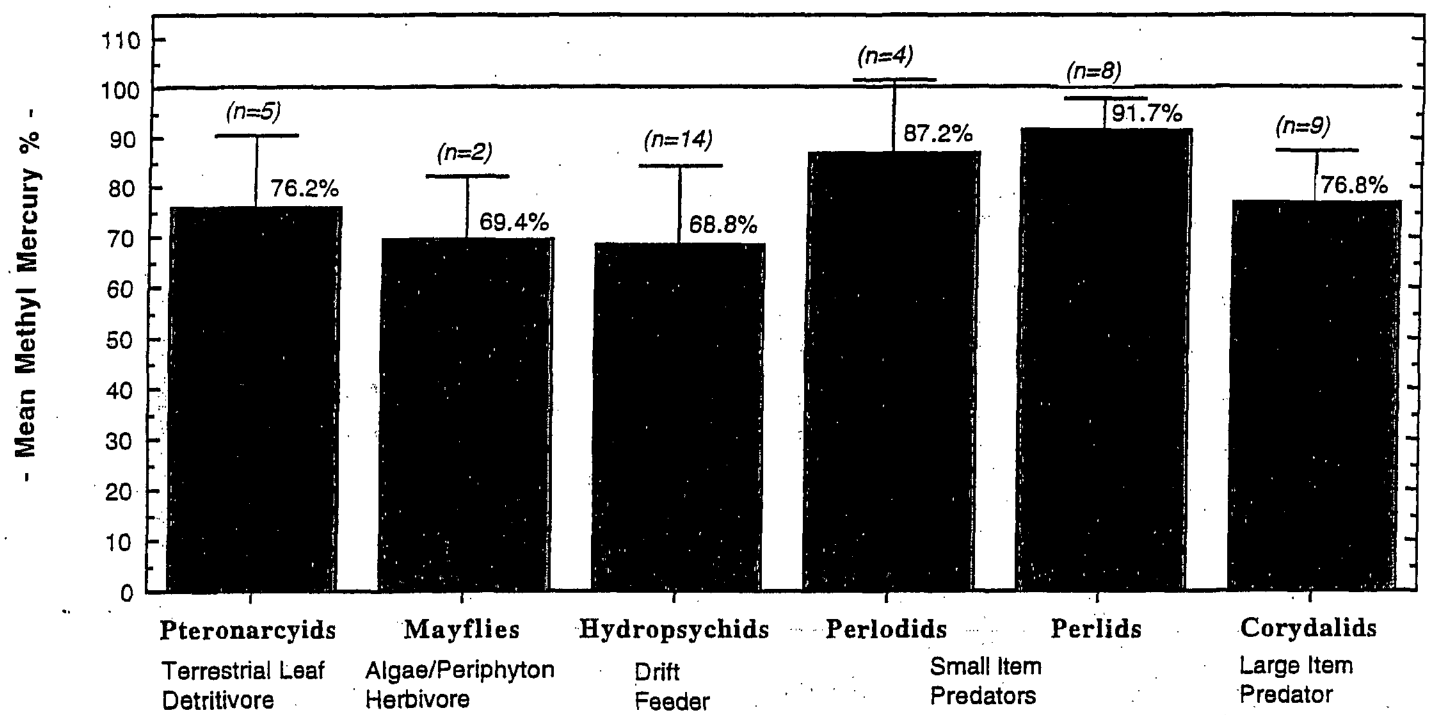
	Mayflies			Pteronarcyids			Hydropsyche			Perlodids			Perlids			Hellgrammites		
	MeHg	THg	%	MeHg	THg	%	MeHg	THg	%	MeHg	THg	%	MeHg	THg	%	MeHg	THg	%
Bear R, Hwy 49							.216	.286	75.5%									
Below Camp FW							.138	.162	85.2%									

LARGE VALLEY RIVER

	Mayflies			Pteronarcyids			Hydropsyche			Perlodids			Perlids			Hellgrammites		
	MeHg	THg	%	MeHg	THg	%	MeHg	THg	%	MeHg	THg	%	MeHg	THg	%	MeHg	THg	%
Lower Feather							.060	.078	77.1%									

Fig. 32. Mean Methyl Mercury Percentages (Of Total Mercury) In Major Sierra Nevada Stream Macro-Invertebrates

(multi-individual composite samples x n composite collections with 95% confidence intervals)



15.7%. Of the 14 Hydropsychid samples, 13 contained ≥ 56% methyl mercury. Small Perlodid stoneflies had methyl mercury percentages of 74-100% (mean = 87.2% ± 14.6%). Perlid stoneflies varied over a relatively narrow range of 83-101% methyl mercury (mean = 91.7% ± 6.6%) and Corydalid hellgrammites varied in methyl mercury fraction between 58% and 91% (mean = 76.8% ± 10.7%). These mean methyl mercury fractions are displayed graphically in Figure 32.

All of the benthic invertebrate trophic levels demonstrated relatively similar methyl mercury fractions of 69% to 92% on average. Methyl mercury accounted for more than 2/3 of the total mercury accumulated by each of these organisms. It is notable that there was no clear pattern of increasing methyl fraction with trophic level, as might be theoretically expected. However, the data clearly indicates the importance of the methyl species of mercury for biotic accumulation, consistent with many other studies in other aquatic habitats.

Mercury in Englebright Reservoir fish

In July 1996, we used an experimental gillnet from a boat to collect a sample of fish from the midsection of Englebright Reservoir, which receives the inflows from all three forks of the Yuba River. We had difficulty obtaining a large sample, but were able to collect at least a single representative of each of five reservoir fish species. Five Sacramento suckers were taken, together with one each hardhead, carp, smallmouth bass, and largemouth bass. The bass were small (11-12 inches, < 1 pound), while individuals of the other sampled species were mid to large sized adults. Data are presented below in Table 6.

This collection was notable for the relatively quite high mercury levels that were found throughout. Mercury in fresh (wet weight) edible filet muscle ranged from 0.41 to 0.89 ppm, with all values being near, at, or above the 0.50 ppm health advisory level. This was particularly significant in that the majority of the sampled fish were of species that are low in the trophic food web and typically demonstrate relatively very low levels of mercury accumulation. Hardhead is a native species that is herbivorous, while carp is an introduced species that feeds primarily on small invertebrates in the bottom sediment (Moyle 1976). The Sacramento sucker is a native species with feeding habits similar to carp. Comparative data from Clear Lake in the Coast Range, which is known to contain extremely elevated concentrations of sediment inorganic mercury, have consistently demonstrated carp muscle mercury to be in the ≤ 0.25 ppm range, even in very large and old individuals (TSMP 1990, 1991, 1992). The finding of significantly higher mercury concentrations accumulating in carp and other low trophic level fish within Englebright Reservoir indicates that the mercury in this Sierra Nevada foothill reservoir is more readily bioavailable to resident fish.

Table 6. Englebright Reservoir Fish Muscle (Filet) Mercury Concentrations
(fresh/wet weight ppm Hg, July 1996)

Identification	Weight (g)	Length (mm)	Weight (lbs)	Length (inches)	Muscle Hg (wet wt ppm)
Hardhead	1,160	440	2.55	17.3	0.47
Carp	2,350	540	5.17	21.3	0.88
Sacramento Sucker	870	410	1.91	16.1	0.57
Sacramento Sucker	1,020	450	2.24	17.7	0.68
Sacramento Sucker	1,110	470	2.44	18.5	0.50
Sacramento Sucker	1,150	460	2.53	18.1	0.41
Sacramento Sucker	1,460	523	3.21	20.6	0.89
Smallmouth Bass	330	280	0.73	11.0	0.52
Largemouth Bass	390	315	0.86	12.4	0.64

Only the bass in the collection were upper level predators. However, the two individuals sampled in this collection were quite small and young. Comparably sized bass from other systems characteristically contain lower mercury accumulations than co-occurring larger adults (TSMP 1990, Slotton 1991, Slotton *et al.* 1996). The relatively elevated levels in the young smallmouth (0.52 ppm) and largemouth (0.64 ppm) bass taken in this collection are consistent with the other Englebright data in suggesting that there is a considerable amount of fish uptake of mercury in this system. However, a more comprehensive sampling should be undertaken before drawing any firm conclusion on this matter, particularly from a regulatory standpoint.

While similar fish could not be collected at both the reservoir and river sites upstream or downstream, the data indicate a significant general increase in mercury bioavailability to fish within the reservoir, even as compared to the most highly elevated upstream stretches of the Yuba River tributaries. What is most interesting is the consistently low levels of mercury accumulation, across a wide range of sizes and ages, in rainbow trout taken below Englebright Reservoir (Site 16).

DISCUSSION AND CONCLUSIONS

Biotic mercury presence and distribution in the Sierra gold region

A clear signature of anthropogenic mercury was present in the aquatic biota sampled throughout the historic Sierra Nevada gold region in this research. Concentrations ≥ 0.01 mg kg^{-1} (dry weight) were found in virtually all invertebrates sampled. On a wet weight basis, fish filet muscle mercury was ≥ 0.03 mg kg^{-1} at all sites (≥ 0.14 mg kg^{-1}, dry weight). Both invertebrates and fish demonstrated significantly higher mercury concentrations in regions that have sustained greatest intensities of gold mining pressure, both historically and at present.

Trout and invertebrate samples indicate relatively low current levels of mercury bioavailability in the majority of the Feather and American River watersheds. In contrast, significantly greater bioavailability was indicated by higher bioaccumulation of mercury in a number of areas. Notably higher mercury regions included the upper forks of the Yuba River, with the mid-reaches of the Middle and South Forks having the highest biotic mercury concentrations in that drainage. Other notably elevated mercury streams within the Sacramento river watershed included the mid-section of the Middle Fork of the Feather River, Deer Creek, particularly below Lake Wildwood, and tributaries throughout the gold mining region of the Bear River drainage. The North Fork of the Cosumnes River, in the San Joaquin watershed, demonstrated the highest concentrations of biotic mercury among all of the 57 study sites. Elevated to a lesser extent, but on a relative basis as compared to adjacent sites were the North Fork of the Middle Fork of the American River (49), and Spanish Creek (7, tributary to the North Fork Feather River). The above noted streams with elevated biotic mercury included the highest densities of active dredging operations, which also corresponded generally to the greatest historical mining intensities. At sites located upstream of heavily mined stretches, e.g. the Plumbago site (27) on the Middle Fork Yuba River and the headwaters collections on the Bear River (Site 44), significantly lower mercury concentrations were found throughout the food web, as compared to levels within and downstream of intensively mined reaches.

The relative biotic mercury concentrations found in this study can presumably be linked to relative concentrations of aqueous, bioavailable mercury moving down each of these streams. It is important to distinguish between *concentration* and *mass load*. Sites with the highest concentrations of mercury may not necessarily be the most important overall contributors of mercury to the downstream Delta/Bay system. However, with regard to potential mercury remediation projects in the Sacramento River watershed, it is precisely those regions identified as having the greatest mercury concentrations that offer the most realistic options for effective mitigation work.

One important conclusion of the survey work is that the elevated mercury regions did not demonstrate a point source signature. Where biotic accumulations of mercury were elevated, this elevation was generally distributed across many miles of stream or river. The elevated bioavailable mercury regions could thus be localized to specific tributaries or series of river miles, but not to highly localized "hot spot" point sources. This is consistent with the historic widespread use of mercury throughout the gold mining region and its subsequent redistribution downstream.

Fish mercury concentrations in relation to environmental and health concerns

While these data clearly indicate the differences in relative mercury bioavailability among the various streams of the region, the absolute concentrations in rainbow trout were all well below existing health criteria. Even at the highest mercury sites, the normalized 250 g rainbow trout, fresh weight, filet muscle mercury levels were less than 50% of the 0.5 ppm guidelines suggested by the California Department of Health Services and the Academy of Sciences, and ≤ 21% of the existing U.S. FDA fish criterion of 1.0 ppm. The entire data set for 250 g normalized rainbow trout ranged between 0.03 and 0.21 mg kg^{-1} (ppm). Larger fish ranged higher but were still all within the 0.5 ppm guidelines. We conclude that there is relatively little direct health hazard associated with the consumption of rainbow trout from these Sierra Nevada streams and rivers. The notably elevated levels of mercury in edible muscle of fish from within Englebright Reservoir suggests that a problem may exist in some of the foothill reservoirs--one that may warrant additional study. The fact that this elevated mercury phenomenon was not additionally found downstream of the reservoir indicates that the foothill reservoir habitat may be trapping bioavailable mercury in addition to the bulk, inorganic mercury which deposits there with sediment.

Influence of reservoirs on downstream biotic mercury

It was expected that mercury bioavailability might be relatively low in the rivers and streams of this region, despite the presence of still considerable amounts of inorganic mercury from the gold mining era. This is because methyl mercury, the predominant form of mercury that enters and moves through the food web, requires a biological process, bacterial methylation, for the bulk of its production (Gilmour *et al.* 1992). The opportunity for bacterial mercury methylation or even the presence of significant bacterial populations is minimized in the fast moving, cold, clear water habitat typical of many of these Sierra Nevada foothill streams. However, once transported to calmer waters such as downstream reservoirs, turbid valley rivers, the Sacramento/San Joaquin Delta, and San Francisco Bay, the potential for bacterial methylation of mercury derived from the

Sierra gold mining region increases dramatically. The foothill reservoirs, in particular, are likely sites of enhanced mercury methylation. Limited prior analyses of fish from some of these reservoirs have indeed found markedly higher mercury concentrations than those found in this study of the upstream rivers (TSMP 1990, 1991, 1992). Our sampling in Englebright Reservoir also detected quite elevated levels of mercury in edible filet muscle from a variety of species.

We hypothesized that, as a result of enhanced mercury methylation within Sierra foothill reservoirs, there might be a detectable net export of bioavailable mercury from them to their downstream rivers. In contrast, the data collected in this study indicate the reverse. Not only do the reservoirs not appear to be net exporters of bioavailable mercury, but they seem to be acting as sinks for bioavailable as well as inorganic mercury. In most instances where we sampled upstream and downstream of Sierra foothill reservoirs, significantly *lower* mercury was found in the downstream biota, throughout the entire aquatic food web (e.g. upstream/downstream of Englebright, New Bullards Bar, and Camp Far West Reservoirs). We conclude that, despite the likely enhancement of mercury methylation within these reservoirs, the bioavailable mercury must be quickly taken up within the reservoir ecosystem itself, becoming largely unavailable for downstream transport. It was understood that these reservoirs must act as giant sinks for the inorganic mercury moving into them from upstream. The finding that they are also apparently not net exporters of bioavailable mercury is a particularly interesting and relevant result of this study. Production and consumption of methyl mercury in the reservoir water column appears to be in equilibrium.

In any case, collections of biotic indicator species from below the final dams and reservoirs of the main stems of the Feather, Yuba, Bear, and American Rivers demonstrated uniformly low levels of time-integrated mercury bioavailability as compared to the elevated mercury stretches identified in the gold mining region. The Cosumnes River in the San Joaquin watershed, which was extremely elevated in bioavailable mercury and is a rare un-dammed system, may represent a more direct source of bioavailable mercury to the Delta than any of the rivers in the Sierra Nevada portion of the Sacramento River watershed.

Trophic feeding level relationship to mercury accumulation

Within each site, mercury concentrations in biota generally corresponded to trophic feeding level, with higher trophic levels of invertebrates containing greater concentrations of mercury. Corresponding rainbow trout, which prey on all of these invertebrates to varying extents, had still higher mercury accumulations, while piscivorous fish such as native squawfish and the larger brown trout had the highest mercury concentrations of all. Trophic bioconcentration of mercury is thus indicated to be a dominant mode of mercury accumulation by biota in this region. For basic ecological research, an interesting aspect of this work is the finding that relative mercury concentrations in aquatic species may offer a useful tool for determining the relative, time-integrated trophic feeding habits of specific aquatic species.

Correlations between the mercury contents of biota of different trophic levels were similar, whether identical types of organism were used for the comparison or a variety of representatives of each trophic guild. This suggests that when identical invertebrate species are not available between sites, a variety of species within the same trophic feeding guild may be utilized as comparative general indicators of relative mercury bioavailability.

Inter-trophic mercury correlations between various groups of co-existing invertebrates were found to be uniformly stronger than mercury concentration correlations between invertebrates and corresponding trout. This is likely due to the relative site fidelity of stream invertebrates, as compared to trout, which can wander extensively throughout their lifetime accumulation of mercury.

Correlations between mercury in stream invertebrates and mercury in co-occurring trout were stronger with increasing invertebrate trophic level. Predatory invertebrate species such as Perlid stoneflies and Corydalid hellgrammites were found to be the best indicators of corresponding trout mercury levels. The excellent correspondence between larger, predaceous invertebrates and co-occurring trout may be a function of similar diet and, particularly in the case of the large hellgrammites, similar ages and thus similar periods of mercury integration. Mercury in smaller, younger organisms such as most mayflies, Hydropsychid caddis nymphs, and young predators may not correlate as well with trout mercury, but may instead be a better indicator of shorter term conditions of mercury bioavailability. Under potentially dramatic seasonally or annually changing conditions of mercury bioavailability, changes will be far less pronounced in older organisms as compared to more ephemeral species, for which the most recent time period represents a larger proportion of the entire lifetime accumulation (Slotton *et al.* 1995b). Thus, different organisms may be utilized for different types of information. Trout mercury is of direct interest for health reasons and provides a general indicator of regional, long-term mercury availability. Larger predaceous species may be utilized as surrogates for trout. The larger/older invertebrates of all types provide localized, long-term integration of relative mercury availability, when same types are compared. Finally, smaller/younger invertebrates can potentially be used as integrators of mercury conditions over shorter time scales. Ongoing research by our U.C. Davis Heavy Metals Limnology Group is investigating all of these areas.

Future Considerations

Stream invertebrates appear to be appropriate indicators for determining relative, time-integrated mercury bioavailability between sites throughout the Sierra Nevada gold region.

However, the nature of the trophic structure of the invertebrate community must be considered and potentially significant temporal changes should be taken into account. Invertebrates are more widely available than trout and, because they do not have the mobility of fish, their mercury accumulations can be linked with greater confidence to conditions directly at and upstream of a given locale. Certain invertebrate species can also function as surrogates for trout, with larger predatory types showing the strongest relationship. Other species may be useful in determining short-term mercury conditions. The great advantage of using native biota as indicators, as compared to standard water grab sampling protocol, is their natural and continuous integration of conditions over time and their accumulation of, by definition, the bioavailable fraction of mercury.

As this comprehensive survey indicates that the elevated mercury regions of the gold country watersheds are not of a point source nature, potential future mercury remediation efforts would probably be best directed toward regional approaches such as an improved mercury buy-back program through ongoing small-scale miners. Costly point-source engineering solutions are not supported by the data.

Future research projects include similar survey work in the Sierra Nevada gold region to the south, particularly the Cosumnes and Mokelumne Rivers, survey work throughout the California Coast Range mercury mining district and into the Delta, together with simultaneous investigation of the research questions highlighted above. Another major area of research will involve the study of how the various mercury loads to the Delta/Bay system behave once in that system, with a particular emphasis on the long-term potential bioavailability of different mercury compounds from a variety of sources.

REFERENCES

CVRWQCB. 1987. *Regional Mercury Assessment.* Central Valley Regional Water Quality Control Board, March 1987.

Gilmour, C.C, E.A. Henry, and R. Mitchell. 1992. *Environ. Sci. Technol.*, 26:2281-2287.

McCafferty, W.P. 1981. *Aquatic Entomology.* Jones and Bartlett Publishers, Boston. 448 pp.

Merritt, R.W. and K.W. Cummins. 1984. *An Introduction to the Aquatic Insects of North America, 2nd edition.* Kendall-Hunt Publishing Company, Dubuque. 722 pp.

Moyle, P.B. 1976. *Inland Fishes of California.* University of California Press, Berkeley, Los Angeles, London, 405 pp.

Pennak, R.W. 1978. *Freshwater invertebrates of the United States, 2nd edition.* John Wiley & Sons, New York, etc. 803 pp.

Sadiq and Zaidi 1983. A study of various factors affecting digestion of fish tissues prior to mercury determination. *Internat. J. Environ. Anal. Chem.*, 16:57-66.

Slotton, D.G. 1991. *Mercury bioaccumulation in a newly impounded Northern California reservoir.* Doctoral dissertation, University of California, Davis, December 1991. 363 pp.

Slotton, D.G., S.M. Ayers, J.E. Reuter, and C.R. Goldman. 1995. Gold mining impacts on food chain mercury in northwestern Sierra Nevada streams. *Technical Completion Report for the University of California Water Resources Center, Project W-816*, August 1995, 46 pp.

Slotton, D.G., J.E. Reuter, and C.R. Goldman. 1995. Mercury uptake patterns of biota in a seasonally anoxic northern California reservoir. *Water, Air, and Soil Pollution*, 80:841-850.

Slotton, D.G., S.M. Ayers, J.E. Reuter. 1996. *Marsh Creek Watershed 1995 Mercury Assessment Project, Final Report* Conducted for Contra Costa County, March 1996, 66 pp.

Thorp, J.H. and A.P. Covich. 1991. *Ecology and classification of North American freshwater invertebrates.* Academic Press, Inc., New York, etc. 911 pp.

TSMP. 1990. Toxic Substances Monitoring Program: Ten year summary report, 1978-1987. State of California Water Resources Control Board publication 90-1WQ, August 1990. Prepared by Del Rasmussen and Heidi Blethrow, Division of Water Quality.

______ 1991. Toxic Substances Monitoring Program, 1988-1989. State of California Water Resources Control Board publication 91-1WQ, June 1991. Prepared by Del Rasmussen and Heidi Blethrow, Division of Water Quality.

______ 1992. Toxic Substances Monitoring Program, 1990 data report. State of California Water Resources Control Board publication 92-1WQ, May 1992. Prepared by Del Rasmussen, Division of Water Quality.

LOW DO

B.1.10 Lower Calaveras River, Low Dissolved Oxygen

Summary of Proposed Action

The California Regional Water Quality Control Board-Central Valley Region, Regional Board, recommends the addition of the lower Calaveras River to California's Clean Water Act Section 303(d) list due to impairment by low dissolved oxygen. Information available to the Regional Board on dissolved oxygen levels in the lower Calaveras River indicates that water quality objectives are not being attained. A description for the basis for this determination is given below.

Table B-1. 303(d) Listing/TMDL Information

Waterbody Name	Lower Calaveras River	**Pollutants/Stressors**	Low Dissolved Oxygen
Hydrologic Unit	531.30	**Sources**	Urban Runoff/Storm Sewers
Total Waterbody Size	50 river miles	**TMDL Priority**	
Size Affected	5 miles	**TMDL Start Date (Mo Yr)**	
Extent of Impairment	Between the Stockton Diversion Canal and the San Joaquin River	**TMDL End Date (Mo Yr)**	
Upstream Extent Latitude	37° 59' 38"	**Upstream Extent Longitude**	121° 16' 48"
Downstream Extent Latitude	37° 58' 00"	**Downstream Extent Longitude**	121° 22' 05"

Watershed Characteristics

The lower Calaveras River is located within the San Joaquin Delta Hydrologic Unit, flows through central Stockton, California, and joins the San Joaquin River near Rough and Ready Island.

Water Quality Objectives Not Attained

The Water Quality Control Plan (Basin Plan) for the Sacramento River and San Joaquin River Basins contains a numeric objective applicable to the Calaveras River which requires dissolved oxygen (DO) not be reduced below 5 milligrams per liter (mg/l) (CRWQCB-CVR, 1998; http://www.swrcb.ca.gov/~rwqcb5/bsnplnab.pdf).

Evidence of Impairment

A report of DeltaKeeper data collected between 8 November 1999 and 7 February 2000 found DO concentrations in the lower Calaveras River below the Basin Plan objective in 10 of 32 samples. Data in the same report collected between 15 October 1996 and 8 November 1996 found DO concentrations below the Basin Plan objective in 8 of 12 samples (Lee and Jones-Lee, 2000a and 2001b).

Table B-2. Summary of DO Concentrations in the Lower Calaveras River

Data Source	Sample Years	Number of Samples	Range of DO Concentrations	Number of Samples Below Objective
Lee and Jones-Lee, 2000a and 2001b	October/November 1996; November 1999 to February 2000	44	0.9 – 11.7 mg/L	18

Extent of Impairment

Dissolved oxygen concentrations in the lower Calaveras River (measured in Stockton, California) have been documented to fall below the Basin Plan objective of 5 mg/l, as demonstrated by the DeltaKeeper data discussed above. Data for the lower Calaveras River is limited to one sampling point approximately in the middle of the Stockton urban area. The sampling point is likely representative of DO levels in the portion of the Calaveras River surrounded by Stockton. The Regional Board is therefore recommending listing the lower Calaveras River for DO between the Stockton Diversion Canal and the San Joaquin River.

Potential Sources

The impaired reach of the lower Calaveras River is wholly within the Stockton urban area. The most likely source of oxygen demanding substances is from runoff from the urban area.

B.1.21 Five Mile Slough, Low Dissolved Oxygen

Summary of Proposed Action

The California Regional Water Quality Control Board-Central Valley Region, Regional Board, recommends the addition of Five Mile Slough to California's Clean Water Act Section 303(d) list due to impairment by low dissolved oxygen. Information available to the Regional Board on dissolved oxygen levels in Five Mile Slough indicates that water quality objectives are not being attained. A description for the basis for this determination is given below.

Table B-1. 303(d) Listing/TMDL Information

Waterbody Name	Five Mile Slough	**Pollutants/Stressors**	Low Dissolved Oxygen
Hydrologic Unit	544.00	**Sources**	Urban Runoff/Storm Sewers
Total Waterbody Size	1.5 miles	**TMDL Priority**	
Size Affected	1 mile	**TMDL Start Date (Mo/Yr)**	
Extent of Impairment	From Plymouth Road bridge to the confluence with Fourteen-Mile Slough.	**TMDL End Date (Mo/Yr)**	
Upstream Extent Latitude	38° 00' 49"	**Upstream Extent Longitude**	121° 21' 08"
Downstream Extent Latitude	38° 00' 49"	**Downstream Extent Longitude**	121° 22' 10"

Watershed Characteristics

Five Mile Slough is located in the Delta, extends through urban Stockton from Five Mile Creek, and is bordered by residential housing, schools, a park, and a golf course. The Delta is characterized by tidal waters with limited flushing flows during the dry seasons. Five Mile Slough supports recreational uses, including boating, fishing, and swimming.

Water Quality Objectives Not Attained

The Water Quality Control Plan (Basin Plan) for the Sacramento River and San Joaquin River Basins contains a numeric objective applicable to Five Mile Slough which requires dissolved oxygen (DO) not be reduced below 5 milligrams per liter (mg/l) (CRWQCB-CVR, 1998; http://www.swrcb.ca.gov/~rwqcb5/bsnplnab.pdf).

Evidence of Impairment

A report of DeltaKeeper data collected between 8 November 1999 and 7 February 2000 found DO concentrations in Five Mile Slough below the Basin Plan objective in 19 of 32 samples. Data collected between 15 October 1996 and 8 November 1996 found DO concentrations below the Basin Plan objective (5 mg/l) in 5 of 9 samples (Lee and Jones-Lee, 2000a and 2001b).

Table B-2. Summary of Dissolved Oxygen Concentrations in Five Mile Slough

Data Source	Sample Years	Number of Samples	Range of DO Concentrations	Number of Samples Below Objective
Lee and Jones-Lee, 2000a and 2001b	October/November 1996; November 1999 to February 2000	41	0.25 – 10.6 mg/L	24

Extent of Impairment

The available data for Five Mile Slough is for a sampling site near the transition of Five Mile Slough from Five Mile Creek (a relatively narrow urban creek) to a slough (relatively wide). Regional Board staff recommends listing Five Mile Slough from near the sampling site at Plymouth Road Bridge to the confluence with Fourteen-Mile Slough.

Potential Sources

The impaired reach of Five Mile Slough receives runoff from the Stockton urban area. The most likely source of oxygen demanding substances is runoff from the urban area.

B.1.30 Mormon Slough, Low Dissolved Oxygen

Summary of Proposed Action

The California Regional Water Quality Control Board-Central Valley Region, Regional Board, recommends the addition of Mormon Slough to California's Clean Water Act Section 303(d) list due to impairment by low dissolved oxygen. Information available to the Regional Board on dissolved oxygen levels in Mormon Slough indicates that water quality objectives are not being attained. A description for the basis for this determination is given below.

Table B-1. 303(d) Listing/TMDL Information

Waterbody Name	Mormon Slough	**Pollutants/Stressors**	Low Dissolved Oxygen
Hydrologic Unit	544.00	**Sources**	Urban Runoff/Storm Sewers
Total Waterbody Size	6 miles	**TMDL Priority**	
Size Affected	1 mile	**TMDL Start Date (Mo/Yr)**	
Extent of Impairment	From Commerce Street to the Stockton Deep Water Ship Channel.	**TMDL End Date (Mo/Yr)**	
Upstream Extent Latitude	37° 56' 43"	**Upstream Extent Longitude**	121° 17' 26"
Downstream Extent Latitude	37° 57' 09"	**Downstream Extent Longitude**	121° 18' 23"

Watershed Characteristics

Mormon Slough is located within the San Joaquin Delta Hydrologic Unit in south-central Stockton, California and flows into the Stockton Deep Water Ship Channel near the Port of Stockton.

Water Quality Objectives Not Attained

The Water Quality Control Plan (Basin Plan) for the Sacramento River and San Joaquin River Basins contains a numeric objective applicable to Mormon Slough which requires dissolved oxygen (DO) not be reduced below 5 milligrams per liter (mg/l). (CRWQCB-CVR, 1998; http://www.swrcb.ca.gov/~rwqcb5/bsnplnab.pdf).

Evidence of Impairment

A report of DeltaKeeper data collected between 8 November 1999 and 7 February 2000 found DO concentrations in Mormon Slough below the Basin Plan objective in 27 of 30 samples (Lee and Jones-Lee, 2000a and 2001b).

Table B-2. Summary of Dissolved Oxygen Concentrations in Mormon Slough

Data Source	Sample Years	Number of Samples	Range of DO Concentrations	Number of Samples Below Objective
Lee and Jones-Lee, 2000a and 2001b	November 1999 to February 2000	30	0.5 – 9.6 mg/L	27

Extent of Impairment

Dissolved oxygen concentrations in Mormon Slough near Stockton have been documented to fall below the Basin Plan objective of 5 mg/l as demonstrated by the DeltaKeeper data discussed above. The data is limited to a sampling point in Mormon Slough near the transition of Mormon Slough from an urban creek (relatively narrow) to a slough (relatively wide). The sampling point may, therefore, not be representative of DO levels in the narrower portion of the Slough. Based on this evidence, Mormon Slough, between Commerce Street (the approximate transition point from urban creek to slough) and the Stockton Deep Water Ship Channel is being recommended for addition to the 303(d) list due to low DO.

Potential Sources

The impaired reach is within the Stockton urban area. The most likely source of oxygen demanding substances is from runoff from the urban area.

B.1.32 Mosher Slough, Low Dissolved Oxygen

Summary of Proposed Action

The California Regional Water Quality Control Board-Central Valley Region, Regional Board, recommends the addition of Mosher Slough to California's Clean Water Act Section 303(d) list due to impairment by low dissolved oxygen. Information available to the Regional Board on dissolved oxygen levels in Mosher Slough indicates that water quality objectives are not being attained. A description for the basis for this determination is given below.

Table B-1. 303(d) Listing/TMDL Information

Waterbody Name	Mosher Slough	**Pollutants/Stressors**	Low Dissolved Oxygen
Hydrologic Unit	544.00	**Sources**	Urban Runoff/Storm Sewers
Total Waterbody Size	5 miles	**TMDL Priority**	
Size Affected	2 miles	**TMDL Start Date (Mo/Yr)**	
Extent of Impairment	From I-5 bridge to confluence with Bear Creek.	**TMDL End Date (Mo/Yr)**	
Upstream Extent Latitude	38° 01' 57."	**Upstream Extent Longitude**	121° 21' 51"
Downstream Extent Latitude	38° 02' 35."	**Downstream Extent Longitude**	121° 23' 12"

Watershed Characteristics

Mosher Slough is located within the San Joaquin Delta Hydrologic Unit, in the primarily residential north side of Stockton, California, and joins Bear Creek in the northwest corner of the city limits.

Water Quality Objectives Not Attained

The Water Quality Control Plan (Basin Plan) for the Sacramento River and San Joaquin River Basins contains a numeric objective applicable to Mosher Slough which requires dissolved oxygen (DO) not be reduced below 5 milligrams per liter (mg/l) (CRWQCB-CVR, 1998; http://www.swrcb.ca.gov/~rwqcb5/bsnplnab.pdf).

Evidence of Impairment

A report of DeltaKeeper data collected between 8 November 1999 and 7 February 2000 found DO concentrations in Mosher Slough below the Basin Plan objective in 18 of 32 samples. Data collected between 15 October 1996 and 8 November 1996 found DO concentrations below the Basin Plan objective in 1 of 11 samples (Lee and Jones-Lee, 2000a and 2001b).

Table B-2. Summary of Dissolved Oxygen Concentrations in Mosher Slough

Data Source	Sample Years	Number of Samples	Range of DO Concentrations	Number of Samples Below Objective
Lee and Jones-Lee, 2000a and 2001b	October/November 1996; November 1999 to February 2000	43	1.3 – 9.3 mg/L	19

Extent of Impairment

Dissolved oxygen concentrations in Mosher Slough near Stockton have been documented to fall below the Basin Plan objective of 5 mg/l, as demonstrated by the DeltaKeeper data discussed above. Just above the sampling point in Mosher Slough, the characteristics of the Slough change from a narrow urban creek to a much wider Slough. The sampling point may, therefore, not be representative of DO levels in the narrower portion of the Slough. Based on this evidence, Mosher Slough between the I-5 bridge (the approximate transition point from urban creek to slough) and its confluence with Bear Creak is being 303(d) listed due to low DO.

Potential Sources

The impaired reach of Mosher Slough receives runoff from the Stockton urban area. The most likely source of oxygen demanding substances is from runoff from the urban area.

B.1.45 Smith Canal, Low Dissolved Oxygen

Summary of Proposed Action

The California Regional Water Quality Control Board-Central Valley Region (Regional Board), recommends the addition of Smith Canal to California's Clean Water Act Section 303(d) list due to impairment by low dissolved oxygen. Information available to the Regional Board on dissolved oxygen levels in Smith Canal indicates that water quality objectives are not being attained. A description for the basis for this determination is given below.

Table B-1. 303(d) Listing/TMDL Information

Waterbody Name	Smith Canal	**Pollutants/Stressors**	Low Dissolved Oxygen
Hydrologic Unit	544.00	**Sources**	Urban Runoff/Storm Sewers
Total Waterbody Size	2 miles	**TMDL Priority**	
Size Affected	2 miles	**TMDL Start Date (Mo/Yr)**	
Extent of Impairment	From Yosemite Lake to the confluence with the San Joaquin River	**TMDL End Date (Mo/Yr)**	
Upstream Extent Latitude	37° 58' 03"	**Upstream Extent Longitude**	121° 18' 24"
Downstream Extent Latitude	37° 57' 25"	**Downstream Extent Longitude**	121° 20' 54"

Watershed Characteristics

The Smith Canal is a dead end slough connecting the San Joaquin River near Rough and Ready Island with Yosemite Lake at Legion Park in downtown Stockton, CA. Smith Canal is located within the San Joaquin Delta Hydrologic Unit and receives storm water discharges from 3,300 acres of urban downtown Stockton, CA area. The land uses are 50% residential, 18% commercial, and 26% street. Institutional and industrial uses occupy the remaining 6% (Chen and Tsai, 1999).

Water Quality Objectives Not Attained

The Water Quality Control Plan (Basin Plan) for the Sacramento River and San Joaquin River Basins contains a numeric objective applicable to Smith Canal which requires dissolved oxygen (DO) not be reduced below 5 milligrams per liter (mg/l) (CRWQCB-CVR, 1998; http://www.swrcb.ca.gov/~rwqcb5/bsnplnab.pdf).

Evidence of Impairment

DO measurements collected from a variety of locations in Smith Canal between 1995 and 2000, have found concentrations below the Basin Plan objective of 5.0 mg/L on many occasions.

Fish kills were observed along Smith Canal by a resident in 1994, by DeltaKeeper in 1995 and 1996, and by CVRWQCB staff in 1994 and 1995. During one of the events in 1994, threadfin shad were observed floating at the surface of Smith Canal. Floating at the surface can be due to the loss of equilibrium associated with inadequate dissolved oxygen levels. These observations prompted a study by the CVRWQCB in the fall of 1995 designed to determine if low DO concentrations were responsible for the fish kills. Continuous monitoring data collected for the report in Smith Canal found DO concentrations during dry weather to be at or above Basin Plan objectives. However, during rain events between 10 and 13 December 1995 and again between 15 and 18 December 1995 DO concentrations dropped below Basin Plan objective after an initial peak during the rain events (Larsen *et al*, 1998).

An assessment of water quality data from Smith Canal performed by Camp Dresser & McKee Inc. for the City of Stockton between October 1997 and September 1998 found DO concentrations often below Basin Plan objectives. DO concentrations at the Pershing Ave. bridge over Smith Canal were below Basin Plan objectives many times during each month of the twelve month study and were below objectives many times per month at the Smith Canal Pedestrian Bridge in all but three months of the study. DO concentrations at the downstream Smith Canal Pedestrian Bridge were generally higher than the upstream Pershing Ave. bridge and DO concentrations overall were lower in conjunction with wet weather events (CDM, 1999).

A report of DeltaKeeper data collected between 8 November 1999 and 7 February 2000 found DO concentrations in Smith Canal below the Basin Plan objective in 25 of 31 samples. Data in the same report collected between 15 October 1996 and 8 November 1996 found DO concentrations below the Basin Plan objective in 6 of 10 samples (Lee and Jones-Lee, 2000a and 2001b).

Table B-2. Summary of Dissolved Oxygen Concentrations in Smith Canal

Data Source	Sample Years	Number of Samples	Range of DO Concentration	Number of Samples Below Objective
Larsen *et al*, 1998	October to December 1995	Continuous/ intermittent	1.7 - >11mg/L	n/a
Lee and Jones-Lee, 2000a and 2001b	October/November 1996; November 1999 to February 2000	41	0.4 - 11 mg/L	31
CDM, 1999	October 1997 to September 1998	Continuous	0 – >11 mg/L	n/a

Extent of Impairment

Dissolved oxygen concentrations in the Smith Canal in Stockton, CA have been documented to fall below the Basin Plan objective of 5 mg/l on many occasions between 1995 and 2000. This data also indicates that some DO concentration episodes below the Basin Plan objectives have coincided with wet weather events. Due to the relatively short length of Smith Canal and uniform characteristics (straight channel surrounded by urban land), the samples collected indicate impairment of all of Smith Canal by low DO.

Potential Sources

The impaired reach of Smith Canal is wholly within the Stockton urban area. The most likely source of oxygen demanding substances is from runoff from the urban area.

R49-d

Calaveras - DO = Cala
5-mile - DO = Low DO
Mormon - DO = Low DO
Smith - DO = Low DO

Dissolved Oxygen Depletion in the Stockton Sloughs

Report prepared for DeltaKeeper by
G. Fred Lee & Associates

August 2000

G. Fred Lee & Associates

27298 E. El Macero Dr.
El Macero, California 95618-1005
Tel. (530) 753-9630 • Fax (530) 753-9956
e-mail: gfredlee@aol.com
web site: http://www.gfredlee.com

August 25, 2000

William Jennings
DeltaKeeper
3536 Rainier Avenue
Stockton, CA 95204

Dear Bill:

In accord with your request for my assistance in helping the DeltaKeeper interpret some of the water quality characteristic data that DeltaKeeper has been collecting on the Stockton sloughs, I wish to provide the following comments on the DO data that you have asked me to review.

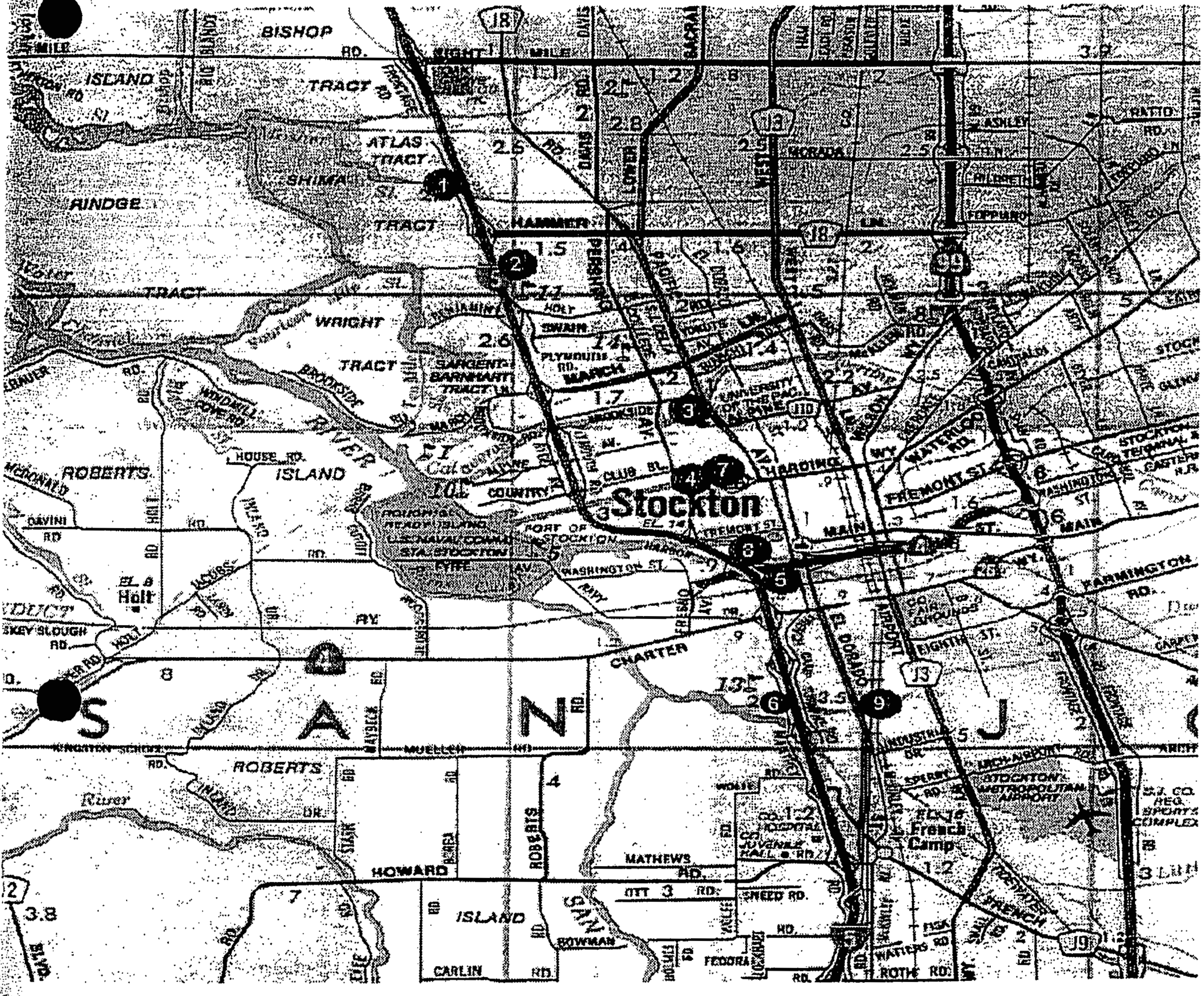
Dissolved Oxygen Depletion in the Stockton Sloughs

During the fall and winter of 1999-2000, the DeltaKeeper collected DO data on several City of Stockton sloughs. The sampling locations used are shown in Figure 1. The data are presented in Table 1.

Examination of the data in Table 1 shows that DO concentrations of less than 2 mg/L were found on several occasions in Mormon Slough, Five Mile Slough, Mosher Slough, and Smith Canal. Table 1 also presents the Stockton slough monitoring data collected by the DeltaKeeper for the fall of 1996. These data show that this low DO problem in the Stockton sloughs has been occurring in other years. A review of the data shows that often the DO concentration in the sloughs increases during a rainfall event. This is evidently related to dilution and mixing.

Lee and Jones-Lee (2000) summarized the studies of Chen and Tsai (2000), who conducted a limited study of dissolved oxygen depletion in Smith Canal (which is one of the Stockton sloughs) after stormwater runoff events. The purpose of this study was to evaluate the reasons for the dissolved oxygen depression in Smith Canal that occurs after stormwater runoff. Smith Canal is a dead-end slough connected to the San Joaquin River opposite Rough and Ready Island. It receives stormwater inflow from an urban area of Stockton. During or soon after a stormwater runoff event, the water quality in Smith Canal is sufficiently deteriorated so that fish kills have occurred. Smith Canal has a drainage area of 3,300 ac., with 50 percent residential, 18 percent commercial and 26 percent streets. The institution and industrial activities occupy about six percent. In the late 1990s the City of Stockton conducted a multi-year monitoring program to measure stormwater input and water quality response in Smith Canal.

Figure 1



DeltaKeeper Dissolved Oxygen Sampling Sites - November 1999

1 Mosher Slough - Mariner's Drive bridge at I-5
2 Five-Mile Slough - at Plymouth Road bridge
3 Calaveras River - at Woods Bridge, north of UOP campus
4 Smiths Canal - at Pershing Avenue bridge
5 Mormon Slough - at Lincoln Street bridge
6 Walker Slough - at Manthey Road bridge and I-5 (Van Buskirk Park)
7 Smiths Canal - at Yosemite Street
8 Mormon Slough - at Turning Basin
9 Walker Slough - upstream from confluence with Duck Creek

Table 1
Dissolved Oxygen Concentrations in Stockton Sloughs during November 1999 and January-February 2000

Mosher Slough

Date	Time	Depth (ft)	Temp (C)	DO mg/L	DO % Sat.[a]	Spec Cond[b]	Tide	Notes
11/8/99	850	3.4	14.5	8.5	86	66	low	" rain 11/7-11/8
11/9/99	845	2.9	14.7	4.0	39	78	low	
11/10/99	1020	1.5	14.7	2.3	23	108	low	
11/11/99	1015	1.2	14.8	1.4	14	120	low	blackish brown
11/12/99	920	1.3	15.2	1.6	16	138	incoming	
11/13/99	925	1.3	15.3	1.8	18	123	incoming	
11/14/99	950	1.3	15.3	1.9	19	125	incoming	
11/15/99	920	1.3	15.3	2.5	25	142	incoming	
11/16/99	915	1.2	14.8	2.4	23	150	incoming	
11/17/99	1013	1.5	15.3	3.3	33	95	incmg/mid	
11/18/99	925	1.5	13	1.3	12	93	incmg/low	
11/19/99	850	0.6	11.8	2.0	19	104	outg/vlow	
11/20/99	830	1.3	12.7	6.4	60	57	outg/low	
11/21/99	745	1.5	12.7	5.3	50	133	outg/low	
11/22/99	900	1.2	10.1	5.5	49	131	outg/low	
11/23/99	900	1.4	10.5	4.9	44	137	outg/mid	
11/24/99	910	1.1	11	4.6	41	146	outg/low	
1/14/00	922	1	9.4	8.6	75	225	incoming	day after rain
1/19/00	904	1	11.7	6.1	57	104	low/outgoing	rain
1/20/00	1016	1	12.1	4.8	45	121	low/outgoing	rain
1/21/00	959	1	11	3.9	35	140	low/outgoing	no rain
1/22/00	958	1	11.3	4	37	161	low/outgoing	no rain
1/23/00	1012	1.5	11.6	5.5	50	147	low/outgoing	rain
1/25/00	1544	1	13.1	9.3	88	154	low/outgoing	no rain - fast, muddy flow
1/26/00	1433	0.5	12	5.9	54	199	low/outgoing	no rain
1/27/00	1442	1.5	11.5	7.4	68	184	low/outgoing	no rain
1/28/00	1411	1.5	11.6	6.3	58	194	low/outgoi	rain

[a] Percent dissolved oxygen saturation
[b] Specific Conductivity in μmhos/cm at 20 C

							ng	
2/1/00	850	1	11.1	5.4	49	139	low/outgoi ng	day after rain
2/2/00	1735	1	12.5	4.1	38	177	low/outgoi ng	no rain
2/3/00	1040	1	10.5	8.6	77	173	low/outgoi ng	rain
2/4/00	914	1	11.8	6.4	59	158	low/outgoi ng	day after rain
2/7/00	904	1	11.7	3.8	35	185	low/outgoi ng	3 days after rain

Five Mile Slough

Date	Time	Depth (ft)	Temp (C)	DO (mg/l)	DO% Sat	Spec Cond	Tide	Notes
11/8/99	915	1.1	14.5	6.	59	328	low	" rain 11/7-8
11/9/99	900	0.3	13.6	0.8	8	251	low	
11/10/99	1040	0.8	14.8	1.9	19	356	low	
11/11/99	1030	0.5	15.2	3.1	31	309	low	blackish brown
11/12/99	930	1.1	14.6	2.6	26	326		
11/13/99	945	1.2	14.6	4.8	47	282	incoming	
11/14/99	1000	1.1	15.3	6	60	295	incoming	
11/15/99	935	1.1	15.8	6.5	66	317		
11/16/99	930	0.8	15.2	4.8	48	329		
11/17/99	1026	1	14.6	4	39	181	high/slack	
11/18/99	950	1	12.8	3	28	199	slack	
11/19/99	905	1	11	3.8	36	214	mid/outg	
11/20/99	850	0.9	12	2.9	29	126	low	
11/21/99	800	0.9	12.7	3.9	36	162	mid/incmg	
11/22/99	916	1.1	10	6.2	55	182	mid	
11/23/99	915	1.0	10.3	6.9	62	210	slack/high	
11/24/99	925	1.3	10.2	7.8	69	238	mid	
1/14/00	922	1	9.4	8.6	75	225	incoming	day after rain
1/19/00	918	1	11.8	2.4	22	150	low/outgoing	rain – oil sheen
1/20/00	1036	1	12.2	2.4	23	151	low/outgoing	rain – oil sheen
1/21/00	1012	1	10.8	2.4	21	144	low/outgoing	no rain
1/22/00	1012	1	11.7	2.8	26	178	low/outgoing	no rain
1/23/00	1026	1.5	11.5	8.7	80	67	High	rain
1/25/00	1414	1	14.6	6.7	66	109	low/outgoing	day after rain
1/26/00	1500	1	13	5.2	49	74	low/outgoing	no rain
1/27/00	1452	0.5	13	4.4	42	81	low/outgoing	no rain

1/28/00	1424	0.5	12	5.5	52	103	low/outgoing	rain
2/1/00	902	1	10	4.7	42	94	low/outgoing	day after rain
2/2/00	1719	0.5	13.6	4.2	40	96	low/outgoing	duckweed
2/3/00	935	1	10.5	8.6	77	173	low/outgoing	rain
2/4/00	930	1	11.5	6.1	57	86	low/outgoing	day after rain
2/7/00	915	0.5	11.4	4.6	42	107	low/outgoing	3 days after rain

Walker Slough

Date	Time	Depth (ft)	Temp (C)	DO mg/L	DO % Sat	Spec Cond	Tide	Notes
11/8/99	1115	1.3	15.4	6.4	64	287	Low	" rain 11/7-8
11/9/99	945	1.7	14.5	4.7	46	359	Low	
11/10/99	1200	1.1	15.5	5.7	58	330	Low	
11/11/99	1140	1.3	15.7	5.3	54	380	Low	
11/12/99	1115	1.2	15.2	5.1	50	429	Outg	
11/13/99	1115	1.3	15.2	7	70	457	Outg	
11/15/99	1050	1.2	15.6	6.4	54	448	Incmg	
11/16/99	1045	1.2	15.3	5.7	57	408	incmg/mid	heavy brown scum
11/17/99	1150	1.1	15.5	5.6	56	400	incmg/mid	oil circles
11/18/99	1105	1.1	14	5.9	57	351	incmg/low	
11/19/99	1225	1.1	12.5	5.6	53	390	incmg/low	rain
11/20/99	1110	0.7	13	5.6	53	185	low/slack	
11/21/99	1020	0.6	11.8	4.7	43	260	low/slack	
11/22/99	1045	0.7	9.1	7.0	61	277	incm/low	
11/23/99	1035	1.4	9.5	7.3	64	329	outg/vlow	
11/24/99	1055	1.2	9.9	7.3	64	376	outg/low	
1/14/00	1100	1	9.3	10	88	706	high/incoming	day after rain
1/19/00	1039	1	11.9	4.9	46	256	low/slack	rain
1/20/00	1153	1	12.1	5.2	49	241	low/incom	rain
1/21/00	1135	1	11.1	5.6	51	215	low/outgoing	no rain
1/22/00	1117	1	12.1	6	56	222	low/outgoing	no rain
1/23/00	1128	1	11.8	9.1	84	163	low/outgoing	rain
1/25/00	1544	1	13.1	9.3	88	154	low/outgoing	no rain
1/26/00	1610	1	13	9.4	89	88	low/outgoing	no rain
1/27/00	1610	1.5	12.6	9.3	88	108	low/outgoing	no rain
1/28/00	1637	1	11.3	8.2	75	140	low/outgoing	rain
2/1/00	1008	1	10.2	8	71	168	low/outgoing	day after rain
2/2/00	1559	1	12.5	9.5	89	205	slack/outgoing	no rain
2/3/00	1040	1	10.5	8.6	77	173	low/outgoing	rain
2/4/00	1053	1	11.3	8.4	77	152	low/outgoing	day after rain
2/7/00	1045	1	10.9	9.7	87	108	low/outgoing	3 days after rain

Mormon Slough

Date	Time	Depth (ft)	Temp (C)	DO mg/L	DO % Sat	Spec Cond	Tide	Notes

11/8/99	1050	1.2	15.7	8.3	83	84	low	" rain 11/7-8
11/10/99	1135	1	16	1.3	14	165	low	
11/11/99	1130	1.1	15.9	0.7	8	185	low	blackish brown
11/12/99	1100	1.4	15.6	0.5	4.8	264	outg	
11/13/99	1100	1.5	15.5	0.6	6	269	incmg	
11/15/99	1030	1.2	15.7	2.2	22	335	incmg	
11/16/99	1030	1.1	15.4	2.0	20	349	outg	
11/17/99	1135	1.4	15.4	1.0	10	293	incmg/mid	
11/18/99	1040	1.4	14.2	0.7	7	245	incmg/mid	
11/19/99	1205	1.5	13	1.5	14	270	incmg/mid	
11/20/99	1050	1.2	14.1	3.5	34	115	incmg/low	
11/21/99	1005	1.0	13.3	2.6	25	149	low/slack	
11/22/99	1021	0.6	11.6	3.4	31	162	outg/vlow	
11/23/99	1020	1.0	10.8	3.2	29	172	slack/vlow	
11/24/99	1045	1.2	11.1	3.6	33	196	slack/low	
1/14/00	1045	1	9.5	4	35	749	high/slack	day after rain
1/99/00	1022	1	12.2	4.3	40	117	low/outgoing	rain
1/20/00	1138	1	12	3.4	32	318	low/incoming	rain
1/21/00	1120	1	11.7	3.1	29	322	low/outgoing	no rain
1/22/00	1102	1	11.8	2.8	26	456	low/outgoing	no rain
1/23/00	1117	1	11.8	9.6	89	72	low/outgoing	rain
1/25/00	1527	1	13.7	5.9	57	182	low/outgoing	no rain–oily bubbles
1/26/00	1552	1.5	12.7	4.0	38	113	low/outgoing	no rain
1/27/00	1343	1.5	12.4	3.5	33	219	low/outgoing	no rain
1/28/00	1623	1	11.6	3.4	32	281	low/outgoing	rain
2/1/00	955	1	10.6	3.1	28	305	low/outgoing	day after rain
2/2/00	1624	1.5	12.9	4.8	45	385	slack/outgoing	no rain
2/3/00	1025	1	11.3	3.7	34	336	low/outgoing	rain
2/4/00	1037	1	12.1	4.0	37	192	low/outgoing	day after rain
2/7/00	1035	1	12.1	2.7	25	278	low/outgoing	3 days after rain

Smith Canal

Date	Time	Depth (ft)	Temp (C)	DO mg/L	DO % Sat	Spec Cond	Tide	Notes
~~11/8/99~~	~~1020~~	~~3.1~~	~~15.7~~	~~7.7~~	~~77~~	~~272~~	~~Low~~	~~" rain 11/7-8~~
11/9/99	930	0.9	15.6	0.4	4	334	low	
11/10/99	1115	1.3	15.9	1.5	15	327	low	
11/11/99	1105	1.3	15.8	1.7	17	356	low	blackish brown
11/12/99	1045	1.4	15.8	2.9	29	411	outgoing	
11/13/99	1045	1.3	15.4	3.4	35	359	incoming	
11/15/99	1015	1.4	15.3	3.5	35	388	incoming	
11/16/99	1015	1.4	15.3	2.9	29	393	incom/mid	
11/17/99	1104	1.2	15	2.3	23	390	incom/mid	

11/18/99	1025	1.2	14.3	1.6	16	375	incom/low	
11/19/99	1150	1.3	13.6	1.8	18	296	incmg/mid	
11/20/99	1020	1.1	13.5	1.6	16	268	incmg/low	
11/21/99	950	1.4	13.3	0.7	6	279	low/slack	
11/22/99	1001	1.3	11.9	1.1	10	292	outg/low	
11/23/99	955	1.5	10.8	1.4	13	327	outg/vlow	
11/24/99	1012	1.5	11.2	1.7	15	352	outg/low	
1/14/00	1026	1	9.1	3.9	34	718	high/slack	day after rain
1/19/00	1004	1	11.4	5.2	48	359	low/outgoing	rain
1/20/00	1122	1	11.6	4.0	37	405	low/incoming	rain
1/21/00	1058	1	11	3.6	33	419	low/outgoing	no rain
1/22/00	1048	1	11.4	3.3	30	449	low/outgoing	no rain
1/23/00	1101	2	11.8	5.7	52	331	low/outgoing	rain
1/25/00	1501	1	13.1	8.7	83	100	low/outgoing	no rain
1/26/00	1537	1	12.9	7.0	6	60	low/outgoing	no rain
1/27/00	1357	1	12.2	5.4	50	86	low/outgoing	no rain
1/28/00	1609	1	12.4	4.8	45	121	low/outgoing	rain
2/1/00	938	1	11.1	3.5	32	169	low/outgoing	day after rain
2/2/00	1640	1	12.4	3.8	35	215	slack/outgoing	no rain
2/3/00	1010	1	11.3	3.6	33	184	low/outgoing	rain
2/4/00	1015	1	11.7	4.4	41	171	low/outgoing	day after rain
2/7/00	1018	1	11.9	3.2	30	208	low/outgoing	3 days after rain

Calaveras River

Date	Time	Depth (ft)	Temp (C)	DO mg/L	DO % Sat	Spec Cond	Tide	Notes
11/8/99	1000	2.2	14.9	9.1	90	101	low	" rain 11/7-11/8
11/9/99	915	1.1	14.6	4.8	47	126	low	
11/10/99	1055	0.8	14.9	4.0	40	136	low	
11/11/99	1050	1.9	14.8	3.5	35	151	low	blackish brown
11/12/99	1030	2.1	15.0	2.9	29	153		
11/13/99	1030	2.1	14.8	3.2	32	133	outgoing	
11/14/99	1020	2.0	14.9	3.4	34	137	incoming	
11/15/99	1000	2.1	15.0	3.9	39	152	incoming	
11/16/99	1015	2.2	14.9	4.2	42	161	incoming	
11/17/99	1050	1.4	14.7	5.4	54	176	incom/mid	
11/18/99	1010	1.4	14.0	4.8	47	175	incmg/low	
11/19/99	920	2	13	5.1	48	175	incmg/vlow	
11/20/99	850	1.0	12.9	8.6	82	160	incmg/low	
11/21/99	830	0.6	12.7	7.2	68	169	incmg/low	
11/22/99	951	1.5	11.5	7.6	70	169	outg/low	
11/23/99	935	2.0	10.9	8.2	75	182	outg/vlow	
11/24/99	1000	2.1	10.6	8.4	76	187	outg/low	
1/14/00	1009	1	9.5	4.6	40	212	high/incoming	day after rain

1/19/00	942	1	11.8	8.8	81	170	low/outgoing	rain
1/20/00	1100	1	12.1	9.9	92	199	low/outgoing	rain
1/21/00	1044	1	11.4	9.9	91	177	low/outgoing	no rain
1/22/00	1032	1	11.3	10.2	93	198	low/outgoing	no rain
1/23/00	1047	1	12.1	10.2	95	152	low/outgoing	rain
1/25/00	1440	1	12.7	10.3	97	198	low/outgoing	no rain
1/26/00	1524	1	12.6	10.7	100	118	low/outgoing	no rain
1/27/00	1422	1	12.1	11.0	103	149	low/outgoing	no rain
1/28/00	1555	1	11.2	11.1	101	191	low/outgoing	rain
2/1/00	924	1	10.3	11.5	103	229	low/outgoing	day after rain
2/2/00	1655	1	11.5	11.6	106	189	slack/outgoing	no rain
2/3/00	1000	1	11.2	11.8	107	205	low/outgoing	rain
2/4/00	955	1	11.4	11.7	107	198	low/outgoing	day after rain
2/7/00	940	1	11.1	11.7	42	107	low/outgoing	3 days after rain

Monitoring of Stockton Sloughs, 1996

Mosher Slough

Date	Time	Depth (ft)	Temp (C)	DO (mg/l)	DO %	Spec Cond	Tide	Weather
10/15/96	1405	1.5	16.3	9.3	97	274	Out-Low	Clear
10/29/96	1250	1.3	13.6	9.9	96	215	Out-Low	Raining
10/29/96	1307	2.4	13.5	9.7	95	215	Out-Low	Raining
10/30/96	1345	1.8	13.4	9.4	90	253	Out-Low	Partly Cloudy
10/31/96	1447	2.4	13.1	5.5	54	224	Out-Low	Overcast
11/1/96	1010	3.6	13.1	4.1	39	233	In-High	Sunny
11/1/96	1643	2.3	13.1	6.5	62	180	Out-Low	Clear
11/1/96	1648	2.3	13.5	5.7	55	202	Out-Low	Clear
11/2/96	1400	2.8	13.1	5.8	56	242	Out-High	Overcast
11/3/96	1615	2.8	12.4	6.0	56	190		Partly Cloudy
11/8/96	1105	2.2	12.7	8.0	75	219	Low-In	Clear and Warm

Five Mile Slough

Date	Time	Depth (ft)	Temp (C)	DO (mg/l)	DO %	Spec Cond	Tide	Weather
10/15/96	1425	1.6	22.3	9.4	110	838	Out-Low	Clear
~~10/29/96~~	~~1335~~	~~1.4~~	~~13.9~~	~~9.5~~	~~84~~	~~365~~	~~Out-Low~~	~~Raining~~
10/30/96	1404	1.7	13.9	5.9	60	165	Out-Low	Partly Cloudy
10/31/96	1504	2.2	14.2	0.86	8.5	255	Out-Low	Overcast
11/1/96	1143	1.9	13.3	0.31	2.9	288	In-High	Sunny
11/1/96	1705	2.0	14.6	0.25	2.5	285	Low	Clear
11/2/96	1345	2.0	15.0	0.55	5.5	339	Out-High	Overcast
11/3/96	1630	2.1	15.5	4.2	42	391		Partly Cloudy
11/8/96	1120	1.7	13.7	10.6	102	452	Low-In	Clear and Warm

Smith Canal

Date	Time	Depth	Temp	DO	DO	Spec	Tide	Weather

		(ft)	(C)	(mg/l)	%	Cond		
10/15/96	1500	5.1	20.9	9.3	107	1393	In-Low	Clear
10/15/96	1500	2.0	21.6	11	126	1383	In-Low	Clear
10/29/96	1645	4.8	13.8	10	97	966	In	Raining
10/30/96	1432	3.4	14.1	6.7	69	384	Out-Low	Partly Cloudy
10/31/96	1535	3.5	13.6	0.6	5.6	387	Out-Low	Partly Cloudy
11/1/96	1237	4.9	13.1	0.3	3.3	533	Out-High	Sunny.
11/1/96	1734	3.7	13.5	0.2	2.1	466	In-Low	Clear
11/2/96	1441	4.2	13.0	0.3	2.6	470	Out-High	Partly Cloudy
11/3/96	1655	4.3	12.8	0.2	2.4	473		Partly Cloudy
11/8/96	1138	5.8	12.2	2.7	26	602	Low-In	Clear and Warm

Calaveras River

Date	Time	Depth (ft)	Temp (C)	DO (mg/l)	DO %	Spec Cond	Tide	Weather
10/15/96	1444	3.7	21.1	6.7	79	959	Out-Low	Clear
10/29/96	1525	6.3	13.8	9.1	88	549	In-Low	Raining
10/30/96	1541	4.6	13.1	7.7	77	486	In-Low	Partly Cloudy
10/31/96	1707	3.3	13.8	2.4	23	487	In-Low	Partly Cloudy
11/1/96	1550	3.1	13.3	1.0	10	323	Out-Low	Clear
11/1/96	1557	6.4	13.0	1.0	9.5	303	Out-Low	Clear
11/1/96	1600	11.0	12.8	0.9	8.9	296	Out-Low	Clear
11/2/96	1552	3.3	13.3	1.2	12	333	Out-Low	Partly Cloudy
11/2/96	1559	6.4	13.3	1.2	12	333	Out-Low	Partly Cloudy
11/2/96	1605	11.3	13.3	1.2	11	332	Out-Low	Partly Cloudy
11/8/96	1020	5.0	12.6	5.3	50	429	Low-In	Clear and Warm
11/8/96	1028	9.2	12.4	4.9	46	427	Low-In	Clear and Warm

Duck Creek

Date	Time	Depth (ft)	Temp (C)	DO (mg/l)	DO %	Spec Cond	Tide	Weather
10/15/96	1515	1.7	20.4	12.3	140	462	In-Low	Clear
10/29/96	1715	2.9	13.1	8.8	84	385	In	Raining
10/30/96	1500	1.6	14.4	6.2	62	411	In-Low	Partly Cloudy
10/31/96	1555	2.0	14.4	4.1	40	380	Low	Partly Cloudy
11/1/96	1300	3.6	13.8	3.1	30	471	Out-High	Sunny
11/1/96	1800	2.7	14.2	4.6	45	416	In-Low	Clear
11/2/96	1507	3.4	14.3	5.6	50	451	Out-High	Partly Cloudy
11/3/96	1718	3.2	14.1	6.3	62	485		Partly Cloudy
11/8/96	1145	2.1	12.8	8.2	77	616	Low-In	Clear and Warm

In the Chen and Tsai (2000) studies, the dissolved oxygen in Smith Canal decreased to about 1 mg/L about two days after initiation of the stormwater runoff event. It was found that the sediments in Smith Canal had an oxygen demand of about 0.3 g/ft^2/day, which translates to about 3 g/m^2/day, which is in the high range of SOD for waterbodies.

Chen and Tsai (2000) applied the Stockton SJR DO Model to the DO depletion that occurs after runoff events. The Stockton SJR DO Model was modified to include sediment scour transport and deposition of scoured particles. Further, a routine was added to the model to account for the oxygen demand of the scoured sediments. Chen and Tsai (2000) were able to tune the model so that it tracked reasonably closely the DO depletion. They concluded that the primary cause of DO depletion at the dead-end part of Smith Canal was due to constituents present in the urban stormwater discharged to this point. They also concluded that the primary cause of dissolved oxygen depletion is the scour of the sediments and the oxygen demand associated with the sediments.

Chen and Tsai (2000) conducted a limited study of dissolved oxygen depletion in Smith Canal (which is one of the Stockton sloughs) after stormwater runoff events. The purpose of this study was to evaluate the reasons for the dissolved oxygen depression in Smith Canal that occurs after stormwater runoff. Smith Canal is a dead-end slough connected to the San Joaquin River opposite Rough and Ready Island. It receives stormwater inflow from an urban area of Stockton. During or soon after a stormwater runoff event, the water quality in Smith Canal is sufficiently deteriorated so that fish kills have occurred. Smith Canal has a drainage area of 3,300 ac., with 50 percent residential, 18 percent commercial and 26 percent streets. The institution and industrial activities occupy about six percent. In the late 1990s the City of Stockton conducted a multi-year monitoring program to measure stormwater input and water quality response in Smith Canal.

In the Chen and Tsai (2000) studies, the dissolved oxygen in Smith Canal decreased to about 1 mg/L about two days after initiation of the stormwater runoff event. It was found that the sediments in Smith Canal had an oxygen demand of about 0.3 g/ft^2/day, which translates to about 3 g/m^2/day, which is in the high range of SOD for waterbodies.

Chen and Tsai (2000) applied the Stockton SJR DO Model to the DO depletion that occurs after runoff events. The Stockton SJR DO Model was modified to include sediment scour transport and deposition of scoured particles. Further, a routine was added to the model to account for the oxygen demand of the scoured sediments. Chen and Tsai (2000) were able to tune the model so that it tracked reasonably closely the DO depletion. They concluded that the primary cause of DO depletion at the dead-end part of Smith Canal was due to constituents present in the urban stormwater discharged to this point. They also concluded that the primary cause of dissolved oxygen depletion is the scour of the sediments and the oxygen demand associated with the sediments.

Chen and Tsai (2000) found that the BOD_5 in stormwater runoff to Smith Canal ranged from 12 to 19 mg/L. They concluded that the BOD was not the cause of the DO depletion that occurs in Smith Canal, that the cause for this depression was due to scouring and resuspension of sediments from the channel (Smith Canal) bottom, as well as scouring and resuspension of sediments present in the storm sewers that discharge to Smith Canal. It was found that the DO in Smith Canal recovered from the depression more than five days after the storm. They concluded that the impact of DO depletion was on aquatic life within Smith Canal and there was little impact on the San Joaquin River Deep Water Ship Channel into which Smith Canal discharges.

In July 1999 Camp, Dresser and McKee (CDM, 1999) issued a technical memorandum entitled, "Assessment of Water Quality Data from Smith Canal," which is appended to the Chen and Tsai (2000) report. This memorandum is a follow-up to the work of Chen and Tsai. In addition to examining the results of the Chen and Tsai studies, CDM also conducted a review of the past City of Stockton stormwater monitoring and Smith Canal water quality characteristic data. The CDM review primarily focused on the water quality characteristic monitoring of the Smith Canal that the City of Stockton has done over recent years. This monitoring included continuous recording of several parameters, including dissolved oxygen, water depth, pH, specific conductivity, and temperature.

CDM (1999) reported, based on a review of both winter and summer data on Smith Canal, that low DOs were also encountered during summer non-stormwater runoff event periods. Generally, poorer water quality was found during the wet season. CDM reported large diel variations in DO of about 2 to sometimes as large as 10 mg/L, indicating high levels of algal photosynthesis and microbial respiration.

Lehman (2000) collected data on Smith Canal and Calaveras River water quality characteristics during August and September 1999 as part of the SJR DO TMDL TAC fall 1999 studies. She reported DOs below the water quality objectives for Smith Canal; the Calaveras River just upstream of where it enters the DWSC also had DO concentrations during August and September below WQOs. Lehman also reported chlorophyll and phaeophytin concentrations for Smith Canal and Calaveras River. The concentrations ranged from about 5 µg/L to almost 40 µg/L, with the majority of the values in the 10 to 20 µg/L range.

The data that DeltaKeeper has provided (Table 1), as well as those of Chen and Tsai and CDM, on the dissolved oxygen concentrations in the City of Stockton sloughs show severe depletion of dissolved oxygen through the late fall and winter. While there is some question about the significance of small short-term DO depletions below 5 mg/L (which is the US EPA national water quality criterion for DO), where these excursions below this criterion occur for limited periods of time and to a limited extent of no more than a mg/L or so, there is no question about the significance of DO concentrations being strongly adverse to aquatic life when the concentrations are as low as the DeltaKeeper has found in the Stockton sloughs over the late fall and winter of 1999-2000. DO concentrations less than 3 mg/L are significantly adverse to aquatic life-related beneficial uses of these sloughs. Additional information on the adverse impacts of low DO to aquatic life is found in the US EPA dissolved oxygen criterion document (US EPA 1986, 1987).

Please feel free to distribute my comments to anyone you feel might be interested. Please contact me if you have questions about them or need further assistance.

Sincerely yours,

G. Fred Lee, PhD, DEE

GFL:ds

References

CDM, "Assessment of Water Quality Data from Smith Canal," Report prepared by Camp Dresser & McKee Inc. for City of Stockton Stormwater Division, Sacramento, CA, July (1999).

Chen, C.W. and Tsai, W., "Rough Loading Calculation for Dissolved Oxygen Links in Lower San Joaquin River," Systech Engineering, Inc., San Ramon, CA, January (2000).

Lee, G.F. and Jones-Lee, A., "Issues in Developing the San Joaquin River Deep Water Ship Channel DO TMDL," Report to SJR DO TMDL Steering Committee and the CVRWQCB, G. Fred Lee & Associates, El Macero, CA, August (2000).

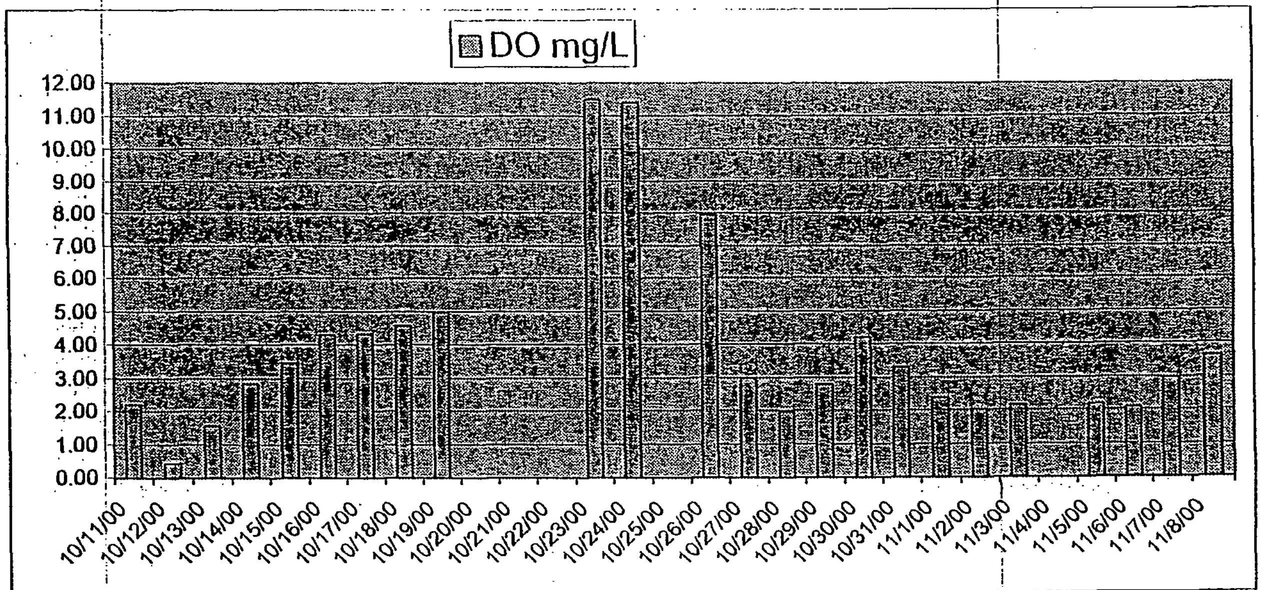
Lehman, P., "Results of the 1999 Field Study in the Stockton Deep Water Channel for August and September," (Draft Summary #1 – Preliminary Data), January (2000).

US EPA, "Ambient Water Quality Criteria for Dissolved Oxygen," US Environmental Protection Agency Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC, EPA 440/5-86-003, April (1986).

US EPA, Quality Criteria for Water 1986, US EPA 44/5-86-001, Office of Water Regulations and Standards, Washington, D.C., May (1987).

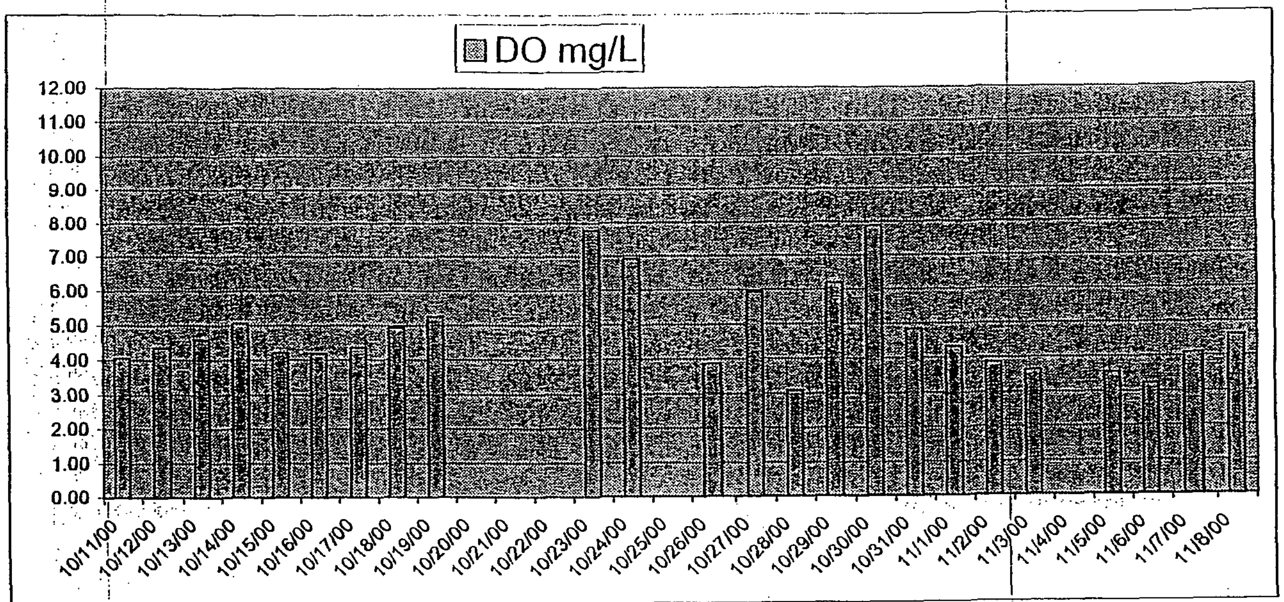
Smith Canal

Date	DO mg/L	Rain in Past 24 Hours
11-Oct-00	2.19	0.30
12-Oct-00	0.43	0.22
13-Oct-00	1.55	
14-Oct-00	2.84	
15-Oct-00	3.45	
16-Oct-00	4.29	
17-Oct-00	4.32	
18-Oct-00	4.58	
19-Oct-00	4.97	
23-Oct-00	11.49	
24-Oct-00	11.38	
26-Oct-00	7.94	0.48
27-Oct-00	3.00	0.57
28-Oct-00	1.97	0.08
29-Oct-00	2.79	0.71
30-Oct-00	4.20	0.21
31-Oct-00	3.30	
01-Nov-00	2.38	
02-Nov-00	2.01	
03-Nov-00	2.16	
05-Nov-00	2.17	
06-Nov-00	2.08	
07-Nov-00	2.97	
08-Nov-00	3.62	



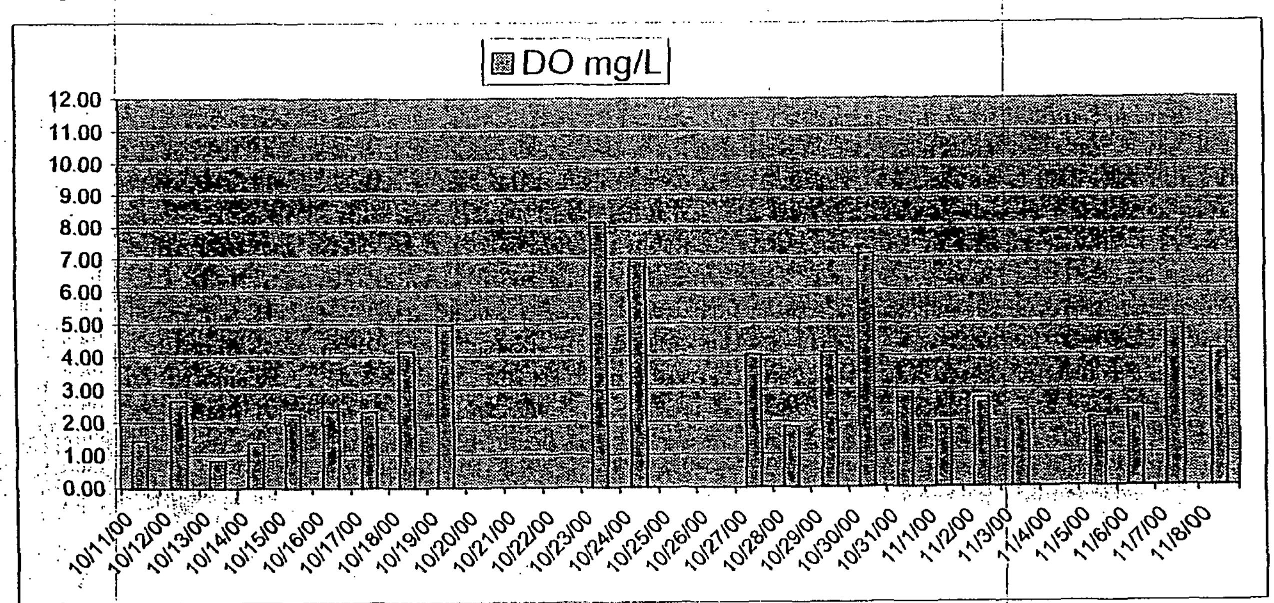
Mosher Slough

Date	DO mg/L	Rain in Past 24 Hours
17-Oct-00	4.36	0.30
11-Oct-00	4.06	0.22
12-Oct-00	4.37	
13-Oct-00	4.59	
14-Oct-00	5.06	
15-Oct-00	4.22	
16-Oct-00	4.20	
18-Oct-00	4.94	
19-Oct-00	5.25	
23-Oct-00	7.79	
24-Oct-00	6.92	
26-Oct-00	3.88	0.48
27-Oct-00	5.93	0.57
28-Oct-00	3.10	0.08
29-Oct-00	6.18	0.71
30-Oct-00	7.87	0.21
31-Oct-00	4.85	
01-Nov-00	4.33	
02-Nov-00	3.87	
03-Nov-00	3.65	
05-Nov-00	3.55	
06-Nov-00	3.22	
07-Nov-00	4.11	
08-Nov-00	4.61	



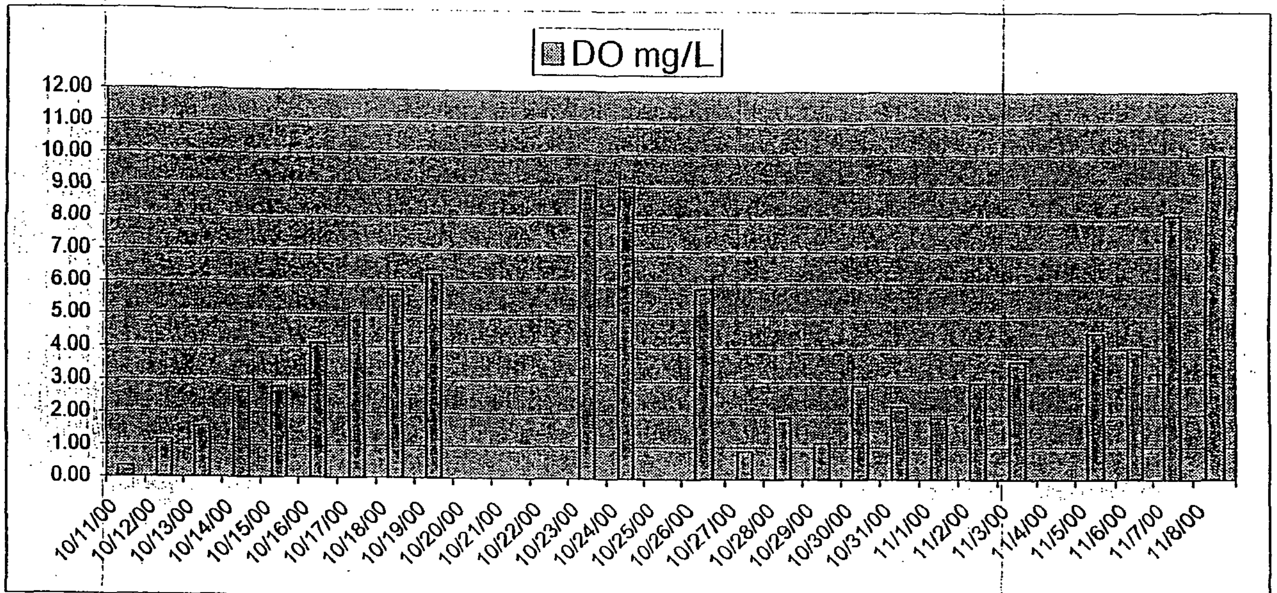
Mormon Slough

Date	DO mg/L	Rain in Past 24 Hours
11-Oct-00	1.44	0.30
12-Oct-00	2.66	0.22
13-Oct-00	0.82	
14-Oct-00	1.36	
15-Oct-00	2.26	
16-Oct-00	2.33	
17-Oct-00	2.32	
18-Oct-00	4.15	
19-Oct-00	4.95	
23-Oct-00	8.15	
24-Oct-00	6.99	
26-Oct-00		0.48
27-Oct-00	4.04	0.57
28-Oct-00	1.84	0.08
29-Oct-00	4.10	0.71
30-Oct-00	7.12	0.21
31-Oct-00	2.87	
01-Nov-00	1.96	
02-Nov-00	2.70	
03-Nov-00	2.29	
05-Nov-00	2.07	
06-Nov-00	2.32	
07-Nov-00	4.91	
08-Nov-00	4.15	



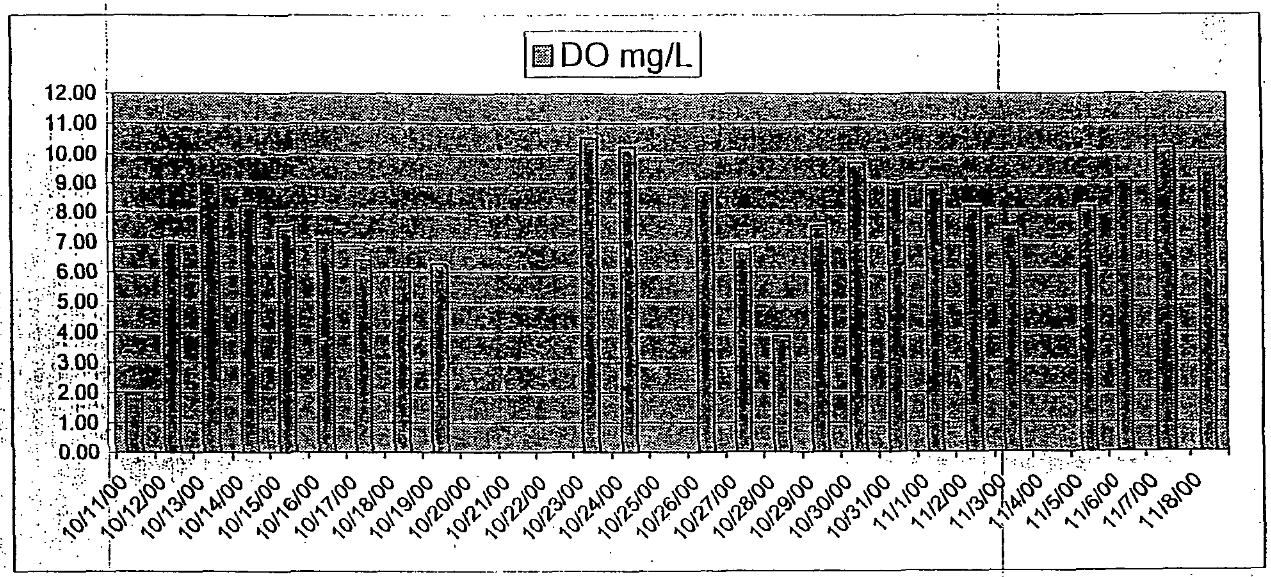
Five Mile Slough

Date	DO mg/L	Rain In Past 24 Hours
11-Oct-00	0.34	0.30
12-Oct-00	1.18	0.22
13-Oct-00	1.58	
14-Oct-00	2.78	
15-Oct-00	2.81	
16-Oct-00	4.12	
17-Oct-00	5.05	
18-Oct-00	5.77	
19-Oct-00	6.25	
23-Oct-00	9.05	
24-Oct-00	9.01	
26-Oct-00	5.85	0.48
27-Oct-00	0.89	0.57
28-Oct-00	1.93	0.08
29-Oct-00	1.15	0.71
30-Oct-00	2.90	0.21
31-Oct-00	2.26	
01-Nov-00	1.93	
02-Nov-00	2.99	
03-Nov-00	3.62	
05-Nov-00	4.48	
06-Nov-00	4.02	
07-Nov-00	8.12	
08-Nov-00	10.02	



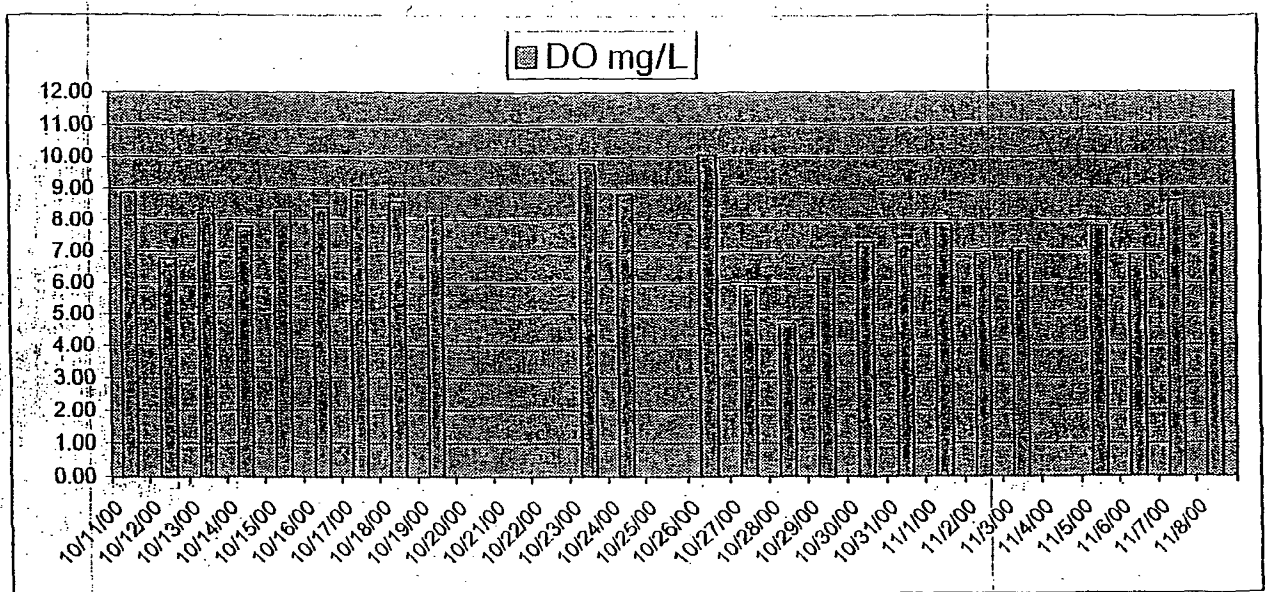
Calaveras River

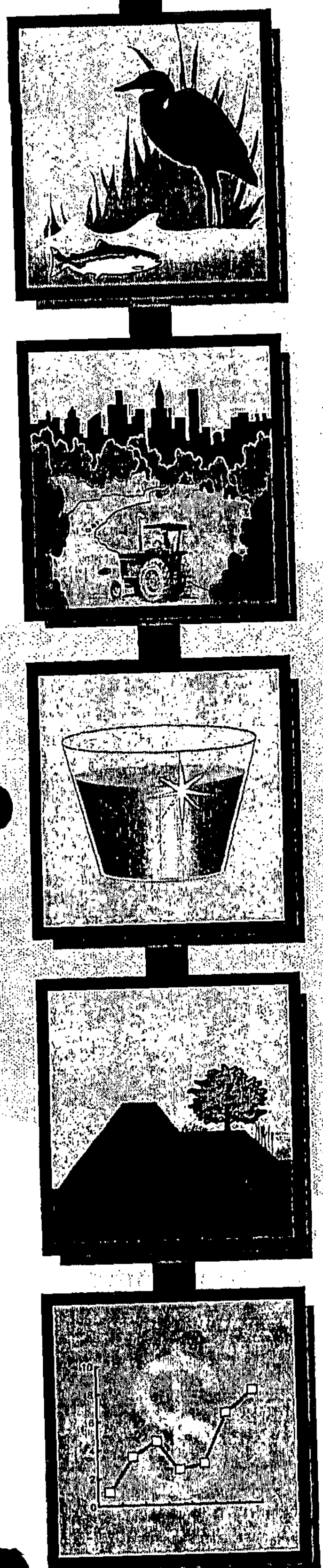
Date	DO mg/L	Rain In Past 24 Hours
11-Oct-00	1.95	0.30
12-Oct-00	7.03	0.22
13-Oct-00	9.11	
14-Oct-00	8.22	
15-Oct-00	7.55	
16-Oct-00	7.08	
17-Oct-00	6.41	
18-Oct-00	5.99	
19-Oct-00	6.27	
23-Oct-00	10.54	
24-Oct-00	10.22	
26-Oct-00	8.83	0.48
27-Oct-00	6.76	0.57
28-Oct-00	3.89	0.08
29-Oct-00	7.54	0.71
30-Oct-00	9.69	0.21
31-Oct-00	8.95	
01-Nov-00	8.90	
02-Nov-00	8.17	
03-Nov-00	7.35	
05-Nov-00	8.19	
06-Nov-00	9.15	
07-Nov-00	10.19	
08-Nov-00	9.45	



Walker Slough

Date	DO mg/L	Rain in Past 24 Hours
11-Oct-00	8.85	0.30
12-Oct-00	6.77	0.22
13-Oct-00	8.19	
14-Oct-00	7.77	
15-Oct-00	8.28	
16-Oct-00	8.41	
17-Oct-00	8.94	
18-Oct-00	8.59	
19-Oct-00	8.15	
23-Oct-00	9.77	
24-Oct-00	8.81	
26-Oct-00	10.05	0.48
27-Oct-00	5.88	0.57
28-Oct-00	4.68	0.08
29-Oct-00	6.45	0.71
30-Oct-00	7.29	0.21
31-Oct-00	7.28	
02-Nov-00	6.89	
03-Nov-00	7.15	
05-Nov-00	7.79	
01-Nov-00	7.87	
06-Nov-00	6.90	
07-Nov-00	8.64	
08-Nov-00	8.23	





CALFED
BAY-DELTA
PROGRAM

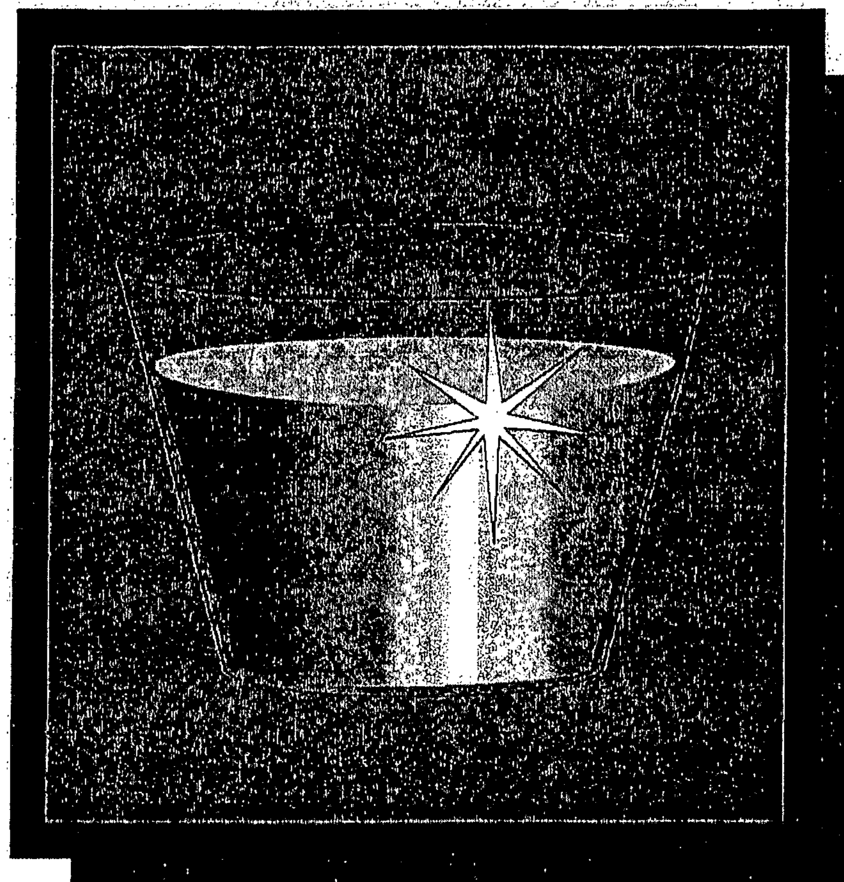
Water Quality Program Plan

Calfed Bay-Delta Program. 2000. Water Quality Program Plan, Final Programmatic EIS/EIR Technical Appendix. July 2000. http://calfed.ca.gov/environmental_docs/306.html

See: Ch 2 & 3

Final Programmatic EIS/EIR Technical Appendix

July 2000



Water Quality Program Plan
July 2000

To improve the quality of the waters of the Sacramento-San Joaquin Delta estuary for all beneficial uses, including domestic, industrial, agricultural, recreation, and aquatic habitat.

CALFED
BAY-DELTA
PROGRAM

Water Quality Program Plan

July 2000

CALFED
BAY-DELTA
PROGRAM

2. LOW DISSOLVED OXYGEN CONCENTRATION AND OXYGEN-DEPLETING SUBSTANCES

2. LOW DISSOLVED OXYGEN CONCENTRATION AND OXYGEN-DEPLETING SUBSTANCES

2.1 SUMMARY

Low DO concentration and the presence of oxygen-depleting substances appears to occur in isolated areas of designated impaired water bodies. The following water bodies are listed in the January 1998 CWA Section 303(d) list as impaired from low DO concentration: Delta waterways, Sacramento River, San Joaquin River, and Bay Regions. Each region is discussed below, along with recommended approaches to solve the problems caused by low DO.

Low DO concentration and the presence of oxygen-depleting substances appears to occur in isolated areas of designated impaired water bodies.

Oxygen-depleting substances originate from a variety of sources. Common sources are degrading organic material from in-stream plants or plant matter from stormwater systems. Usually, stormwater-introduced plant material does not substantially affect DO, since most material is introduced during the wet season. However, stormwater systems also discharge during the dry season due to urban irrigation and water use. Dry season discharge is more concentrated than its winter counterpart. Agricultural drain water (irrigation return) also may carry oxygen-depleting substances. Unpermitted wastewater from industries also contains oxygen-depleting substances and nutrients. Nutrients promote the growth of algae and other water organisms. When these organisms die, they degrade and exert a demand on oxygen in the stream. Some industrial wastewater and some eroded soil in the river water contain nutrients.

2.2 PROBLEM STATEMENT

Oxygen depletion occurs at isolated locations in the Delta, causing DO concentrations to fall below water quality criteria (5 milligrams per liter [mg/l]). Oxygen depleting substances are found in various discharges. The substances may either exert a direct oxygen-depleting effect (i.e., biochemical oxygen demand [BOD]) or decrease oxygen by an indirect method (i.e., nutrients that cause algal growth, which eventually dies off and exerts an oxygen demand.) Low DO impairs or blocks fish migration; kills aquatic organisms, including fish; creates odors; and impairs fish reproduction and juvenile rearing.

2.3 OBJECTIVE

The objective is to correct the causes of oxygen depletion in affected areas, to reduce incidences of low DO, and to reduce the impairment of beneficial uses.

2.4 DELTA WATERWAYS

This section on Delta waterways addresses:

- the San Joaquin River near Stockton;
- Stockton tributaries, including Little Johns, Lone Tree, and Temple Creeks; and
- Urban waterways near Stockton, including Smith Canal, Mosher Slough, 5-Mile Slough, and the Calaveras River.

2.4.1 Problem Description

San Joaquin River near Stockton

DO concentrations have decreased to below the 5-mg/l standard between June and November in the San Joaquin River near Stockton. The main channel near Stockton has been identified as a candidate Bay Protection and Toxic Cleanup Program hot spot. It appears that low DO concentrations occur over a 10-mile reach of the San Joaquin River and can reach as low as 2.5 mg/l in fall. These low DO concentrations are called an "oxygen sag" and may act as a barrier to upstream migration of adult San Joaquin River fall-run chinook salmon that migrate upstream to spawn in the Merced, Tuolumne, and Stanislaus Rivers between September and December.

The main channel near Stockton has been identified as a candidate Bay Protection and Toxic Cleanup Program hot spot.

The San Joaquin River population of chinook salmon has declined, is considered a "species of concern" by the U.S. Fish and Wildlife Service (USFWS), and is a candidate for listing by the National Marine Fisheries Service. Low DO concentrations also can stress, kill, or block migration of other fish.

Oxygen depletion in the San Joaquin River is highest in late summer and fall, when high water temperature reduces the oxygen-carrying capacity of the water and increases biotic respiration rates. Low or negative streamflow past Stockton reduces dilution and mixing, which reduces re-aeration of the water. Respiring algal blooms create a high oxygen demand during these months, which exacerbates other factors. Organic carbon or nutrients from algal blooms, petroleum products, wastewater effluent, or confined animal operations deplete oxygen due to microbial digestion of the carbon. Redox (reduction/oxidation) reactions also may contribute to the oxygen depletion in the river through chemical conversion of oxygen. In addition, San Joaquin River tributaries add oxygen-depleted water after stormwater runoff events in the critical period (late summer). The tributaries introduce low DO water, and they introduce more of the same oxygen-depleting substances. Urban stormwater facilities also may contribute oxygen-depleting substances when the facilities discharge urban irrigation runoff and other urban non-point source effluent.

Oxygen depletion in the San Joaquin River is highest in late summer and fall, when high water temperature reduces the oxygen-carrying capacity of the water and increases biotic respiration rates.

Effluent from the Stockton Regional Wastewater Control Facility (RWCF) is considered to be a relatively large anthropogenic (of human origin) source of the oxygen-depleting substances in the San Joaquin River. The City of Stockton has invested considerable time and money to develop and test an accurate water quality model for the San Joaquin River near Stockton. This model is being used to investigate and evaluate alternative river management strategies. The model suggests that the RWCF is a source of BOD and ammonia in the river, but that sediment oxygen demand and algal respiration may be the dominant mechanisms causing low DO during simulated low-flow periods. The contribution of the RWCF discharge to organic sediment deposits appears relatively small compared to river loads of organic materials, although further studies are warranted to determine the factors involved.

The City of Stockton has invested considerable time and money to develop and test an accurate water quality model for the San Joaquin River near Stockton.

The City of Stockton model results also suggest that:

- A flow of 500 cubic feet per second (cfs) will increase DO by 1-1.3 mg/l.
- A temperature decrease of 2 degrees will increase DO by 1 mg/l.
- A 50% reduction of sediment oxygen demand will increase DO by 1.2 mg/l.
- An algal bloom can decrease DO concentrations by 3 mg/l.
- Removal of the entire RWCF discharge would increase DO concentration by only 1 mg/l and would not be sufficient to meet DO standards for the San Joaquin River.

The Turning Basin is another important source of oxygen-depleting substances in the San Joaquin River in late summer. Each year, the Department of Water Resources (DWR) monitors top and bottom concentrations of DO in the ship channel between Prisoner's Point and the Turning Basin. DO concentrations are lowest in the highly stratified Turning Basin, where they reach <1 mg/l near the bottom. This oxygen-depleted water moves downstream with the tide and into the main channel. The oxygen-depleted water forms a plume at the bottom of the main channel that has a minimum at the mouth of the Turning Basin before placement of the flow restriction barrier in Old River. A depression in the channel at the mouth of the Turning Basin probably accumulates oxygen-depleting substances from the bottom of the Turning Basin.

The Turning Basin is another important source of oxygen-depleting substances in the San Joaquin River in late summer.

It is uncertain whether the low DO concentrations observed in the Turning Basin near the bottom are substantially affecting DO concentrations in the San Joaquin River. The water movement between the Turning Basin and the ship channel, as well as the concentrations of DO and BOD in the water, should be more intensively monitored.

Another suspected source of oxygen depletion is unpermitted discharges of waste from concentrated animal feedlots and other less specific industrial sources. These sources are not confined to the Stockton area but are found throughout the Central Valley and beyond. They are mentioned here only because they are suspected of contributing to low DO levels in the San Joaquin River. Wastewater from such sources exert a demand on DO by introducing organic material that is consumed by micro-organisms and by introducing material that is chemically oxidized. Nutrients from confined animal facilities (and other similar wastes) contribute to algal production, which can intensify oxygen depletion as the algae respires. Confined animal facilities and some agriculture-based industry (fertilizer manufactures and users) also can introduce significant quantities of ammonia, which is lethal to fish at various concentrations, and pH. Data on unpermitted discharges are not readily available. Documenting sources in this portion of the program will include locating these unpermitted discharges.

Another suspected source of oxygen depletion is unpermitted discharges of waste from concentrated animal feedlots and other less specific industrial sources.

Several agencies have contributed in attempts to solve the low DO problem in the Stockton reach of the San Joaquin River during late summer. One strategy was to reduce oxygen depletion in the San Joaquin River by (1) controlling the effluent from the RWCF and Port of Stockton; and (2) forcing more water down the main channel with a rock barrier placed at the head of Old River, thus improving dilution and re-aeration capacity of the river. DWR constructed the barrier. The Regional Water Quality Control Board (RWQCB) has reduced the City of Stockton's effluent limit for carbonaceous BOD to 10 mg/l during this period (from 4/1 to 10/31). Pre- and post-barrier DO concentration measurements by DWR (1987-1992) in fall, however, indicate that the increased streamflow created by the barrier has little effect on DO concentrations in the oxygen sag in dry and critically dry years. The higher streamflow merely moves the DO sag downstream. The oxygen sag persists in the channel throughout fall until cool water temperature and high mixing and streamflow from seasonal precipitation dissipate the sag. Further studies, including DWR longitudinal DO profiles, are needed to confirm findings.

Stockton Tributaries

Data from the 1980s indicate that BOD concentrations frequently exceeded 30 mg/l in Little Johns Creek, Lone Tree Creek, and Temple Creek. A maximum BOD of 126 mg/l was measured in Temple Creek. These high BOD levels are believed to be caused by waste discharge from dairies and have the potential to reduce DO concentrations.

California ranks number one in the country for dairy, number one for chicken egg production, and number three for sheep and lamb production. The total livestock and poultry value for California is $6.3 billion. With these numbers comes the animal wastes that need to be properly managed. San Joaquin Valley's 1,600 dairies with 850,000 head, create as much waste as 21 million people, yet state inspectors to regulate these activities are few. Chronic and catastrophic discharges of these wastes into Central Valley and Bay/Delta waterways contributes to problems such as nutrient loading, elevated ammonia, algal blooms, and low dissolved oxygen. Antibiotics, hormones, and selenium as drugs or feed additives also have been considered potential problems of concern.

Chronic and catastrophic discharges of animal wastes into Central Valley and Bay/Delta waterways contributes to problems such as nutrient loading, elevated ammonia, algal blooms, and low dissolved oxygen.

Urban Waterways near Stockton

Urban stormwater discharge into waterways around the City of Stockton may contribute to decreases of oxygen concentrations to less than 5 mg/l. After storms, DO concentrations as low as 0.34 mg/l have been recorded in Smith Canal, Mosher Slough, 5-Mile Slough, and the Calaveras River. The lowest concentrations occur after the first storm of the year. Low DO concentrations were associated with fish kills in the field, and laboratory tests demonstrated death of threadfin shad at 3.3– 4.7 mg/l. Urban stormwater runoff from the City of Stockton and San Joaquin County is the probable source of the low DO concentrations, but the actual sources and mechanisms are unknown. Chen and Tsai (1999) conducted a study of DO depletion in Smith Canal after stormwater events. They concluded that scour of the sediments and other constituents during storm events and the oxygen demand associated with sediments are primary factors in DO depletion. Chen and Tsai (1999) concluded that DO depletion in Smith Canal affects aquatic life within Smith Canal; but there was little impact on the San Joaquin River Deep Water Ship Channel, where Smith Canal discharges.

In urban waterways near Stockton, the lowest DO concentrations occur after the first storm of the year.

2.4.2 Approach to Solution

San Joaquin River near Stockton

Priority Actions

1. Encourage continued removal of oxygen-depleting substances from the RWCF, the Port of Stockton, and other National Pollutant Discharge Elimination System (NPDES) and Waste Discharge Requirement (WDR) permittees, to improve water quality during chinook salmon migration.

2. Develop best management practices (BMPs) with information gathered as a result of implementing the "Information Needed" portion of this section.

3. Provide technical and financial assistance and regulatory incentives for implementing BMPs to control oxygen depletion.

4. Work in conjunction with the RWCF and the Port of Stockton to develop and test new physical or operational management practices (MPs).

   Possible management actions include (1) physical mixing or other methods to decrease stratification and increase aeration in the ship channel and Turning Basin during periods of low DO, (2) changing the effluent discharge location, (3) changing the channel configuration (i.e., filling the hole at the end of the Turning Basin or deepening the main channel), and (4) constructing wetlands to increase treatment of effluent.

The goals of the proposed actions are to:

- Eliminate the occurrences of DO concentrations below 5 mg/l throughout the water column,
- Reduce the impairment or blockage of fish migration past Stockton,
- Reduce the occurrence of algal blooms,
- Reduce stress to fish due to low DO concentrations near Stockton, and
- Eliminate fish kills near Stockton.

Performance of all of these measures can be determined by appropriate monitoring programs.

Information Needed

Field studies are needed to help support the following ongoing activities:

- Quantify and identify the relative contribution of various sources of oxygen-depleting substances or oxygen-depleted water to the oxygen sag in the San Joaquin River.
- Determine the mechanisms that produce the oxygen depletion or the oxygen-depleting substances at these sources.
- Evaluate the importance of the channel depression at the mouth of the Turning Basin to the oxygen depletion.
- Compare causes and characteristics of spring and fall oxygen sag.
- Determine two- and three-dimensional flow patterns.
- Develop accurate models to determine what substances introduced to the river will produce DO sags downstream and where.
- Identify and test new MPs.
- Evaluate the effectiveness of current MPs.
- Evaluate the sources and loadings of nutrients contributing to oxygen-depleting algal blooms. (Also see Section 3, "Drinking Water.")

Existing Activities

The City of Stockton has been testing and modeling low DO in the San Joaquin River for several years. In addition, the City of Stockton is actively involved in the technical evaluation of DO conditions and alternatives for managing water quality in the lower San Joaquin River channels in the Delta. The recent report by the City of Stockton, "Potential Solutions for Achieving the San Joaquin River Dissolved Oxygen Objectives," provides a summary of recent DO conditions (1985-1996), based on the combination of DWR monitoring and routine measurements by the City.

The City of Stockton has been testing and modeling low DO in the San Joaquin River for several years. DWR has been sampling the San Joaquin River and the Turning Basin for several years and has compiled extensive data.

DWR has been sampling the San Joaquin River and the Turning Basin for several years and has compiled extensive data. Some oxygen depletion is emanating from the ship channel Turning Basin; however, the exact cause of such depletion is unknown. Studies are ongoing and expanding.

The U.S. Army Corps of Engineers (Corps) placed an aeration jet at the mouth of the Turning Basin as mitigation for DO effects from the ship channel. The aeration system has since been removed. Data may still be available regarding the efficacy of the aeration system. Any further studies should be coordinated with the Corps' efforts.

The CVRWQCB has established a watershed-based stakeholder group to assist in developing technically based comprehensive total maximum daily load (TMDL) evaluation and allocation for sources of BOD and nutrients. CALFED has awarded an $860,000 grant to determine causes and loads contributing to causes of low DO in the lower San Joaquin River. Study plans are being finalized, and work is expected to begin in various stages during the first half of 2000. The stakeholder group includes representatives from municipalities, state and federal agencies, agricultural interests, environmental interests, local industry, and academic institutions. This ongoing effort will help to identify management actions that will best achieve the established water quality objectives.

CALFED has awarded an $860,000 grant to determine causes and loads contributing to causes of low DO in the lower San Joaquin River.

Stockton Tributaries

Priority Actions

1. Assess the current water quality impairment due to high BOD in these creeks.

2. Develop new strategies to assist farmers in containing wastes on the fields, including financial incentives such as low-interest loans to upgrade their systems.

3. Undertake further efforts to enforce the WDRs of permitted and unpermitted dischargers.

The goals of these actions are to maintain DO concentrations above the 5-mg/l standard, maintain BOD concentrations below 30 mg/l, and restore natural ecosystem processes and functions in the creeks.

Information Needed

Monitoring data are needed to determine the current BOD and chemical oxygen demand (COD) loads in these creeks, the associated DO concentration, and the potential impact of current BOD levels on the ecosystem.

Urban Waterways near Stockton

Priority Actions

1. Develop strategies with the City of Stockton and other stakeholders to eliminate the DO problem.

The goals are to maintain DO concentrations in the sloughs above the 5-mg/l standard, avoid fish kills, and restore natural ecosystem processes and function.

Information Needed

More information is needed to verify that low DO concentrations are produced by urban stormwater runoff, to determine the causal substances and mechanisms of low DO concentrations, and to determine the impact of low DO concentrations on the ecosystem.

Special studies need to be conducted in 5-Mile Slough, Mosher Slough, and the Calaveras River to determine the substances and mechanisms causing low DO concentrations.

2.5 EAST SIDE DELTA TRIBUTARIES

East side Delta tributaries include the Mokelumne, Cosumnes, and Calaveras Rivers.

2.5.1 Problem Description

High deposition of fine sediments from channel disturbance on the Mokelumne River affects sediment permeability and, in combination with high water temperature, may cause low inter-substrate DO concentrations that negatively affect spawning and rearing habitat of salmonids and other fish. Other activities such as cattle grazing and agricultural runoff in the watershed could contribute to the problem. Studies are needed to determine the causes of low inter-substrate DO and the extent of impacts on aquatic life. East Bay Municipal Utilities District, in partnership with other agencies, is actively engaged in salmon habitat restoration efforts and data collection along the lower Mokelumne River. This work will add to the information base on DO problems in the river and should be expanded. CALFED supports these efforts. No information is currently available on the DO status of the Calaveras River.

High deposition of fine sediments from channel disturbance on the Mokelumne River affects sediment permeability and, in combination with high water temperature, may cause low inter-substrate DO concentrations that negatively affect spawning and rearing habitat of salmonids and other fish.

2.5.2 Approach to Solution

Priority Actions

1. Assess the extent and severity of this problem and develop strategies to reduce the problem. MPs should include decreasing the fine-sediment load.

The goal is to reduce fine-sediment loads that may cause low inter-substrate DO concentrations and impair the spawning and rearing habitat of salmonids and other fish.

The goal is to reduce fine-sediment loads that can cause low inter-substrate DO concentrations and impair the spawning and rearing habitat of salmonids and other fish.

2.6 LOWER SACRAMENTO RIVER TRIBUTARIES

2.6.1 Problem Description

Poor inter-substrate permeability and the resulting low DO concentration are primary stresses for salmon and steelhead spawning habitat in the American River. Impervious clay lenses below the gravel may contribute to the low permeability.

Poor inter-substrate permeability and the resulting low DO concentration are primary stresses for salmon and steelhead spawning habitat in the American River.

2.6.2 Approach to Solution

Priority Actions

1. Possible management actions include development of gravel enhancement programs, channel restoration programs, and river corridor assessments and MPs; and regulation of high water temperature reservoir releases.

The goals are to reduce sediment loads, which may cause low inter-substrate DO concentrations that affect salmon spawning and rearing habitat, and to establish full salmon spawning and rearing activity.

2.7 SAN JOAQUIN RIVER REGION

The San Joaquin River Region includes the Merced, Tuolumne, and Stanislaus Rivers.

2.7.1 Problem Description

The Merced, Tuolumne, and Stanislaus Rivers are tributaries of the San Joaquin River. A history of erosive land use practices and mining activities for aggregate and minerals is associated with depositing large amounts of fine sediment. High sediment deposition affects sediment permeability and causes low inter-substrate DO concentrations that negatively affect spawning and rearing habitat of salmonid and other fish.

A history of erosive land use practices and mining activities for aggregate and minerals is associated with depositing large amounts of fine sediment.

2.7.2 Approach to Solution

Priority Actions

1. Possible management actions include development of gravel enhancement programs, channel restoration programs, and river corridor assessments and MPs; and regulation of high water temperature reservoir releases.

The goals are to eliminate the low inter-substrate DO concentrations that affect salmon spawning and rearing habitat, and to establish full salmon spawning and rearing activity.

Existing Activities

The Tuolumne River Technical Advisory Committee currently is funding work, using a field technique that measures inter-substrate permeability. Such measurements would be useful in the assessment of the ecological health of stream beds.

2.8 SUISUN MARSH WETLANDS

2.8.1 Problem Description

The CWA Section 303(d) list includes Suisun Marsh as an impaired water body due to flow regulation and modification, and urban and stormwater sewer runoff. In fall 1994, DO concentrations reached as low as 1 mg/l and were frequently 4 mg/l in Goodyear, Cordelia, and Frank Horan Sloughs after the islands in the marsh were flooded for duck club management. The islands are flooded with channel water that becomes nearly anaerobic while on the islands. This island water then flows into the main channel on ebb tide and can cause low DO concentrations in the channel. Low DO concentrations were measured during the Suisun Marsh Salinity Control Test in 1994; but the severity, extent, and frequency of the problem are unknown. DO concentrations also decrease to 1 mg/l in summer and fall in the slough that receives effluent from the Fairfield-Suisun Treatment Facility. The relative contribution of urban and sewer discharge to this oxygen depletion is unknown.

The islands are flooded with channel water that becomes nearly anaerobic while on the islands. This island water then flows into the main channel on ebb tide and can cause low DO concentrations in the channel.

2.8.2 Approach to Solution

Priority Actions

1. Assess the level and ecological importance of the addition of oxygen-depleted water to the main channel.

The Suisun Marsh Preservation Agreement negotiations and Suisun Marsh Ecological Work Group need to assess the level and ecological importance of the addition of oxygen-depleted water to the main channel and develop MPs as appropriate.

The goals are to maintain DO concentrations above the 5-mg/l standard and attain natural ecosystem process and function in the marsh.

The goals are to maintain DO concentrations above the 5-mg/l standard and attain natural ecosystem process and function in the marsh.

Information Needed

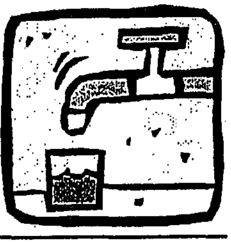
A new field technique is needed to measure inter-substrate permeability. The new technique can be used to monitor inter-substrate DO concentrations and to develop an index of spawning habitat quality for each river, based on inter-substrate permeability and DO concentrations. (Biological indices and other ecological assessments would be performed through the Ecosystem Restoration Program, in coordination with the Water Quality Program.)

Monitoring programs and special studies are needed to assess the frequency, distribution, severity, and causes of DO concentrations below 5 mg/l in Suisun Marsh; and their potential effects on ecosystem process and function.

Existing Activities

The Suisun Marsh Ecological Work Group has been assembled to address problems such as low DO in the Suisun Marsh area.

3. DRINKING WATER



3. DRINKING WATER

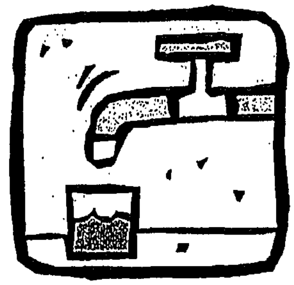
The CALFED drinking water objective is to continuously improve source water quality that allows for municipal water suppliers to deliver safe, reliable, and affordable drinking water that meets and, where feasible, is better than applicable drinking water standards. This section of the Water Quality Program Plan identifies drinking water quality concerns that result from using Delta waters as a source of drinking water supply and identifies proposed Water Quality Program actions that can be taken in the nearer term that may improve source water quality. Bromide, organic carbon, and salts are constituents of major concern for drinking water; salts are of importance to agricultural uses of Delta waters. Concentrations and loadings of these constituents will be affected by actions in the Water Quality Program and by the choice of storage and conveyance options. Section 3.7 presents an analysis of the capacity of Water Quality Program actions to affect concentrations of bromide and organic carbon in drinking water supplies taken from the Delta. Since bromide is a constituent of the total salt load, the analysis in Section 3.7 also can serve as a preliminary model for the effects of the Water Quality Program on total salt in the system.

Bromide, organic carbon, and salts are constituents of major concern for drinking water; salts are of importance to agricultural uses of Delta waters.

3.1 SUMMARY

As part of its commitment to continual improvement of water quality, CALFED is developing an overall Drinking Water Quality Improvement Strategy to guide its activities. The Strategy is composed of a combination of actions and studies that will be conducted under the scrutiny of the Delta Drinking Water Council. Actions and studies include source protection and control, conveyance improvements, storage and operations improvements, monitoring and assessment, treatment studies and facilities, health effects studies, capturing more drinking water during periods of high Delta water quality, and improving the opportunities for voluntary exchanges or purchases of high-quality source waters. This Strategy is critically needed because about two-thirds of Californians drink water that comes from the Delta, and their health can be affected by the quality of that water. Safe drinking water is not a fixed target. Its definition changes continually as new scientific information becomes available, as understanding of water quality and human health impacts improves, and as regulatory developments reflect new scientific findings. The CALFED Drinking Water Quality Improvement Strategy must, therefore, be a continually evolving process to achieve the vision not only of providing drinking water that meets standards for public health protection but also of continually striving toward excellence in drinking water

About two-thirds of Californians drink water that comes from the Delta, and their health can be affected by the quality of that water.



quality. This section identifies the initial features of this Strategy, with the understanding that this constitutes only the beginning of a continuing process. Evolution of the Strategy will be through the full involvement of CALFED agencies, stakeholders, and the public.

Several source water constituents create difficulties for the production of a safe drinking water supply from Delta sources. These include bromide, natural organic matter, microbial pathogens, nutrients, salinity, and turbidity. All are naturally occurring, to one degree or another, and some are magnified by anthropogenic actions. Changes in treating drinking water and reducing sources of contaminants can improve the quality and safety of drinking water from the Delta. Future drinking water regulations may, however, require improvements beyond those that can be gained through the actions specified in this section. (See Section 3.7.) The priority actions listed in the following pages are those that can be implemented in the nearer term with the potential to improve water quality. The degree to which taking these actions may correct the problems is not addressed.

Pollutants in Delta waters come from tidal interaction with the ocean and from point and non-point sources located throughout the Delta and tributary watersheds. Other pollutants can enter the aqueducts and reservoirs of the drinking water supply system. Pathogens largely come from urban stormwater runoff; livestock operations; recreational users of the Delta; storage reservoirs; and, potentially, inadequately treated discharges of wastewater. Sources of organic matter, primarily organic carbon (usually expressed as total organic carbon [TOC]), include runoff from the following sources: soils, agricultural drainage, urban stormwater tidal wetlands as a result of natural plant decay, algae, and wastewater treatment plant discharges. The most important source of bromide is sea-water intrusion, which also is reflected in agricultural drainage from areas irrigated with Delta water. Other sources of bromide may include geological formations, groundwater influenced by ancient sea salts, and use of bromine-containing chemicals in the watersheds of the Delta. Salinity, as reflected in total dissolved solids (TDS), comes from sea-water intrusion and, to a lesser extent, from natural leaching of soils, agricultural drainage, wastewater treatment plants, and stormwater runoff. Turbidity results from storm events, all types of runoff, resuspended sediments, and phytoplankton populations. Nutrients largely result from erosion; agricultural runoff, including livestock operations; urban stormwater runoff; and wastewater treatment plant discharges. Mass loading analyses have not been conducted to establish the relative amounts of pollutants from each of these sources.

Pollutants in Delta waters come from tidal interaction with the ocean and from point and non-point sources located throughout the Delta and tributary watersheds.

Pathogens are a direct health concern. A primary purpose of drinking water treatment is to remove or inactivate pathogens. TOC and bromide react with disinfectants during the treatment process to form disinfection by-products (DBPs) that are a public health concern and will be more stringently regulated in

TOC and bromide react with disinfectants during the treatment process to form disinfection by-products (DBPs) that are a public health concern and will be more stringently regulated in the near future.

the near future. Nutrients contribute to excess growth of algae in storage reservoirs and in aqueducts, which can result in treatment difficulties and production of unpleasant flavors and odors.

High levels of TDS, salinity, and turbidity adversely affect consumer acceptance and treatment plant operations. High TDS reduces the ability to implement local water management programs, such as water recycling and groundwater replenishment, results in direct economic impacts on residential and industrial water users, and reduces options for blending with other supplies.

3.2 Drinking Water Focus of the Water Quality Program

The Water Quality Program addresses water quality problems exclusive of those that would be addressed by the Storage and Conveyance elements of the CALFED Program. Several drinking water regulations that pose treatment challenges will be implemented and will need to be complied with prior to implementation of storage and conveyance alternatives. Therefore, the primary focus is on water quality improvements in the nearer term, although the Water Quality Program also will be an important aspect of long-term solutions.

Several drinking water regulations that pose treatment challenges will be implemented and will need to be complied with prior to implementation of storage and conveyance alternatives.

CALFED will pursue aggressively a mix of strategies to improve in-Delta water quality. Program actions to address the drinking water concerns of the more than 22 million Californians who rely on Delta water fall into four broad categories. These actions will:

- Enable users to capture more drinking water during periods of high Delta water quality.
- Reduce contaminants and salinity that impair Delta water quality.
- Evaluate alternative approaches to drinking water treatment, to address growing concerns over DBPs and salinity.
- Enable voluntary exchanges or purchases of high-quality source waters for drinking water uses.

None of these actions, by itself, can assure adequate supplies of good-quality drinking water that meet current and future state and federal regulations. All the actions must be pursued in conjunction with other CALFED actions, such as conveyance and storage improvements, to generate significant improvements in drinking water at the tap.

Both specific and regionwide approaches to drinking water quality improvements address the following locations: the Bay-Delta Region, Sacramento and American Rivers, North Bay Aqueduct, South Bay Aqueduct, Clifton Court Forebay and Bethany Reservoir, Contra Costa Water District intakes, Delta-Mendota Canal (DMC) at the City of Tracy intake, San Joaquin River, California Aqueduct, south of O'Neill Forebay and Check 13, and Castaic Lake and Lake Silverwood.

Priority actions and information needed are identified to ensure that Water Quality Program objectives are achieved in each geographic area.

3.3 PROBLEM STATEMENT

Source water from the Bay-Delta poses treatment challenges and public health concerns for the 22 million Californians who drink the water. Low water quality reduces options for recycling the water and blending with other sources, and increases utility costs of treating the water to meet drinking water regulations and protect public health.

Low water quality reduces options for recycling the water and blending with other sources, and increases utility costs of treating the water to meet drinking water regulations and protect public health.

3.4 OBJECTIVE

The CALFED drinking water quality objective is to continuously improve source water quality that allows for municipal water suppliers to deliver safe, reliable, and affordable drinking water that meets and, where feasible, is better than applicable drinking water standards. This objective promotes improved water management through source control and prevention projects, exchanges, blending, purchases of high-quality water, wastewater recycling, groundwater use, and alternative approaches to drinking water treatment. Of primary importance is the reduction and maintenance of pathogen loadings in source waters to required levels, and the reduction of TOC and bromide levels to avoid production of harmful levels of DBPs. Reduction of TDS will facilitate improved water management.

Of primary importance is the reduction and maintenance of pathogen loadings in source waters to required levels, and the reduction of TOC and bromide levels to avoid production of harmful levels of DBPs.

3.5 PROBLEM DESCRIPTION

Delta waters are used to produce drinking water for approximately 22 million people in California. Utilities divert source water at several points in the Delta, each with distinct water quality characteristics. These waters are subsequently treated by a variety of means to control pathogens and other contaminants of concern, and to meet federal and state drinking water regulatory requirements. Depending on the specific source water at the intakes, existing treatment plant configurations, attendant operational constraints, and regulatory requirements, utilities may have difficulty in simultaneously providing adequate supplies of drinking water while complying with drinking water regulations and meeting customer requirements for palatability. Therefore, two inter-related concerns arise from source water quality: (1) the treated water may not meet all applicable drinking water standards, and (2) the treated water may not be aesthetically acceptable to the consumers. Because treated water quality is a product of source water quality and treatment methods, treatment options can be significantly narrowed based on source water quality and drinking water regulations.

Utilities may have difficulty in simultaneously providing adequate supplies of drinking water while complying with drinking water regulations and meeting customer requirements for palatability.

The process of treating surface waters generally involves mixing coagulant chemicals with the source water. This process causes the removal of some dissolved organic material and most of the particulates to aggregate and to settle out. The settled water is then filtered, usually through beds of special sand and anthracite mixtures, removing many more microbial contaminants. At one or more points in the process, oxidative disinfectant chemicals are applied for specified contact times. Water that flows from the treatment facility into the pipes that distribute the water to homes and businesses must additionally contain a sufficient disinfectant residual (usually chlorine or chloramine) to prevent regrowth of harmful bacteria or other organisms in the distribution system, up to the taps of customers.

The constituents in Delta waters identified of most concern with respect to production of drinking water include microbial pathogens, bromide, natural organic matter, dissolved solids, salinity, turbidity, and nutrients. Some other contaminants of Delta waters, including pesticides, metals, and methyl tert-butyl ether (MTBE), were evaluated and considered to be of limited significance to drinking water at this time because of their relatively low concentrations in Delta waters.

The constituents in Delta waters identified of most concern with respect to production of drinking water include microbial pathogens, bromide, natural organic matter, dissolved solids, salinity, turbidity, and nutrients.

3.5.1 Pathogens

Microbial pathogens are a direct threat to public health. The primary purpose of drinking water treatment is to remove or kill pathogens. Under the 1989 Surface Water Treatment Rule (SWTR), surface water must be treated by filtration or disinfection to minimize disease risks from microbes. In addition, turbidity, which can compromise disinfection, must be removed. Emphasis in this rule was on reducing risks from *Giardia, Legionella,* and viruses. The Interim Enhanced Surface Water Treatment Rule was promulgated in December 1998 and adopted more stringent turbidity removal requirements. The Long-Term 2 Enhanced Surface Water Treatment Rule (to be promulgated by May 2002) is expected to include requirements for the control of *Cryptosporidium.*

The primary purpose of drinking water treatment is to remove or kill pathogens.

Filtration and disinfection are required for drinking water from Delta sources. Levels of microbial pathogens in Delta waters do not specifically influence the degree of these treatments, since current regulations are based on uniform treatment requirements. However, future regulations may require treatment that is proportional to pathogen levels in source waters. Pathogen levels in Delta waters are largely unknown at this time. Primary disinfection by utilities using Delta water sources usually is accomplished by physical removal and oxidation with chlorine. An increasing number of utilities are using ozone or a combination of disinfectants.

Chlorine has been used as a primary disinfectant for drinking water for decades. It is effective for bacteria, viruses, and *Giardia* at reasonably feasible concentrations and contact times. It is well understood, relatively simple, and inexpensive. However, it is not able to inactivate *Cryptosporidium.* If future regulations required disinfection of *Cryptosporidium*, alternative disinfectants would be needed.

Chlorine has been used as a primary disinfectant for drinking water for decades.

Some utilities have adopted ozone treatment in addition to other conventional treatment measures. Ozone is a strong oxidant that is effective for inactivation of most pathogenic microorganisms, including *Cryptosporidium*. However, in the presence of bromide such as found in Delta waters, bromate is formed. Bromate is a health concern and is the subject of new drinking water regulations and ongoing health effects research. Optimized conventional filtration is not completely effective to remove all *Cryptosporidium* from drinking water, and chlorinated disinfectants are relatively ineffective in killing or inactivating it. However, membrane filtration, including low-pressure ultrafiltration membranes, does effectively remove *Cryptosporidium* and *Giardia*, and may provide an alternative to additional ozone disinfection. Membrane filtration has been used successfully in small systems, but it is not known whether the technology is adaptable to large systems such as generally are used to treat Delta waters. For this and other reasons, more California water systems are considering converting

Optimized conventional filtration is not completely effective to remove all Cryptosporidium from drinking water, and chlorinated disinfectants are relatively ineffective in killing or inactivating it.

to ozone for their primary disinfection. Ozone treatment is also very effective in controlling adverse tastes and odors that are frequently associated with algae in source waters. Other emerging treatment technologies include ultraviolet and chlorine dioxide disinfection, but their potential to produce unwanted chemical byproducts and their economic feasibility are as yet unproven.

3.5.2 Disinfection By-Products

An unfortunate side effect of oxidative disinfection is the formation of unwanted chemical by-products, some of which result in adverse health impacts. Additionally, the objectionable taste and odor (T&O) characteristics of some DBPs affect consumer acceptance. Different oxidants and different sources of water yield different types and concentrations of by-products.

An unfortunate side effect of oxidative disinfection is the formation of unwanted chemical by-products, some of which result in adverse health impacts.

The Safe Drinking Water Act Amendments of 1996 directed EPA to set regulations that protect against microbial pathogens while simultaneously decreasing the occurrence of DBPs. EPA promulgated the first stage of rules (Stage 1 Disinfectants/Disinfection By-Product Rule (D/DBP) and Interim Enhanced Surface Water Treatment Rule) in December 1998. These rules will be effective in December 2001. The Stage 1 D/DBP Rule lowers the maximum contaminant level (MCL) for total trihalomethanes (TTHMs) to 80 ug/l, and sets MCLs for haloacetic acids (60 ug/l) and bromate (10 ug/l). EPA is required to promulgate the Stage 2 D/DBP Rule and Long-Term 2 Enhanced Surface Water Treatment Rule by 2002. These rules currently are being negotiated.

Ozone does not produce halogenated by-products such as chloroform and the other chloro-bromo-THMs, although it produces bromoform and bromate in the presence of organic carbon and bromide. Therefore, ozone use combined with chloramine enables utilities to more easily meet lower TTHM standards. However, ozonation is more complex and expensive than chlorination. Ozonation of natural organic matter generates higher levels of assimilable organic carbon that can support bacterial regrowth in drinking water distribution systems. Because ozonation does not produce a persistent disinfection residual, other disinfectants (generally chloramines) must be used to protect distribution systems from bacterial regrowth and to minimize TTHM formation in the distribution system. Perhaps more importantly, ozone produces chemical by-products of its own. In the presence of bromide, ozone produces bromate, which appears to have the highest cancer-causing potential of the DBPs measured to date. Apart from bromate, ozone has the capacity to produce a number of other oxidized organic by-products, the potentially harmful effects of which are unknown. However, these by-products may be reduced through biological filtration.

Ozonation of natural organic matter generates higher levels of assimilable organic carbon that can support bacterial regrowth in drinking water distribution systems.

Bromide is present in Delta water supplies because of sea-water intrusion into the Delta and agricultural return flows into the San Joaquin River from Delta water. (Bromide in agricultural return flows is primarily due to recycling ocean-derived bromide from areas irrigated with Delta water.) TOC from natural and human sources, and bromide react with disinfectant chemicals to produce a broad range of chemical DBPs with different effects, depending on the disinfectant employed. The presence of bromide in source waters shifts the proportion of bromine-containing DBPs to higher levels. Because of the higher molecular weight of brominated versus chlorinated by-products, it is more difficult for utilities to meet MCLs that are based on weight/volume. Moreover, recent health effects studies suggest that brominated by-products may cause more serious health problems than chloroform, including the possibility of causing miscarriages in pregnant women. In addition, nutrients affect disinfection treatment indirectly by supporting the growth of algae and other organisms, which subsequently adds to the TOC concentrations of the water.

Bromide is present in Delta water supplies because of sea-water intrusion into the Delta and agricultural return flows into the San Joaquin River from Delta water.

3.5.3 *Treatment Control of Disinfection By-Products*

Currently, most water treatment plants use chlorine as the primary disinfectant within the treatment plant. Many facilities also use chlorine to maintain a disinfectant residual as the water travels through the distribution system. This practice ensures the safety of the treated water as it travels to the consumer but forms elevated levels of chlorinated DBPs.

Chloramines (the combination of chlorine and ammonia) can be used as an alternative to chlorine, to provide a safe disinfectant residual within the distribution system. Chloramines form lower levels of DBPs, replacing the long reaction times between chlorine and DBP precursors in the distribution system. Consequently, this process reduces DBP levels that reach the consumer.

Water utilities also may use "enhanced" coagulation to minimize DBP formation. Enhanced coagulation refers to the practice of using elevated coagulant doses to remove DBP precursors prior to their reaction with chlorine. Under optimal conditions, enhanced coagulation can remove from 30 to 50% of the organic DBP precursors and result in significant DBP reductions. However, the effectiveness of this treatment process is variable and highly depends on raw water quality. In addition, enhanced coagulation does not reduce bromide, which is an inorganic DBP precursor.

Enhanced coagulation refers to the practice of using elevated coagulant doses to remove DBP precursors prior to their reaction with chlorine.

One alternative to the use of chlorine for disinfection is ozone. Ozone is a strong disinfectant capable of inactivating most pathogens within short contact times. The use of ozone also can improve the aesthetic qualities of water, including clarity, taste, and odors. Ozone (in place of chlorine) results in the minimal formation of chlorinated DBPs. Because ozone does not provide a lasting disinfectant residual, subsequent chlorination (or chloramination) is required—which forms some DBPs. One drawback to the use of ozone is that it reacts with bromide to form bromate. New bromate regulations will take effect in 2001. Previous studies have shown that bromate formation during ozonation may be controlled through chemical addition of acid or ammonia. These bromate control strategies can significantly increase the overall cost of ozonation.

GAC has relatively high capital and operating costs.

GAC can be used to remove both DBPs and DBP precursors. GAC acts as an adsorbent, removing many organic compounds. Once the GAC adsorption capacity is exhausted, it must be regenerated within a furnace. Typically, GAC must be shipped to an off-site regeneration facility. Consequently, GAC has relatively high capital and operating costs.

Recent developments suggest that the use of membrane processes, such as reverse osmosis or nanofiltration, may provide a viable method for controlling DBP precursors.

Recent developments suggest that the use of membrane processes, such as reverse osmosis or nanofiltration, may provide a viable method for controlling DBP precursors. Membranes can remove both organic precursors and the bromide ion, which both contribute to DBP formation. Additionally, these membranes provide excellent pathogen removal. Drawbacks associated with the use of membranes include the need for extensive pre-treatment to minimize membrane fouling and the difficulty in disposing of the brine waste stream (which results from separating the dissolved material from solution). These concerns result in the relatively high current costs for membrane treatment. Other membrane processes such as microfiltration and ultrafiltration provide excellent pathogen removal but do not reduce DBP precursors to a substantial degree. However, as the processes provide increased pathogen removal, they may contribute to decreased disinfection requirements—resulting in less DBP formation.

Recent private-sector efforts have generated substantial advances in treatment technologies. CALFED will encourage these technologies by funding a demonstration project to design and operate an ultra-violet (UV) disinfection plant. CALFED also will fund demonstration projects to design and operate desalination facilities for agricultural drainage, using membrane treatment technology and focusing on management of brines and on-site waste stream management, and other promising treatment technologies that arise during the Program. Specific treatment goals are to:

- Initiate a UV disinfection plant demonstration project by the end of 2002.
- Initiate a regional desalination demonstration project by the end of 2002.
- Evaluate the practicability of and determine time lines for full-scale implementation by the beginning of 2007.

3.5.4 Source Control of Disinfection By-Products

Research is underway to evaluate the impacts of agricultural practices on the quality and quantity of TOC releases to the Delta. The contribution of natural wetlands to TOC concentrations found in Delta waters at drinking water intakes is not understood. The proposed restoration of wetlands through the CALFED Ecosystem Restoration Program may increase the total amount of TOC at drinking water intakes, increasing the potential to form DBPs. Changing channel flows and increasing the amount of tidal waters exchanged with the estuary (by increasing the tidal wetland volume) may increase the amount of bromide in Delta waters, significantly increasing DBP formation.

Research is underway to evaluate the impacts of agricultural practices on the quality and quantity of TOC releases to the Delta.

3.5.5 Total Dissolved Solids, Salinity, Turbidity, and Nutrients

A major problem during periods of low Delta outflow is tidal mixing of salt into the Delta channels. Salts are also present in fresh-water inflows to the Delta due to municipal and agricultural discharges. The most heavily concentrated source of agricultural discharges to the Delta is the San Joaquin River. The addition of a proposed activity may change contributions of salt to the Delta. The creation of wetlands as a part of the CALFED Ecosystem Restoration Program could contribute organic carbon to drinking water intakes and may change salinity outflow characteristics. In changing salinity outflow characteristics, the restoration projects also may contribute higher levels of bromide to drinking water intakes. The restored wetlands also may use more water, thereby reducing the fresh water available to repel salinity.

A major problem during periods of low Delta outflow is tidal mixing of salt into the Delta channels.

High salt levels in municipal water supplies can result in the following impacts: (1) reduced opportunities for water recycling and groundwater replenishment programs that depend on good source water quality to meet local resource program salinity objectives; (2) economic impacts on industrial and residential water users due to corrosion of appliances, plumbing, and industrial facilities; and (3) aesthetic impacts (salty taste) for drinking water consumers.

Consumer acceptance of drinking water is of major concern. Consumers want water that is both safe and pleasant to drink. Adverse taste, odor, and appearance problems originate from source water and the effects of treatment.

Consumer accept-ance of drinking water is of major concern. Consumers want water that is both safe and pleasant to drink. Adverse taste, odor, and appearance problems originate from source water and the effects of treatment.

Elevated TDS levels can adversely affect consumer acceptance and local water management and water use efficiency programs. Waters with naturally high TDS or salinity taste salty or may be unacceptably hard if calcium and magnesium levels are high. Consumers may resort to the use of ion-exchange systems (water softeners) to produce softer water. Ion-exchange systems are regenerated using highly saline water, which is then flushed into the wastewater system. Dissolved solids in supply water and salt added during use result in higher TDS effluent from wastewater treatment plants. High TDS and salt make the water unacceptable for many wastewater reclamation applications. Multiple (more than once) reclamation cycles are increasingly difficult with higher TDS source water, and water management flexibility is reduced due to lack of ability to blend supplies from different sources. In addition, high TDS levels can cause direct economic impacts on industrial and residential water users, due to more rapid corrosion of infrastructure and appliances.

Turbidity and natural organic matter from stormwater runoff, wetlands, and agricultural activities provide a disinfectant demand that can require higher applied disinfectant doses or longer contact times. These materials also can harbor pathogens and protect them from disinfection. The major factors affecting physical removal processes for Delta waters in warm months are the presence and types of algae, water temperature, and pH.

The presence of nutrients (such as nitrate and phosphate), higher light levels, and warmer waters can enhance algal growth. Algal blooms are common in the Delta, in the aqueducts, and especially in storage reservoirs. Algae may cause physical clogging of filters and air binding, decreased filter runs, increased filter backwashing and decreased overall plant performance, and increased operating costs. The majority of algae are nontoxic; a few species are toxic or produce algal toxins. The presence of algae in the source water can cause large pH swings that can adversely affect coagulation, flocculation, and sedimentation. While algae are effectively removed by treatment, growth of some species of algae in raw waters produces objectionable odors and flavors in finished water, such as geosmin or methylisoborneol (MIB), that are not removed by conventional treatment. Warm and diurnally varying water temperatures can cause temperature inversions in upflow clarifiers that can result in large daily swings in settled water turbidities.

The presence of nutrients, such as nitrate and phosphate, higher light levels, and warmer waters can enhance algal growth.

During winter, high turbidities from storm-related events may necessitate reducing filtration rates to prevent filter breakthrough. Fluctuations in source water turbidity and in the specific components of turbidity over time require close attention to coagulant doses and proper filter operation. In addition, colder water temperatures reduce coagulation effectiveness, and the ability to achieve a filterable floc is made more difficult.

TOC, in and of itself, does not affect the physical removal process; but TOC levels affect the degree of coagulation, flocculation, and sedimentation required. For example, increases in TOC also increase the coagulant demand of the water, thus requiring more coagulant in order to effectively remove the turbidity. Enhanced coagulation for TOC removal is then required. Organic carbon affects treatment in two additional ways: pathogens may adhere to particulate organic carbon and be shielded from disinfection; and oxidative disinfectants do not

TOC, in and of itself, does not affect the physical removal process; but TOC levels affect the degree of coagulation, flocculation, and sedimentation required.

preferentially attack pathogenic organisms. Consequently, the more organic material in the water, the more disinfectant is spent oxidizing the organic matter.

3.6 APPROACH TO SOLUTION

The reader is reminded that Water Quality Program actions are intended to be implemented irrespective of the storage and conveyance alternative selected. Actions focus on source control and prevention, as well as a mix of other approaches that should be undertaken in addition to any water quality improvements that may result from selection of storage and conveyance options. Priorities for action were identified based on the apparent potential of an action to improve water quality and its capability for nearer term implementation. Assignment of priorities does not necessarily reflect the degree to which taking these actions is likely to correct the problems. Please refer to Section 3.7 for a discussion of the capabilities and limitations of planned CALFED water quality actions to address critical drinking water problems.

Priorities for action were identified based on the apparent potential of an action to improve water quality and its capability for nearer term implementation.

The perception is growing that CALFED alternatives should be decided on in a phased approach over several years. Near-term drinking water regulations that pose problems for treatment will be promulgated prior to implementation of storage and conveyance options and realization of associated water quality benefits (Stage 1 of the D/DBP Rule was promulgated in December 1998, and Stage 2 of the regulation is targeted for May 2002). However, the effective date for Stage 2 may be up to 5 years if significant construction of treatment modifications is required. Moreover, a potential Stage 3 regulation, which may require even more stringent standards, should be developed in the next century. Accordingly, this section of the Water Quality Program Plan emphasizes activities likely to result in mitigation of adverse affects in the next several years. Proposals for research, demonstration, pilot, and longer term projects were discussed and developed.

The general approach to shorter term drinking water quality improvement was to reduce loadings of constituents of concern, reduce variability of source water quality, and enhance treatment flexibility, rather than rely on source replacement with higher quality waters or relocation of intakes to attain higher quality source waters. However, these latter options were discussed and developed as appropriate.

To begin to address the concerns as currently understood, the Drinking Water Work Group developed the following list of potential action items that can be implemented in the near future. This is a general list and not all items will apply to each withdrawal point or to each delivery system using Delta source waters.

Potential Action Items That Can Be Implemented in the Near Future

Agricultural drains	Treat drainage, relocate discharge points, release drainage during ebb tidal flows, implement BMPs, and modify land management practices to reduce loadings of TDS, nutrients, TOC, salinity, and selenium. Support land retirement programs for drainage-impaired lands, with local sponsorship.
Animal enclosures	Implement BMPs to reduce entry of fecal matter and associated TOC, nutrients, and pathogens into Delta drinking water sources.
Treated wastewater effluents	Improve treatment, relocate outfalls, encourage a watershed-based approach to permitting that evaluates cumulative impacts by using methods such as total maximum daily loads (TMDLs) of pollutants that affect drinking water quality.
Urban runoff	Treat drainage, relocate outfalls, encourage a watershed-based approach to permitting that evaluates cumulative impacts by using methods such as TMDL of pollutants that affect drinking water quality.
Algae control	Treat water to kill or remove algae, reduce nutrient sources, and evaluate operational measures.
Boating control	Develop and implement education, and support enforcement programs to reduce discharges of fecal matter and other wastes.
Local watershed management	Support community-based watershed efforts to reduce non-point sources of contaminants.
Blending/exchange	Develop a Bay Area blending/exchange project that enables Bay Area water districts to work cooperatively in order to address water quality and supply reliability concerns on a consensual basis. Facilitate water quality exchanges and similar programs to make high-quality Sierra water in the eastern San Joaquin Valley available to urban southern California interests.
Treatment	Invest in treatment technology demonstration.
Delta Drinking Water Council and Work Groups	Support the ongoing efforts of the Delta Drinking Water Council and its technical work group to develop necessary technical information on Delta water quality, identify appropriate treatment options, pursue source water exchange opportunities, and make other evaluations necessary to meet CALFED's goal of continuous improvement in Delta water quality for all uses.

Water Quality Program actions probably will minimally affect the levels of bromide, particularly for State Water Project (SWP) users. Bromide largely derives from sea-water intrusion. Diverting or repelling sea water or substituting cleaner source waters would require substantial reconfiguration of general Delta flows. Similarly, TDS and salinity from sea-water intrusion could not be effectively controlled by Water Quality Program actions.

Water Quality Program actions probably will minimally affect the levels of bromide, particularly for SWP users. Bromide largely derives from sea-water intrusion.

Some actions in this section could adversely affect parties who discharge wastes in the Delta and its tributaries. Prior to imposing these impacts, full project-specific environmental documents must be prepared to assess the complete range of proposed impacts, and mitigation measures must be proposed according to applicable laws.

CALFED is committed to continued stakeholder involvement in developing plans to address the water quality problems of the Bay-Delta estuary. Of particular importance is prioritizing actions for implementation. Stage 1A and Stage 1 actions have been identified in a preliminary fashion, but considerable evolution of these plans remains to be accomplished. The work in progress represented by Stage 1A and Stage 1 plans is subject to change, consistent with the CALFED adaptive management philosophy and in conjunction with ongoing stakeholder support and involvement. As a programmatic document, the CALFED Programmatic EIS/EIR is intended to establish the basic framework supporting detailed plans that will evolve with appropriate stakeholder input. Accordingly, currently identified Stage 1A and Stage 1 actions reflect progress made to date and are incomplete. Linkages of priority actions described in the Water Quality Program Plan and plans for Stage 1A and Stage 1 are not yet fully formed, nor is the exact sequence of water quality actions defined. Therefore, the information does not currently exist to enable the Water Quality Program Plan to be amended to include this detail.

CALFED is committed to continued stakeholder involvement in developing plans to address the water quality problems of the Bay-Delta estuary.

The following discussion addresses specific and regionwide approaches to decrease levels of nutrients, pesticides, pathogens, non-sea-water TDS, and TOC. In all cases, the approaches focus on means to reduce the impacts of constituents of concern irrespective of the storage and conveyance alternatives, consistent with the scope of the Water Quality Program component.

3.6.1 Bay-Delta Region

Priority Actions

1. Refine and expand the comprehensive CALFED Drinking Water Quality Improvement Strategy to identify and control drinking water parameters of concern.

STOCKTON FISH KILLS ASSOCIATED WITH URBAN STORM RUNOFF: THE ROLE OF LOW DISSOLVED OXYGEN

PREPARED FOR THE REGIONAL WATER QUALITY CONTROL BOARD

JUNE 1998

Compiled by:

Karen Larsen and Kristy Cortright

Board Staff Involved in the Preparation of this Report:

Valerie Connor, Senior Environmental Specialist

University Staff Involved in the Preparation of this Report:

Paciencia Young
Linda Deanovic
David E. Hinton

INTRODUCTION

Background

In the fall of 1994, while collecting water samples for toxicity testing, UC Davis Aquatic Toxicology Laboratory (UCD ATL) and Central Valley Regional Water Quality Control Board (CVRWQCB) staff observed a fish kill in the Calaveras River in Stockton following the first rain event of the season. The water samples that were collected from the Calaveras River as well as other urban creeks and sloughs that day (Figure 1) exhibited dissolved oxygen concentrations as low as 0.5 mg/L in the laboratory (the sample collected from 5-mile Slough)(Reyes *et al.*, 1995). In addition, CVRWQCB staff observed fish at the surface of 5-mile Slough gulping air. UCD ATL and CVRWQCB staff hypothesized that the observed fish kill was due to low dissolved oxygen concentrations.

The water samples collected following the first rain event of 1994 were tested with US EPA's three species bioassays (US EPA, 1994). *Ceriodaphnia* mortality and algal growth impairment were observed in several of the samples. Toxicity identification evaluations (TIE) (US EPA, 1989a, 1989b, and 1991) were conducted. The toxicity was found to be caused by the presence of insecticides and herbicides in the water samples. However, no fathead minnow mortality was observed in the laboratory (Reyes *et al.*, 1995).

Additional fish kills were observed in Stockton by a resident living along Smith Canal in 1994 and by CVRWQCB staff in 1994 and 1995. Fish kills were also reported by DeltaKeeper (a citizens' monitoring group) in 1995, 1996, and 1997 (Bill Jennings, pers. comm.). In one of the events in 1994, threadfin shad were observed floating at the surface of Smith Canal and 5-Mile Slough. They were quickly detected by gulls and eaten (Val Connor, pers. comm.). This behavior of floating at the surface can be due to the loss of equilibrium associated with inadequate oxygen levels. The awareness of the fish kills and the field and laboratory observations of the UCD ATL and CVRWQCB staff in 1994 prompted an investigative study in the fall of 1995. This study was designed to determine if low dissolved oxygen concentrations were responsible for the fish kills observed in Stockton's urban creeks and sloughs. This study included a field and a laboratory component. The field component was conducted in Stockton's Smith Canal. It consisted of *in situ* bioassays employing the fathead minnow and simultaneous multi-parameter water quality measurements. In addition, since threadfin shad have been observed in many of the fish kills reported in Stockton, dissolved oxygen tolerance experiments employing the threadfin shad were conducted in the laboratory. This report summarizes the results of the 1995 study.

Threadfin Shad Background

The threadfin shad, *Dorosoma petenense*, is a member of the Clupeidae (herring) family (Wang, 1986). Threadfin shad were introduced into several reservoirs in northern California and the Sacramento-San Joaquin River system in 1954 (Kimsey and Fisk, 1964). They spawn throughout the late spring and summer. Female fish deposit their eggs on submerged vegetation in shallow water (Taber, 1969). Newly hatched larvae are planktonic and are found near the surface of the water column during the day and at mid-depth at night (Taber, 1969). Juvenile threadfin shad swim in schools and typically reach maturity in their second year (Johnson, 1971). Threadfin shad are an important food source for striped bass, largemouth bass (found in and around the Sacramento-San Joaquin Delta), and other centrarchids (Kimsey and Fisk, 1964).

MATERIALS AND METHODS

Fathead Minnow In Situ Bioassays

In situ bioassays employing the fathead minnow were conducted in Smith Canal approximately one-quarter mile west of Pershing Ave. Two-week-old fathead minnows were obtained from Aquatox, Inc., Hot Springs, AK. The minnows were acclimated in the laboratory at 17 °C for at least 24 hours prior to transport to Smith Canal. The bioassay consisted of four replicate chambers each containing five minnows. Minnows were placed in cylindrical chambers made of clear PVC pipe and 1.5 mm nylon mesh (to allow water flow). The chambers were 13 cm long with a diameter of 5 cm. They were clipped to the inside of a square PVC frame that was connected to two air-filled 1-liter plastic soda bottles. The soda bottles kept the apparatus afloat in the water column.

Minnows were transported to Smith Canal in coolers containing continuously aerated laboratory control water. The square PVC frame was tied to an anchor and pulled approximately two feet from the bottom of the canal. Control chambers were placed in laboratory control water in a 5-gallon sealed carboy which was lowered into the water column as well.

Minnows were exposed from 15 to 18 December 1997. Minnows were observed on 18 December at which time mortality was recorded. Water quality parameters in Smith Canal were measured for the duration of the exposure using a Hydrolab™, discussed below.

Multi-parameter Water Quality Measurements

Water quality parameters were measured in Smith Canal using a Surveyor 3 Multi-parameter Water Quality Logging System (Hydrolab™). The Hydrolab™ measured water temperature (°C), pH, specific conductivity (µS/cm), salinity (ppt), and dissolved oxygen (mg/L). The battery was charged (the fully charged battery lasts approximately three days) at the UC Davis laboratory and then the Hydrolab™ was transported to Smith Canal. The probe was placed in Smith Canal approximately one foot below the surface of the water at low tide. The Hydrolab™ was set to measure the water quality parameters at intervals of either 15 or 30 minutes for between 14 and 82 hours.

The Hydrolab™ was then transported back to the laboratory and the data was downloaded to a Microsoft Excel spreadsheet file.

Threadfin Shad

Fish Collection, Transport, and Maintenance

The fish were collected from Denverton Slough in Suisun Marsh using a 30-ft beach seine with one-quarter inch mesh. They were transported to the UC Davis laboratory in fiberglass tanks with aerated water at ambient (collection) temperature. Salt was added to the water to minimize stress on the fish.

Once the shad arrived at the laboratory, they were held for two weeks in aerated flow-through fiberglass tanks with air-equilibrated well water. Fish were fed *Artemia* sp. nauplii. Fish were subjected to simulated natural photoperiod.

Dissolved Oxygen Tolerance

Fish were held in a temperature-controlled water bath at 19.5 °C in individual Plexiglass™ test vessels of a flow-through design (Cech *et al.*, 1979). Test vessel volume was 4.0 L and the mean test water flow rate was 344 ml/min. A 30-cm polyethylene tube (1.67-mm internal diameter) was inserted into each of the test vessels for water sampling. Fish were subjected to decreasing levels of dissolved oxygen by passing in-flowing water through a polyvinyl chloride stripping column (Cech *et al.*, 1979) in which a counterflow of nitrogen gas (regulated through a gas flowmeter) altered dissolved oxygen content. Dissolved oxygen partial pressure (PO_2) in the inflow column was decreased at approximately 1 torr/min (1 torr = 133.3 Pa; 14 torr = $PO_2 \approx 1$ mg O_2/L) from approximately 150 torr PO_2 (approximating air saturation levels) until the endpoint (when the fish lost equilibrium – "belly up") was reached. The PO_2 was monitored every ten minutes using a Cameron Instrument Co., model 100 dissolved oxygen meter. Immediately after a fish's endpoint was recorded, test water inflow to that vessel was stopped, and an aerated water inflow was begun. Control fish were subjected to the same protocol but without changes in dissolved oxygen (Young and Cech, 1996).

Following the experiment fish were anesthetized with MS-222 and weighed.

RESULTS

Fathead Minnow In Situ Experiments

No minnow mortality was observed in either the experimental or the control chambers in Smith Canal. Dissolved oxygen concentrations ranged from 1.75 to 9.3 mg/L and temperature ranged from 10.2 to 18.0 °C in Smith Canal during the in situ experiment (Appendix A, Table 7 and Figure 7).

Multi-parameter Water Quality Measurements

Appendix A, Figures 1 to 7 and Tables 1 to 7, summarizes the data collected using the Hydrolab™. Readings were taken for six different 3-day periods between 6 October and 19 December 1995. The lowest dissolved oxygen reading during the exposure period was 1.75 mg/L at 15.8°C.

Appendix A, Figures 1-3 refer to three different sets of measurements taken during the month of October. The field temperatures measured during these time periods ranged from 17.5-21.4°C, which is similar to the temperature (19.5°C) at which the laboratory experiment with threadfin shad was conducted. These measurements represent a dry period, or background dissolved oxygen concentrations, since there were no rain events in Stockton during the month of October. Dissolved oxygen readings ranged from 6.39-10.52 mg/L during this period.

Appendix A, Figure 4 refers to a set of measurements taken during the month of November. This was also a dry period, with no rain events for the month. Temperatures measured during this time period ranged from 12.0-14.7°C. Dissolved oxygen readings ranged from 7.07-12.26 mg/L.

Appendix A, Figures 5-7 refer to three sets of measurements taken during the month of December. The temperature ranged from 10.2-14.0°C over the three data sets. The first set of measurements were taken 3-6 December during a dry period (Figure 5). Dissolved oxygen readings ranged from 5.79-9.69 mg/L. Figure 6 shows the dissolved oxygen readings for 10-13 December, which coincides with a large rain event (1.53 inches of rain fell on 11 December, 0.80 inches fell on 12 December, and 0.33 inches fell on 13 December). Dissolved oxygen readings ranged from 3.22-8.19 mg/L. Notice that the dissolved oxygen concentrations peak during the storm and then begin to taper off. Figure 7 shows the dissolved oxygen readings for 15-18 December. The first day of this data set corresponds to a rain event (0.33 inches of rain fell on 15 December), while it was dry for the remaining days. The dissolved oxygen readings ranged from 1.75-9.3 mg/L, with the peak occurring during the rain event and then dropping below the minimum one-day national water quality criteria of 3 mg/L (USEPA, 1986).

Threadfin Shad Dissolved Oxygen Tolerance Experiment

Three separate experiments were conducted. Only fish able to survive acclimation in the test vessels were utilized in the experiments. It should be noted that threadfin shad are difficult to transport and keep alive in a laboratory. In the first experiment, only two fish survived acclimation. One fish was exposed to the decreasing oxygen regime and the other was used as a laboratory method control. In the second experiment, five fish survived acclimation. Three fish were exposed to the decreasing oxygen regime and two were used as laboratory method controls. In the third experiment, three fish survived acclimation. Two were exposed to the decreasing oxygen regime and one was used as a laboratory method control.

As dissolved oxygen concentrations were decreased, the fish activity increased. The shad began to dart back and forth and swim up against the side of the chambers. The fish began to gasp more frequently. Once the endpoint was reached the shad turned "belly up", gasping. Recovery took less than three minutes once oxygen levels were increased. One fish died.

Control fish swum gently back and forth for the duration of the experiment. No control fish died or lost equilibrium.

Mean dissolved oxygen minimum values, the oxygen concentration at which the shad lost equilibrium, ranged from 3.29 to 4.71 mg/L (Appendix A, Figure 8). The endpoint did not seem to be affected by the weight of the fish, which ranged from 1.22-1.67g.

DISCUSSION

Fish kills have been reported in Stockton urban creeks and sloughs since 1966 (Haley, 1967). Dissolved oxygen data obtained in the laboratory in 1994 suggested that low dissolved oxygen concentrations may have been the cause of the observed fish mortality. In addition, this drop in dissolved oxygen concentrations seemed to have been associated with a rainfall event. Data obtained by DeltaKeeper (a non-profit environmental organization) in five Stockton area sloughs/creeks (Appendix A, Figure 9) during the first flush rainfall event in 1996 showed dissolved oxygen concentrations decreasing to as low as 0.34 mg/L approximately 72 hours after the peak rain (Appendix A, Figure 10) (DeltaKeeper, unpublished data).

During the fathead minnow *in situ* bioassay, the Hydrolab™ readings exhibited dissolved oxygen concentrations as low as 1.75 mg/L, which is well below both the one-day minimum ambient water quality criteria for dissolved oxygen of 3.0 mg/L for both salmonid and non-salmonid adults (USEPA, 1986) and the Basin Plan limit of 5.0 mg/L. However, no significant fathead minnow mortality was observed. In contrast, the threadfin shad lost equilibrium in the laboratory at a dissolved oxygen concentration between 3.2 and 4.7 mg/L, which is a higher dissolved oxygen concentration than that observed in the field at several sites in Stockton. Clearly, the minnow is not as sensitive to low dissolved oxygen concentrations as the shad. The fathead minnow has been reported to be more tolerant of low dissolved oxygen concentrations than other fish species (Castleberry and Cech, 1992). USEPA has reported that although non-salmonids are generally less sensitive to low dissolved oxygen concentrations than salmonids, the exceptions to this may include the Clupeidae family (which include the shad and the smelts but not the fathead minnow) (USEPA, 1986).

When dissolved oxygen concentrations in a waterway fall below the level at which indigenous species lose equilibrium these species become easy prey for avian predators and do not have the opportunity to recover as the dissolved oxygen levels return to normal over time. If this phenomenon occurs frequently after rain events there is the potential for substantial negative effects on indigenous species of fish.

Another concern is that an acute or chronic decrease in dissolved oxygen may cause a lethal effect when other toxicants are present at sublethal concentrations (USEPA, 1986). Lloyd (1961) reported an increase in toxicity to rainbow trout of several toxicants with a decrease in dissolved oxygen. This effect is especially important in the case of urban runoff in which toxicants such as surfactants, pesticides, and metals are commonly found.

The City of Stockton has proposed a study to determine the cause of the decreased dissolved oxygen concentrations associated with rainfall events.

If these efforts are inconclusive, subsequent research should focus on *in situ* studies on multiple sites with indigenous species, such as the threadfin shad, accompanied by Hydrolab™ readings and analysis (biological and/or chemical) as funding permits. If possible, long-term studies should be conducted in order to characterize any seasonal patterns that may occur. At the least, any study focusing on precipitation-related urban runoff as a possible cause for depressed dissolved oxygen levels should characterize the dissolved oxygen levels in the waterway of concern for an extended time both before and after rain events.

Figure 1. Sampling Sites In Stockton

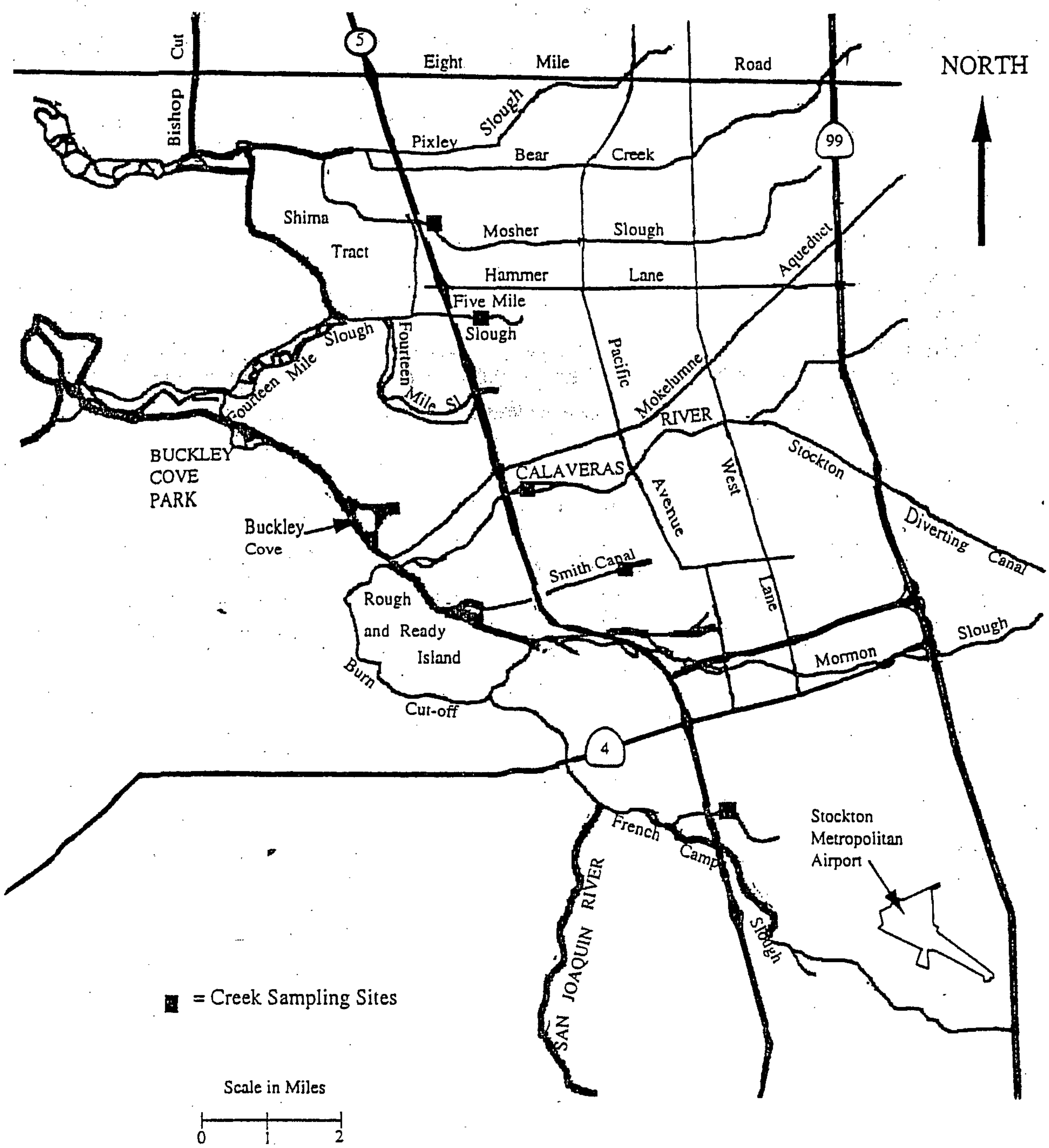


Figure 2. Each point represents the mean critical dissolved oxygen minima (mg/L) per experiment of threadfin shad acclimated at 19.5 °C in relation to mean weight. Sample sizes range from 1 to 3.

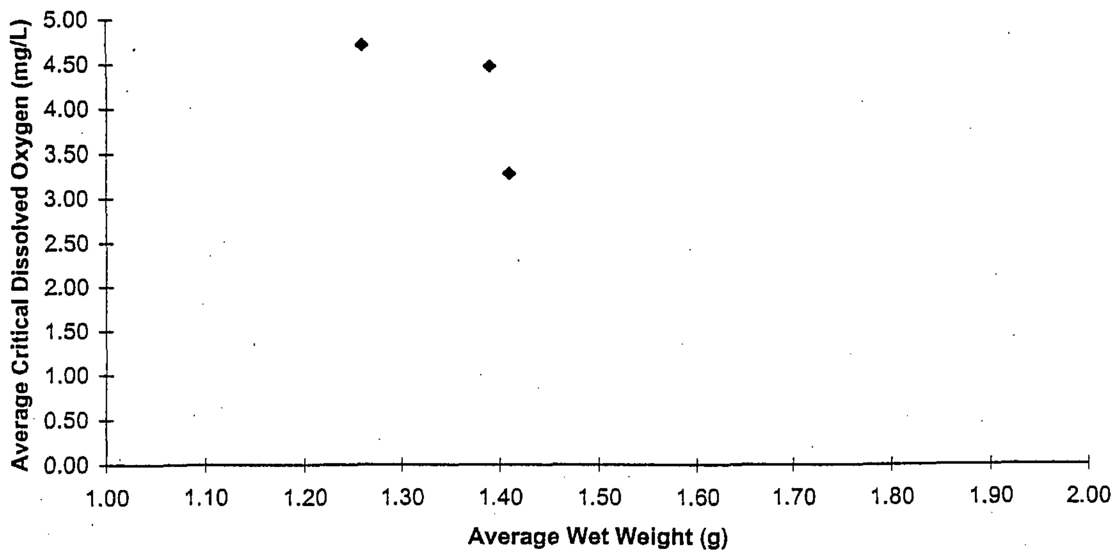


Figure 3. Dissolved oxygen and rainfall measurements in Stockton urban creeks and sloughs from 15 October to 8 November 1995.

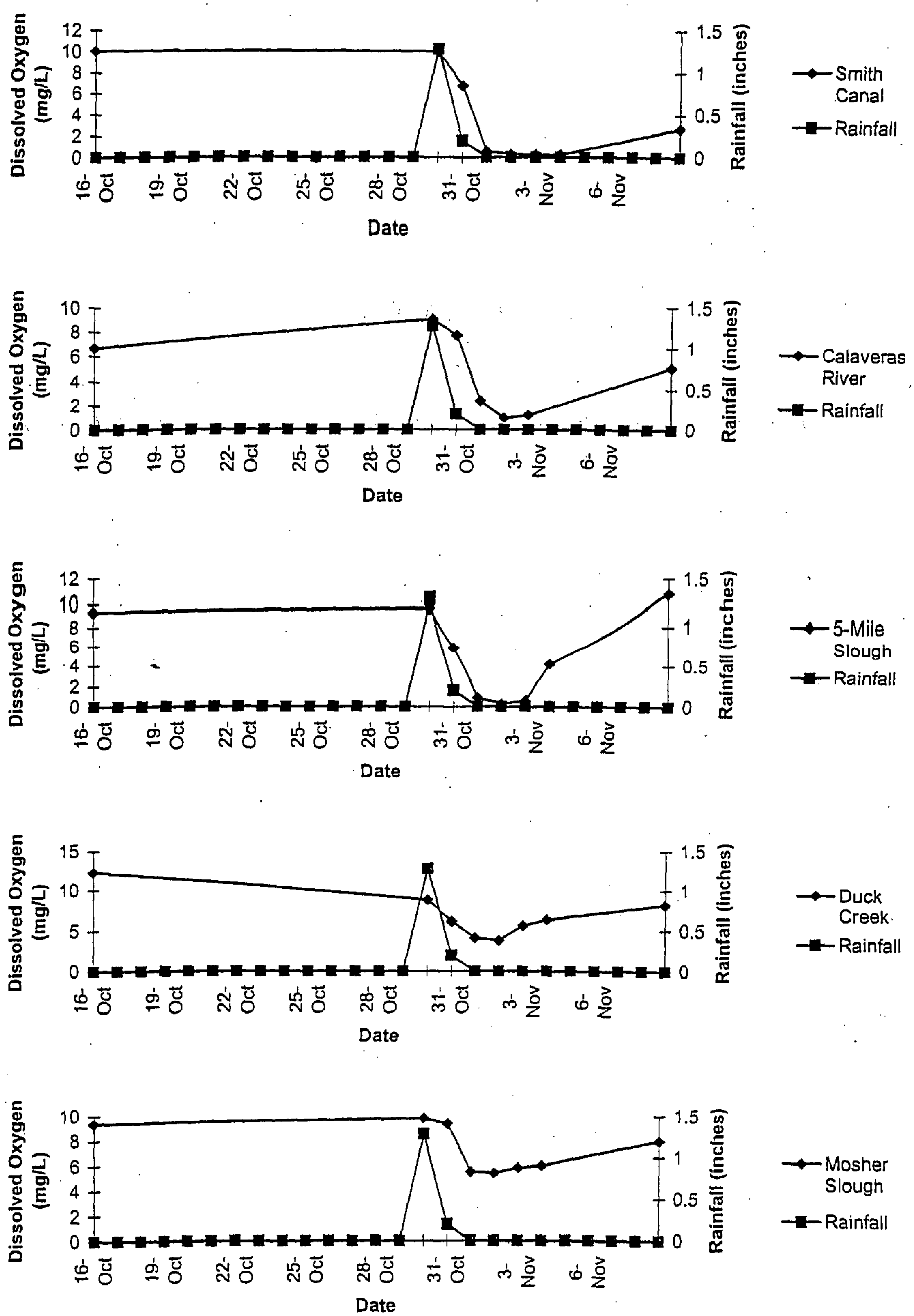


Figure 1. Dissolved oxygen measurements in Smith Canal from 6 to 9 October 1995.

Table 1. Summary of water quality parameters measured in Smith Canal from 6 to 9 October 1995.

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond uS/cm	Salin ppt	DO %Sat	DO mg/l
100695	163000	21.00	7.55	416	0.2	84.9	7.56
100695	164500	20.94	7.53	409	0.2	83.1	7.40
100695	170000	20.92	7.47	409	0.2	80.8	7.20
100695	171500	20.89	7.42	409	0.2	77.5	6.92
100695	173000	20.94	7.43	413	0.2	78.8	7.02
100695	174500	20.90	7.44	403	0.2	81.1	7.23
100695	180000	20.94	7.44	408	0.2	79.3	7.06
100695	181500	20.98	7.47	405	0.2	82.3	7.33
100695	183000	20.95	7.51	410	0.2	82.0	7.31
100695	184500	21.01	7.54	414	0.2	83.9	7.47
100695	190000	21.05	7.56	418	0.2	84.3	7.50
100695	191500	21.07	7.59	419	0.2	84.6	7.52
100695	193000	21.10	7.66	420	0.2	87.7	7.79
100695	194500	21.14	7.70	420	0.2	89.8	7.98
100695	200000	21.21	7.94	423	0.2	94.6	8.39
100695	201500	21.37	8.14	426	0.2	101.6	8.98
100695	203000	21.38	8.19	428	0.2	112.4	9.93
100695	204500	21.38	8.24	432	0.2	113.1	9.99
100695	210000	21.35	8.21	434	0.2	114.8	10.15
100695	211500	21.28	8.15	432	0.2	112.4	9.95
100695	213000	21.22	8.06	432	0.2	108.0	9.57
100695	214500	21.20	7.98	433	0.2	103.5	9.18
100695	220000	21.15	7.93	433	0.2	99.4	8.82
100695	221500	21.15	7.96	437	0.2	97.4	8.64
100695	223000	21.15	8.01	443	0.2	99.5	8.30
100695	224500	21.14	7.99	452	0.2	100.3	8.91
100695	230000	21.10	7.96	453	0.2	98.0	8.70
100695	231500	21.05	7.95	451	0.2	95.6	8.50
100695	233000	21.03	7.93	455	0.2	96.2	8.55
100695	234500	20.96	7.92	456	0.2	94.5	8.42
100795	0	20.90	7.90	455	0.2	93.8	8.37
100795	1500	20.93	7.91	455	0.2	92.8	8.27
100795	3000	20.93	7.88	455	0.2	92.7	8.28
100795	4500	20.79	7.87	453	0.2	91.6	8.19
100795	10000	20.77	7.86	452	0.2	91.5	8.18
100795	11500	20.75	7.84	446	0.2	92.6	8.28
100795	13000	20.70	7.82	443	0.2	92.0	8.23
100795	14500	20.70	7.78	441	0.2	91.5	8.19
100795	20000	20.65	7.71	439	0.2	90.1	8.08
100795	21500	20.63	7.63	433	0.2	88.0	7.89
100795	23000	20.63	7.56	421	0.2	84.9	7.62
100795	24500	20.56	7.54	425	0.2	84.1	7.55
100795	30000	20.48	7.54	429	0.2	81.2	7.30
100795	31500	20.48	7.47	423	0.2	82.9	7.45
100795	33000	20.39	7.45	410	0.2	80.2	7.22
100795	34500	20.39	7.44	412	0.2	78.6	7.08
100795	40000	20.31	7.40	404	0.2	78.8	7.11
100795	41500	20.32	7.39	410	0.2	76.8	6.93
100795	43000	20.28	7.37	407	0.2	76.4	6.89
100795	44500	20.24	7.34	401	0.2	76.4	6.90
100795	50000	20.23	7.34	403	0.2	75.0	6.78
100795	51500	20.18	7.33	398	0.2	75.7	6.85
100795	53000	20.20	7.31	398	0.2	75.0	6.79
100795	54500	20.16	7.30	401	0.2	73.0	6.60
100795	60000	20.11	7.31	399	0.2	73.3	6.64
100795	61500	20.06	7.31	399	0.2	74.3	6.74
100795	63000	20.06	7.31	404	0.2	71.5	6.49
100795	64500	20.06	7.32	403	0.2	71.6	6.50

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond uS/cm	Salin ppt	DO %Sat	DO mg/l
100795	70000	20.06	7.31	405	0.2	72.3	6.56
100795	71500	20.06	7.32	408	0.2	71.5	6.48
100795	73000	20.03	7.33	411	0.2	70.4	6.39
100795	74500	20.02	7.34	415	0.2	70.6	6.40
100795	80000	19.99	7.35	418	0.2	70.4	6.39
100795	81500	20.02	7.35	422	0.2	71.4	6.48
100795	83000	20.00	7.35	423	0.2	71.3	6.47
100795	84500	19.99	7.36	426	0.2	71.1	6.46
100795	90000	19.99	7.38	428	0.2	71.9	6.53
100795	91500	20.02	7.40	433	0.2	76.3	6.68
100795	93000	20.00	7.43	436	0.2	73.9	6.71
100795	94500	20.00	7.43	437	0.2	74.1	6.73
100795	100000	20.02	7.44	440	0.2	73.3	6.65
100795	101500	20.00	7.45	442	0.2	73.3	6.66
100795	103000	20.01	7.49	444	0.2	75.3	6.84
100795	104500	20.01	7.50	445	0.2	75.1	6.82
100795	110000	20.07	7.55	450	0.2	78.9	7.15
100795	111500	20.09	7.62	452	0.2	80.5	7.29
100795	113000	20.13	7.66	454	0.2	83.6	7.56
100795	114500	20.13	7.67	454	0.2	83.5	7.56
100795	120000	20.18	7.70	456	0.2	85.6	7.74
100795	121500	20.25	7.78	457	0.2	88.4	7.98
100795	123000	20.42	7.86	461	0.2	91.3	8.22
100795	124500	20.28	7.73	456	0.2	84.4	7.62
100795	130000	20.66	7.91	457	0.2	92.3	8.27
100795	131500	20.74	7.96	454	0.2	97.7	8.74
100795	133000	20.89	8.03	450	0.2	102.6	9.16
100795	134500	20.89	8.01	447	0.2	103.0	9.19
100795	140000	20.94	7.98	442	0.2	103.0	9.18
100795	141500	20.93	7.95	435	0.2	101.1	9.02
100795	143000	21.03	7.97	418	0.2	103.5	9.21
100795	144500	21.11	7.95	414	0.2	104.0	9.24
100795	150000	21.07	7.94	415	0.2	102.7	9.13
100795	151500	21.03	7.90	415	0.2	101.1	8.99
100795	153000	20.97	7.84	410	0.2	98.3	8.76
100795	154500	20.98	7.76	412	0.2	95.6	8.52
100795	160000	20.93	7.72	404	0.2	93.6	8.34
100795	161500	20.89	7.66	399	0.2	92.2	8.23
100795	163000	20.91	7.64	400	0.2	90.5	8.07
100795	164500	20.89	7.64	399	0.2	91.1	8.12
100795	170000	20.89	7.61	399	0.2	89.9	8.02
100795	171500	20.86	7.58	401	0.2	84.6	7.55
100795	173000	20.93	7.52	400	0.2	86.1	7.68
100795	174500	20.86	7.51	401	0.2	81.7	7.29
100795	180000	20.87	7.47	398	0.2	85.5	7.63
100795	181500	20.87	7.48	398	0.2	86.1	7.68
100795	183000	20.92	7.49	401	0.2	87.2	7.78
100795	184500	20.96	7.54	399	0.2	90.8	8.09
100795	190000	20.93	7.59	398	0.2	90.1	8.03
100795	191500	20.97	7.66	401	0.2	92.4	8.23
100795	193000	20.99	7.66	403	0.2	92.0	8.19
100795	194500	21.03	7.69	406	0.2	93.7	8.34
100795	200000	21.05	7.76	410	0.2	96.2	8.55
100795	201500	21.08	7.79	413	0.2	98.3	8.74
100795	203000	21.07	7.84	413	0.2	99.8	8.87
100795	204500	21.07	7.86	421	0.2	104.6	9.30
100795	210000	21.05	7.89	419	0.2	101.6	9.03
100795	211500	21.01	7.86	420	0.2	100.8	8.97
100795	213000	21.00	7.86	423	0.2	101.1	9.00
100795	214500	20.96	7.85	424	0.2	100.8	8.98
100795	220000	20.97	7.91	430	0.2	103.1	9.18
100795	221500	20.96	7.95	430	0.2	101.6	9.05

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond uS/cm	Salin ppt	DO %Sat	DO mg/l
100795	223000	20.96	7.99	432	0.2	103.2	9.19
100795	224500	20.92	7.96	435	0.2	102.5	9.13
100795	230000	20.94	7.98	440	0.2	105.3	9.39
100795	231500	20.91	8.04	440	0.2	104.7	9.33
100795	233000	20.89	8.03	444	0.2	105.2	9.38
100795	234500	20.86	8.01	446	0.2	103.8	9.26
100895	0	20.86	7.99	448	0.2	104.4	9.32
100895	1500	20.82	7.98	449	0.2	103.2	9.22
100895	3000	20.79	7.95	449	0.2	101.7	9.09
100895	4500	20.76	7.96	449	0.2	100.4	8.98
100895	10000	20.77	8.02	450	0.2	100.6	8.99
100895	11500	20.76	8.04	455	0.2	101.5	9.07
100895	13000	20.66	8.03	455	0.2	100.7	9.02
100895	14500	20.65	7.98	452	0.2	98.1	8.79
100895	20000	20.00	7.97	453	0.2	98.4	8.83
100895	21500	20.58	7.93	451	0.2	96.9	8.70
100895	23000	20.56	7.87	445	0.2	94.8	8.51
100895	24500	20.53	7.82	441	0.2	92.6	8.32
100895	30000	20.49	7.74	431	0.2	90.3	8.12
100895	31500	20.46	7.68	427	0.2	88.6	7.97
100895	33000	20.41	7.63	423	0.2	87.5	7.88
100895	34500	20.41	7.62	424	0.2	86.3	7.78
100895	40000	20.35	7.59	422	0.2	84.7	7.64
100895	41500	20.32	7.56	413	0.2	84.4	7.62
100895	43000	20.28	7.51	407	0.2	83.5	7.54
100895	44500	20.25	7.48	403	0.2	82.5	7.75
100895	50000	20.22	7.48	407	0.2	81.5	7.37
100895	51500	20.20	7.45	403	0.2	80.8	7.31
100895	53000	20.16	7.43	401	0.2	79.7	7.18
100895	54500	20.18	7.42	401	0.2	79.3	7.17
100895	60000	20.13	7.40	402	0.2	78.0	7.07
100895	61500	20.13	7.39	397	0.2	77.6	7.03
100895	63000	20.10	7.35	393	0.2	77.2	6.99
100895	64500	20.05	7.33	397	0.2	76.1	6.90
100895	70000	20.00	7.34	396	0.2	76.6	6.95
100895	71500	19.97	7.35	396	0.2	75.6	6.87
100895	73000	19.99	7.35	397	0.2	76.3	6.93
100895	74500	19.98	7.35	401	0.2	74.9	6.80
100895	80000	19.98	7.35	403	0.2	74.4	6.75
100895	81500	19.98	7.38	407	0.2	75.8	6.89
100895	83000	19.98	7.41	414	0.2	76.3	6.93
100895	84500	19.97	7.41	415	0.2	75.8	6.89
100895	90000	19.97	7.40	420	0.2	75.6	6.87
100895	91500	19.97	7.40	422	0.2	75.6	6.87
100895	93000	19.92	7.39	422	0.2	74.4	6.76
100895	94500	19.97	7.44	429	0.2	77.1	7.00
100895	100000	19.97	7.48	433	0.2	79.3	7.20
100895	101500	20.06	7.55	440	0.2	82.8	7.51
100895	103000	20.13	7.64	445	0.2	87.0	7.88
100895	104500	20.20	7.69	449	0.2	89.9	8.13
100895	110000	20.25	7.75	449	0.2	92.1	8.32
100895	111500	20.25	7.75	452	0.2	91.9	8.30
100895	113000	20.29	7.81	452	0.2	93.9	8.48
100895	114500	20.44	7.86	453	0.2	98.7	8.88
100895	120000	20.44	7.88	455	0.2	97.1	8.74
100895	121500	20.72	7.87	458	0.2	98.4	8.81
100895	123000	20.42	7.76	455	0.2	90.7	8.17
100895	124500	20.35	7.75	454	0.2	86.3	7.78
100895	130000	20.39	7.71	455	0.2	85.4	7.69
100895	131500	20.40	7.83	455	0.2	90.5	8.15
100895	133000	20.61	7.93	454	0.2	93.0	8.34
100895	134500	21.21	8.12	451	0.2	107.2	9.50

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond uS/cm	Salin ppt	DO %Sat	DO mg/l
100895	140000	21.00	8.14	446	0.2	109.1	9.72
100895	141500	21.14	8.15	440	0.2	110.3	9.79
100895	143000	21.15	8.11	433	0.2	108.9	9.67
100895	144500	21.12	8.09	424	0.2	108.6	9.64
100895	150000	21.16	8.08	418	0.2	109.1	9.68
100895	151500	21.26	8.08	408	0.2	110.3	9.77
100895	153000	21.24	8.06	408	0.2	109.2	9.67
100895	154500	21.22	8.03	408	0.2	108.1	9.58
100895	160000	21.19	7.99	409	0.2	105.8	9.38
100895	161500	21.17	7.94	404	0.2	103.9	9.22
100895	163000	21.13	7.88	395	0.2	102.8	9.13
100895	164500	21.15	7.84	397	0.2	100.6	8.93
100895	170000	21.09	7.80	389	0.2	98.6	8.76
100895	171500	21.07	7.78	386	0.2	99.0	8.80
100895	173000	21.10	7.76	388	0.2	98.1	8.72
100895	174500	21.30	7.69	389	0.2	97.5	8.66
100895	180000	21.07	7.73	389	0.2	96.8	8.60
100895	181500	21.07	7.69	389	0.2	96.4	8.57
100895	183000	21.07	7.63	388	0.2	92.8	8.25
100895	184500	21.07	7.60	386	0.2	92.9	8.26
100895	190000	21.11	7.62	390	0.2	94.6	8.40
100895	191500	21.10	7.62	390	0.2	93.9	8.34
100895	193000	21.08	7.70	387	0.2	96.5	8.58
100895	194500	21.14	7.76	391	0.2	100.2	8.90
100895	200000	21.14	7.85	397	0.2	102.0	9.06
100895	201500	21.17	7.90	407	0.2	102.8	9.13
100895	203000	21.15	7.93	407	0.2	103.5	9.19
100895	204500	21.15	7.93	410	0.2	103.5	9.19
100895	210000	21.14	7.94	413	0.2	104.0	9.23
100895	211500	21.10	7.93	411	0.2	100.4	8.92
100895	213000	21.10	7.92	415	0.2	102.7	9.12
100895	214500	21.05	7.89	415	0.2	101.2	9.00
100895	220000	21.05	7.97	421	0.2	105.6	9.39
100895	221500	21.05	8.02	426	0.2	107.6	9.57
100895	223000	21.04	8.09	433	0.2	110.5	9.83
100895	224500	21.07	8.16	437	0.2	113.4	10.08
100895	230000	21.10	8.21	442	0.2	116.8	10.38
100895	231500	21.05	8.22	442	0.2	115.3	10.25
100895	233000	21.08	8.24	447	0.2	118.2	10.50
100895	234500	21.05	8.26	447	0.2	117.1	10.42
100995	0	21.00	8.24	447	0.2	114.7	10.21
100995	1500	21.00	8.24	449	0.2	114.9	10.23
100995	3000	21.00	8.23	455	0.2	114.5	10.19
100995	4500	20.93	8.19	454	0.2	113.0	10.07
100995	10000	20.89	8.17	458	0.2	112.0	9.99
100995	11500	20.84	0.17	459	0.2	110.7	9.89
100995	13000	20.79	8.14	460	0.2	108.7	9.72
100995	14500	21.79	8.16	462	0.2	109.3	9.77
100995	20000	20.76	8.13	460	0.2	106.1	9.49
100995	21500	20.66	8.13	460	0.2	106.5	9.54
100995	23000	20.66	8.12	460	0.2	106.4	9.53
100995	24500	20.62	8.11	458	0.2	105.3	9.44
100995	30000	20.58	8.07	455	0.2	103.8	9.32
100995	31500	20.54	8.05	454	0.2	102.1	9.17
100995	33000	20.51	7.98	450	0.2	100.1	9.00
100995	34500	20.47	7.91	445	0.2	97.4	8.76
100995	40000	20.42	7.81	437	0.2	93.5	8.42
100995	41500	20.40	7.74	430	0.2	91.5	8.25
100995	43000	20.37	7.65	420	0.2	8.7	8.00
100995	44500	20.30	7.65	421	0.2	88.5	7.98
100995	50000	20.28	7.60	412	0.2	87.4	7.89
100995	51500	20.25	7.57	415	0.2	86.3	7.80

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond uS/cm	Salin ppt	DO %Sat	DO mg/l
100995	53000	20.23	7.56	410	0.2	85.4	7.72
100995	54500	20.20	7.51	406	0.2	84.4	7.63
100995	60000	20.17	7.47	401	0.2	83.4	7.55
100995	61500	20.16	7.44	399	0.2	83.0	7.51
100995	63000	20.13	7.39	400	0.2	81.4	7.37
100995	64500	20.11	7.41	395	0.2	80.9	7.33
100995	70000	20.06	7.39	397	0.2	79.5	7.21
100995	71500	20.06	7.38	396	0.2	79.0	7.17
100995	73000	20.02	7.37	395	0.2	79.0	7.17
100995	74500	19.97	7.38	397	0.2	79.4	7.21
100995	80000	19.95	7.38	395	0.2	78.7	7.15
100995	81500	19.95	7.39	399	0.2	78.6	7.14
100995	83000	19.99	7.41	405	0.2	79.6	7.23
100995	84500	19.98	7.41	409	0.2	78.3	7.11
100995	90000	19.99	7.47	414	0.2	80.1	7.27
100995	91500	19.96	7.47	417	0.2	79.5	7.22
100995	93000	19.97	7.49	422	0.2	80.3	7.29
100995	94500	19.95	7.47	422	0.2	78.9	7.17
100995	100000	19.94	7.48	427	0.2	80.5	7.32
100995	101500	19.92	7.49	427	0.2	80.4	7.31
100995	103000	20.03	7.59	437	0.2	85.4	7.75
100995	104500	21.18	7.68	444	0.2	91.0	8.23
100995	110000	20.16	7.72	446	0.2	89.4	8.09
100995	111500	20.25	7.71	449	0.2	8..6	8.46
100995	113000	20.21	7.72	450	0.2	80.9	8.22
100995	114500	20.29	7.74	450	0.2	92.6	8.36
100995	120000	20.42	7.84	452	0.2	96.7	8.70
100995	121500	20.59	7.97	455	0.2	106.4	9.54
100995	123000	20.82	8.03	459	0.2	111.0	9.92
100995	124500	20.35	7.91	456	0.2	93.4	8.42
100995	130000	20.35	7.77	456	0.2	90.3	8.14
100995	131500	20.33	7.79	456	0.2	88.7	8.00
100995	133000	20.27	7.75	456	0.2	86.4	7.80
100995	134500	20.46	7.87	457	0.2	91.2	8.21
100995	140000	20.66	7.98	456	0.2	97.6	8.74
100995	141500	20.93	8.19	454	0.2	109.3	9.74
100995	143000	21.15	8.20	448	0.2	112.9	10.01
100995	144500	21.33	8.25	444	0.2	116.0	10.26
100995	150000	21.29	8.22	433	0.2	115.3	10.20
100995	151500	21.26	8.21	421	0.2	116.0	10.27
100995	153000	21.28	8.19	421	0.2	115.3	10.21
100995	154500	21.36	8.20	410	0.2	116.8	10.33
100995	160000	21.39	8.19	405	0.2	117.0	10.34
100995	161500	21.35	8.15	408	0.2	115.0	10.17
100995	163000	21.28	8.09	401	0.2	111.9	9.91
100995	164500	21.28	8.04	404	0.2	109.2	9.67

Figure 2. Dissolved oxygen measurements in Smith Canal from 14 to 17 October 1995.

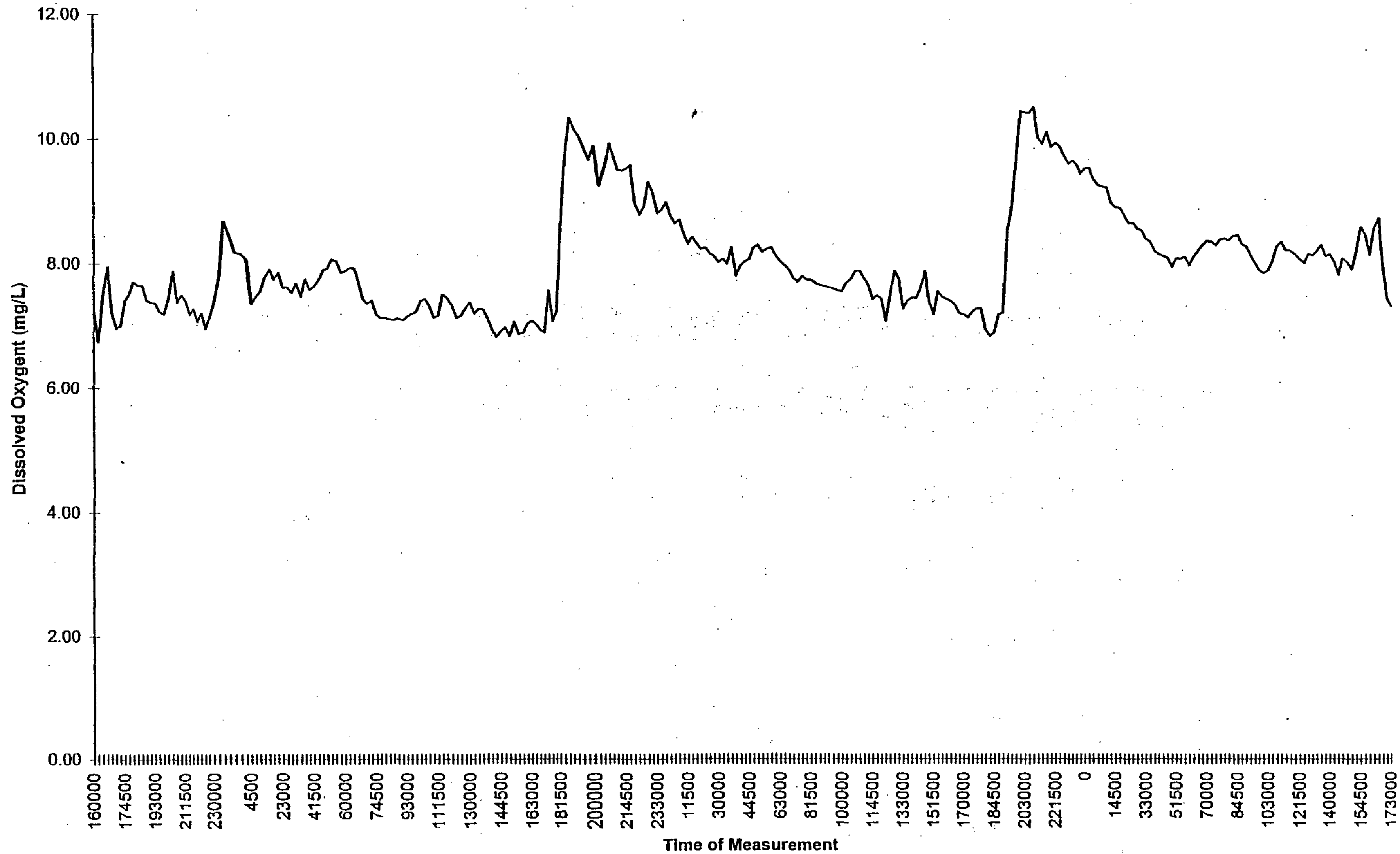


Table 2. Summary of water quality parameters measured in Smith Canal from 14 to 17 October 1995.

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond uS/cm	Salin ppt	DO %Sat	DO mg/l
101495	160000	19.63	7.55	406	0.2	78.9	7.22
101495	161500	19.42	7.50	413	0.2	73.4	6.75
101495	163000	19.45	7.62	421	0.2	81.6	7.49
101495	164500	19.57	7.70	420	0.2	86.8	7.94
101495	170000	19.64	7.55	412	0.2	78.7	7.20
101495	171500	19.59	7.49	403	0.2	76.0	6.96
101495	173000	19.61	7.49	401	0.2	76.7	7.01
101495	174500	19.77	7.58	400	0.2	81.3	7.41
101495	180000	19.76	7.57	394	0.2	82.3	7.51
101495	181500	19.73	7.60	396	0.2	84.5	7.71
101495	183000	19.75	7.61	394	0.2	83.9	7.65
101495	184500	19.68	7.58	392	0.2	83.6	7.64
101495	190000	19.88	7.55	395	0.2	81.6	7.42
101495	191500	19.65	7.53	392	0.2	80.7	7.38
101495	193000	19.75	7.51	393	0.2	80.8	7.37
101495	194500	19.63	7.51	392	0.2	79.0	7.23
101495	200000	19.60	7.51	388	0.2	78.7	7.20
101495	201500	19.81	7.50	381	0.2	81.6	7.44
101495	203000	19.85	7.63	373	0.2	86.4	7.87
101495	204500	19.67	7.53	376	0.2	80.8	7.39
101495	210000	19.77	7.51	368	0.2	82.2	7.50
101495	211500	19.80	7.49	369	0.2	81.1	7.40
101495	213000	19.71	7.46	376	0.2	78.7	7.19
101495	214500	19.71	7.45	374	0.2	79.7	7.28
101495	220000	19.63	7.43	373	0.2	77.2	7.07
101495	221500	19.69	7.43	371	0.2	78.9	7.21
101495	223000	19.73	7.43	377	0.2	76.3	6.96
101495	224500	19.81	7.44	385	0.2	78.3	7.14
101495	230000	19.85	7.47	384	0.2	80.7	7.35
101495	231500	20.01	7.60	375	0.2	85.1	7.73
101495	233000	20.11	7.78	370	0.2	95.8	8.68
101495	234500	20.04	7.85	376	0.2	93.3	8.46
101595	0	20.01	7.76	379	0.2	90.2	8.19
101595	1500	19.99	7.71	384	0.2	89.8	8.16
101595	3000	19.98	7.70	389	0.2	88.8	8.07
101595	4500	19.90	7.57	390	0.2	81.0	7.37
101595	10000	19.88	7.57	397	0.2	82.1	7.47
101595	11500	19.88	7.58	399	0.2	83.0	7.55
101595	13000	19.90	7.60	399	0.2	85.5	7.78
101595	14500	19.86	7.62	403	0.2	86.7	7.90
101595	20000	19.85	7.59	403	0.2	85.0	7.74
101595	21500	19.82	7.59	409	0.2	86.1	7.85
101595	23000	19.80	7.62	407	0.2	83.6	7.62
101595	24500	19.79	7.61	410	0.2	83.6	7.62
101595	30000	19.77	7.62	412	0.2	82.7	7.54
101595	31500	19.76	7.61	414	0.2	84.1	7.68
101595	33000	19.71	7.61	415	0.2	81.9	7.48
101595	34500	19.70	7.63	419	0.2	84.9	7.75
101595	40000	19.66	7.64	419	0.2	83.0	7.59
101595	41500	19.65	7.63	422	0.2	83.4	7.63
101595	43000	19.63	7.63	425	0.2	84.5	7.73
101595	44500	19.63	7.69	427	0.2	86.2	7.89
101595	50000	19.60	7.71	431	0.2	86.6	7.92
101595	51500	19.58	7.73	438	0.2	88.1	8.06
101595	53000	19.57	7.71	438	0.2	87.7	8.03
101595	54500	19.52	7.69	437	0.2	85.6	7.85
101595	60000	19.47	7.69	437	0.2	85.9	7.88
101595	61500	19.46	7.73	438	0.2	86.5	7.93

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond uS/cm	Salin ppt	DO %Sat	DO mg/l
101595	63000	19.45	7.73	440	0.2	86.2	7.92
101595	64500	19.36	7.69	437	0.2	83.9	7.72
101595	70000	19.33	7.63	433	0.2	80.9	7.44
101595	71500	19.30	7.61	432	0.2	79.9	7.36
101595	73000	19.29	7.61	432	0.2	80.4	7.41
101595	74500	19.25	7.57	426	0.2	78.0	7.19
101595	80000	19.24	7.55	423	0.2	77.4	7.13
101595	81500	19.22	7.54	419	0.2	77.3	7.13
101595	83000	19.22	7.52	415	0.2	77.1	7.11
101595	84500	19.23	7.51	410	0.2	77.1	7.10
101595	90000	19.21	7.50	402	0.2	77.3	7.13
101595	91500	19.18	7.49	399	0.2	76.9	7.10
101595	93000	19.18	7.49	394	0.2	77.6	7.16
101595	94500	19.18	7.48	390	0.2	78.0	7.20
101595	100000	19.19	7.48	385	0.2	78.4	7.23
101595	101500	19.23	7.50	382	0.2	80.3	7.40
101595	103000	19.25	7.50	380	0.2	80.7	7.44
101595	104500	19.24	7.49	381	0.2	79.5	7.33
101595	110000	19.21	7.45	379	0.2	77.4	7.14
101595	111500	19.20	7.46	378	0.2	77.7	7.17
101595	113000	19.30	7.52	375	0.2	81.4	7.50
101595	114500	19.30	7.47	373	0.2	80.9	7.45
101595	120000	19.30	7.47	373	0.2	79.6	7.33
101595	121500	19.27	7.44	373	0.2	77.4	7.14
101595	123000	19.28	7.43	371	0.2	77.8	7.17
101595	124500	19.29	7.45	376	0.2	79.0	7.28
101595	130000	19.32	7.47	376	0.2	80.1	7.38
101595	131500	19.37	7.47	374	0.2	78.3	7.20
101595	133000	19.36	7.47	374	0.2	79.1	7.28
101595	134500	19.40	7.46	376	0.2	79.2	7.27
101595	140000	19.38	7.46	379	0.2	77.6	7.13
101595	141500	19.37	7.44	383	0.2	75.5	6.94
101595	143000	19.37	7.42	385	0.2	74.3	6.83
101595	144500	19.41	7.44	387	0.2	75.3	6.92
101595	150000	19.42	7.45	387	0.2	76.0	6.98
101595	151500	19.40	7.44	390	0.2	74.4	6.84
101595	153000	19.50	7.48	387	0.2	77.1	7.07
101595	154500	19.48	7.45	388	0.2	75.0	6.88
101595	160000	19.54	7.47	388	0.2	75.4	6.91
101595	161500	19.50	7.48	391	0.2	76.8	7.04
101595	163000	19.53	7.50	392	0.2	77.3	7.09
101595	164500	19.49	7.48	398	0.2	76.6	7.03
101595	170000	19.47	7.51	403	0.2	75.6	6.94
101595	171500	19.50	7.49	402	0.2	75.4	6.91
101595	173000	19.70	7.70	396	0.2	82.9	7.57
101595	174500	19.57	7.53	400	0.2	77.5	7.09
101595	180000	19.64	7.63	400	0.2	79.1	7.24
101595	181500	20.00	7.90	392	0.2	96.5	8.76
101595	183000	20.20	8.06	376	0.2	108.2	9.79
101595	184500	20.20	8.21	371	0.2	114.4	10.35
101595	190000	20.16	8.19	369	0.2	112.2	10.16
101595	191500	20.12	8.23	370	0.2	111.1	10.06
101595	193000	20.09	8.14	370	0.2	109.0	9.88
101595	194500	20.06	8.11	367	0.2	106.7	9.68
101595	200000	20.07	8.08	363	0.2	109.1	9.89
101595	201500	19.99	7.99	365	0.2	102.1	9.27
101595	203000	19.96	7.97	358	0.2	104.9	9.54
101595	204500	19.94	8.04	346	0.2	109.2	9.93
101595	210000	19.94	7.95	352	0.2	106.7	9.70
101595	211500	19.94	7.91	353	0.2	104.6	9.51
101595	213000	19.92	7.85	353	0.2	104.5	9.51
101595	214500	19.85	7.93	343	0.2	104.6	9.53

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond uS/cm	Salin ppt	DO %Sat	DO mg/l
101595	220000	19.80	7.94	341	0.2	105.2	9.59
101595	221500	19.80	7.84	347	0.2	98.4	8.97
101595	223000	19.80	7.69	350	0.2	96.5	8.80
101595	224500	19.79	7.71	350	0.2	97.8	8.92
101595	230000	19.75	7.79	347	0.2	102.1	9.32
101595	231500	19.75	7.70	352	0.2	100.2	9.14
101595	233000	19.75	7.73	357	0.2	96.7	8.82
101595	234500	19.73	7.73	359	0.2	97.2	8.87
101695	0	19.68	7.78	361	0.2	98.4	8.99
101695	1500	19.68	7.75	366	0.2	95.9	8.76
101695	3000	19.65	7.72	371	0.2	94.5	8.65
101695	4500	19.63	7.74	370	0.2	95.3	8.71
101695	10000	19.63	7.66	381	0.2	92.9	8.49
101695	11500	19.58	7.68	375	0.2	90.9	8.32
101695	13000	19.58	7.66	387	0.2	92.1	8.43
101695	14500	19.56	7.68	392	0.2	90.9	8.33
101695	20000	19.54	7.67	395	0.2	89.9	8.24
101695	21500	19.50	7.70	402	0.2	90.1	8.26
101695	23000	19.49	7.60	405	0.2	89.0	8.17
101695	24500	19.45	7.66	413	0.2	88.4	8.12
101695	30000	19.42	7.63	415	0.2	87.3	8.02
101695	31500	19.40	7.65	419	0.2	87.9	8.07
101695	33000	19.37	7.68	420	0.2	86.9	7.99
101695	34500	19.37	7.70	428	0.2	89.7	8.25
101695	40000	19.30	7.69	423	0.2	84.9	7.81
101695	41500	19.30	7.70	430	0.2	86.6	7.97
101695	43000	19.28	7.69	431	0.2	87.2	8.03
101695	44500	19.24	7.70	435	0.2	87.5	8.07
101695	50000	19.25	7.73	440	0.2	89.5	8.25
101695	51500	19.21	7.71	443	0.2	90.0	8.30
101695	53000	19.18	7.76	443	0.2	88.7	8.19
101695	54500	19.14	7.78	446	0.2	89.1	8.23
101695	60000	19.11	7.81	448	0.2	89.4	8.26
101695	61500	19.08	7.77	451	0.2	88.0	8.14
101695	63000	19.07	7.76	450	0.2	86.8	8.03
101695	64500	19.04	7.75	453	0.2	86.1	7.97
101695	70000	18.98	7.72	454	0.2	85.3	7.90
101695	71500	18.99	7.71	454	0.2	83.9	7.77
101695	73000	18.96	7.69	456	0.2	83.2	7.71
101695	74500	18.92	7.71	457	0.2	84.1	7.80
101695	80000	18.97	7.70	456	0.2	83.5	7.74
101695	81500	18.89	7.70	452	0.2	83.4	7.74
101695	83000	18.87	7.68	447	0.2	82.8	7.69
101695	84500	18.85	7.66	442	0.2	82.5	7.66
101695	90000	18.88	7.65	437	0.2	82.3	7.64
101695	91500	18.88	7.63	433	0.2	82.0	7.62
101695	93000	18.88	7.61	425	0.2	81.8	7.60
101695	94500	18.87	7.59	416	0.2	81.5	7.57
101695	100000	18.85	7.57	408	0.2	81.3	7.55
101695	101500	18.89	7.57	399	0.2	82.8	7.69
101695	103000	18.93	7.58	394	0.2	83.7	7.76
101695	104500	18.99	7.59	388	0.2	85.0	7.88
101695	110000	19.01	7.60	388	0.2	85.1	7.88
101695	111500	18.95	7.59	391	0.2	83.6	7.76
101695	113000	18.96	7.57	386	0.2	82.7	7.66
101695	114500	18.93	7.53	385	0.2	80.1	7.43
101695	120000	18.97	7.53	383	0.2	80.8	7.49
101695	121500	18.99	7.52	382	0.2	80.3	7.44
101695	123000	18.98	7.47	382	0.2	76.5	7.09
101695	124500	18.99	7.48	380	0.2	80.6	7.47
101695	130000	19.06	7.52	377	0.2	85.2	7.88
101695	131500	19.11	7.54	373	0.2	83.7	7.74

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond uS/cm	Salin ppt	DO %Sat	DO mg/l
101695	133000	19.03	7.49	376	0.2	78.7	7.29
101695	134500	19.04	7.48	378	0.2	80.1	7.41
101695	140000	19.06	7.51	383	0.2	80.7	7.46
101695	141500	19.06	7.51	384	0.2	80.5	7.45
101695	143000	19.06	7.55	386	0.2	82.1	7.60
101695	144500	19.13	7.58	384	0.2	85.2	7.88
101695	150000	19.07	7.53	388	0.2	80.0	7.40
101695	151500	19.06	7.51	391	0.2	77.9	7.20
101695	153000	19.22	7.54	386	0.2	81.9	7.55
101695	154500	19.18	7.58	395	0.2	80.9	7.47
101695	160000	19.20	7.56	398	0.2	80.6	7.44
101695	161500	19.22	7.56	398	0.2	80.2	7.40
101695	163000	19.16	7.55	404	0.2	79.5	7.34
101695	164500	19.17	7.53	402	0.2	78.2	7.22
101695	170000	19.17	7.52	400	0.2	78.0	7.20
101695	171500	19.18	7.51	402	0.2	77.5	7.15
101695	173000	19.17	7.53	406	0.2	78.3	7.23
101695	174500	19.21	7.51	403	0.2	79.1	7.29
101695	180000	19.34	7.53	404	0.2	79.1	7.28
101695	181500	19.22	7.50	403	0.2	75.4	6.95
101695	183000	19.19	7.48	408	0.2	74.3	6.85
101695	184500	19.20	7.47	414	0.2	74.9	6.91
101695	190000	19.19	7.54	418	0.2	77.9	7.19
101695	191500	19.25	7.57	425	0.2	78.3	7.22
101695	193000	19.60	7.77	403	0.2	93.6	8.57
101695	194500	19.71	7.89	393	0.2	97.8	8.93
101695	200000	19.73	7.95	385	0.2	105.6	9.64
101695	201500	19.75	8.19	380	0.2	114.6	10.46
101695	203000	19.80	8.22	376	0.2	114.5	10.44
101695	204500	19.77	8.24	376	0.2	114.4	10.44
101695	210000	19.75	8.23	376	0.2	115.2	10.52
101695	211500	19.68	8.14	375	0.2	109.7	10.03
101695	213000	19.68	8.12	375	0.2	108.7	9.93
101695	214500	19.65	8.13	373	0.2	110.6	10.12
101695	220000	19.65	8.08	373	0.2	108.0	9.88
101695	221500	19.59	8.08	362	0.2	108.6	9.94
101695	223000	19.56	8.05	362	0.2	107.9	9.89
101695	224500	19.54	8.02	362	0.2	106.1	9.73
101695	230000	19.54	7.97	363	0.2	105.0	9.62
101695	231500	19.51	7.97	362	0.2	105.3	9.66
101695	233000	19.50	7.97	357	0.2	104.6	9.60
101695	234500	19.49	7.93	361	0.2	103.1	9.46
101795	0	19.46	7.95	362	0.2	103.9	9.54
101795	1500	19.42	7.96	362	0.2	103.9	9.55
101795	3000	19.41	7.93	361	0.2	102.1	9.38
101795	4500	19.42	7.91	363	0.2	101.0	9.28
101795	10000	19.40	7.90	370	0.2	100.7	9.25
101795	11500	19.37	7.91	374	0.2	100.3	9.23
101795	13000	19.37	7.85	378	0.2	97.6	8.98
101795	14500	19.34	7.84	387	0.2	97.0	8.92
101795	20000	19.29	7.84	388	0.2	96.6	8.90
101795	21500	19.25	7.82	389	0.2	95.2	8.78
101795	23000	19.25	7.80	390	0.2	94.0	8.66
101795	24500	19.23	7.79	401	0.2	93.9	8.66
101795	30000	19.18	7.79	406	0.2	92.9	8.57
101795	31500	19.16	7.79	409	0.2	92.4	8.54
101795	33000	19.14	7.78	413	0.2	91.1	8.41
101795	34500	19.08	7.75	413	0.2	90.4	8.36
101795	40000	19.09	7.74	419	0.2	88.8	8.21
101795	41500	19.04	7.73	423	0.2	88.2	8.16
101795	43000	19.01	7.73	425	0.2	87.7	8.13
101795	44500	18.96	7.74	428	0.2	87.4	8.10

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond uS/cm	Salin ppt	DO %Sat	DO mg/l
101795	50000	18.93	7.71	428	0.2	85.7	7.95
101795	51500	18.92	7.74	434	0.2	87.2	8.09
101795	53000	18.88	7.73	437	0.2	87.1	8.09
101795	54500	18.84	7.74	440	0.2	87.4	8.12
101795	60000	18.79	7.73	441	0.2	85.8	7.98
101795	61500	18.78	7.77	445	0.2	87.3	8.12
101795	63000	18.72	7.78	449	0.2	88.2	8.21
101795	64500	18.70	7.80	453	0.2	89.1	8.30
101795	70000	18.70	7.83	456	0.2	89.9	8.37
101795	71500	18.64	7.83	457	0.2	89.6	8.36
101795	73000	18.60	7.83	458	0.2	88.9	8.30
101795	74500	18.60	7.83	460	0.2	89.9	8.39
101795	80000	18.62	7.81	462	0.2	90.1	8.41
101795	81500	18.68	7.85	463	0.2	89.9	8.38
101795	83000	18.62	7.83	463	0.2	90.5	8.45
101795	84500	18.60	7.83	462	0.2	90.7	8.47
101795	90000	18.53	7.81	459	0.2	89.0	8.32
101795	91500	18.54	7.81	457	0.2	88.7	8.29
101795	93000	18.51	7.78	453	0.2	87.1	8.14
101795	94500	18.52	7.74	447	0.2	85.7	8.01
101795	100000	18.55	7.71	442	0.2	84.5	7.90
101795	101500	18.55	7.69	435	0.2	83.9	7.85
101795	103000	18.58	7.67	423	0.2	84.5	7.90
101795	104500	18.66	7.67	410	0.2	86.4	8.05
101795	110000	18.79	7.70	401	0.2	89.0	8.28
101795	111500	18.83	7.72	398	0.2	89.9	8.35
101795	113000	18.82	7.70	399	0.2	88.4	8.22
101795	114500	18.84	7.69	398	0.2	88.4	8.21
101795	120000	18.87	7.66	395	0.2	87.8	8.16
101795	121500	18.89	7.65	393	0.2	87.0	8.08
101795	123000	18.89	7.63	391	0.2	86.4	8.02
101795	124500	18.92	7.64	383	0.2	88.0	8.17
101795	130000	18.94	7.62	382	0.2	87.8	8.14
101795	131500	18.95	7.64	379	0.2	88.6	8.21
101795	133000	18.99	7.63	377	0.2	89.7	8.31
101795	134500	18.99	7.63	378	0.2	87.7	8.13
101795	140000	19.03	7.62	374	0.2	88.1	8.16
101795	141500	18.97	7.60	371	0.2	86.8	8.04
101795	143000	18.99	7.58	379	0.2	84.5	7.83
101795	144500	18.97	7.58	372	0.2	87.3	8.09
101795	150000	18.99	7.60	379	0.2	86.7	8.03
101795	151500	19.02	7.60	382	0.2	85.5	7.92
101795	153000	19.06	7.63	384	0.2	88.6	8.20
101795	154500	19.09	7.71	374	0.2	93.0	8.60
101795	160000	19.22	7.73	379	0.2	91.9	8.48
101795	161500	19.13	7.66	385	0.2	88.2	8.15
101795	163000	19.28	7.73	389	0.2	93.3	8.59
101795	164500	19.42	7.77	389	0.2	95.2	8.74
101795	170000	19.13	7.61	393	0.2	85.0	7.85
101795	171500	19.06	7.56	396	0.2	80.3	7.43
101795	173000	19.03	7.56	397	0.2	79.2	7.33

Figure 3. Dissolved oxygen measurements in Smith Canal from 28 to 29 October 1995.

Table 3. Summary of water quality parameters measured in Smith Canal from 28 to 29 October 1995.

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond uS/cm	Salin ppt	DO %Sat	DO mg/l
102895	150000	18.19	8.13	356	0.2	95.9	9.03
102895	153000	18.00	7.97	357	0.2	88.5	8.37
102895	160000	18.03	7.99	365	0.2	90.7	8.57
102895	163000	18.36	8.04	353	0.2	95.6	8.98
102895	170000	18.41	8.12	349	0.2	99.4	9.33
102895	173000	18.31	8.05	338	0.2	97.7	9.18
102895	180000	18.31	7.99	339	0.2	95.5	8.97
102895	183000	18.28	7.95	333	0.2	94.6	8.89
102895	190000	18.27	7.86	330	0.2	93.0	8.75
102895	193000	18.20	7.77	324	0.2	91.3	8.60
102895	200000	18.17	7.71	321	0.2	89.5	8.43
102895	203000	18.14	7.67	320	0.2	88.3	8.32
102895	210000	18.08	7.63	318	0.2	87.1	8.23
102895	213000	18.05	7.59	318	0.2	85.1	8.04
102895	220000	18.03	7.57	320	0.2	84.4	7.98
102895	223000	18.03	7.58	321	0.2	84.1	7.95
102895	230000	18.04	7.62	325	0.2	84.0	7.94
102895	233000	18.06	7.67	330	0.2	86.1	8.13
102995	0	18.06	7.70	334	0.2	86.0	8.12
102995	3000	18.02	7.71	337	0.2	85.3	8.06
102995	10000	18.02	7.68	341	0.2	84.6	8.00
102995	13000	17.98	7.76	345	0.2	85.6	8.10
102995	20000	17.95	7.77	350	0.2	85.3	8.07
102995	23000	17.90	7.73	352	0.2	83.1	7.87
102995	30000	17.86	7.76	357	0.2	84.2	7.98
102995	33000	17.82	7.81	364	0.2	85.2	8.09
102995	40000	17.77	7.77	365	0.2	83.0	7.88
102995	43000	17.70	7.74	368	0.2	81.8	7.78
102995	50000	17.63	7.70	369	0.2	79.8	7.61
102995	53000	17.56	7.67	371	0.2	78.6	7.50
102995	60000	17.48	7.63	370	0.2	76.7	7.33

Figure 4. Dissolved oxygen measurments in Smith Canal from 26 to 29 November 1995.

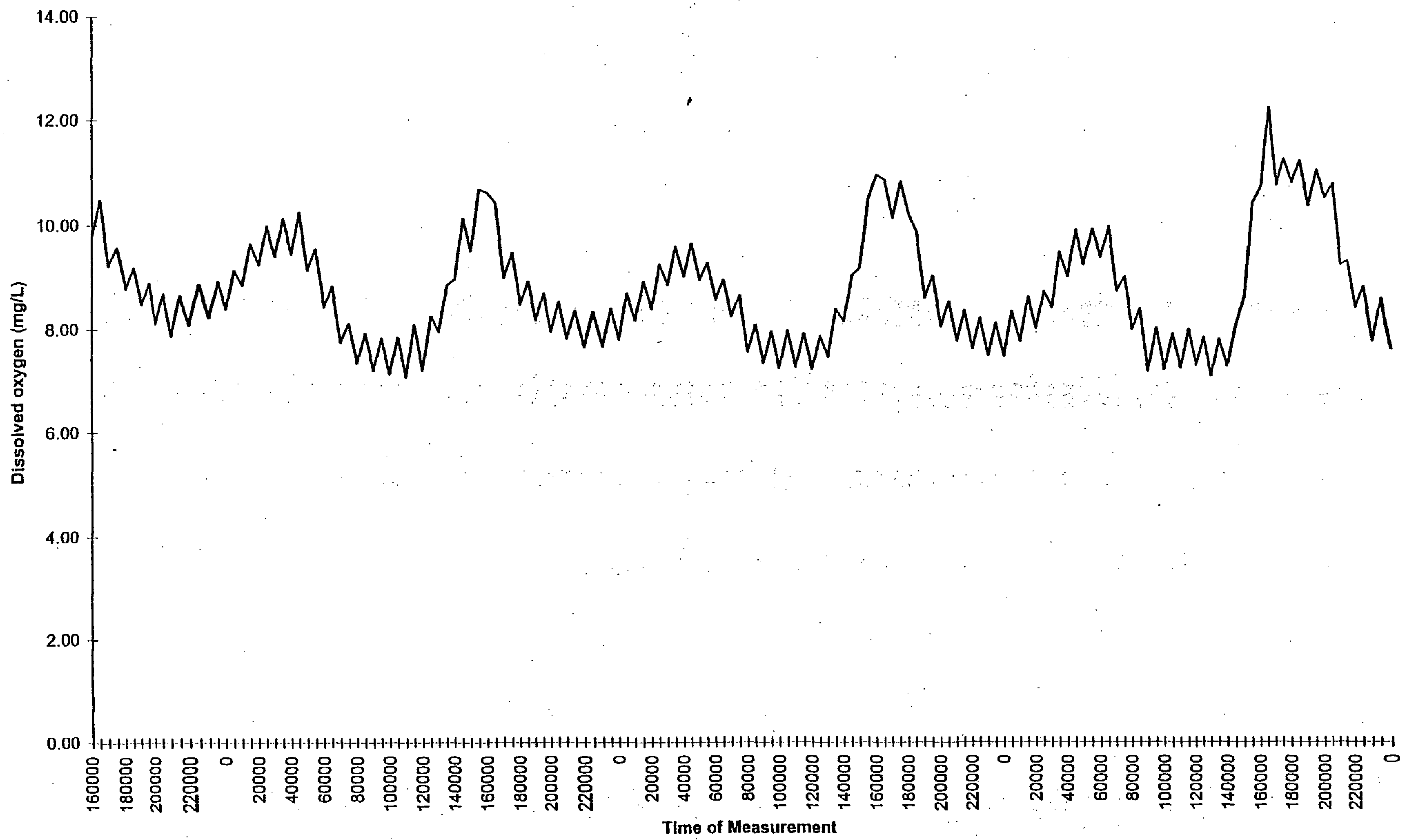


Table 4. Summary of water quality parameters measured in Smith Canal from 26 to 29 November 1995.

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond uS/cm	Salin ppt	DO %Sat	DO mg/l
112695	160000	14.49	7.86	481	0.2	96.5	9.82
112695	163000	14.59	7.82	492	0.2	103.0	10.47
112695	170000	14.64	7.71	504	0.3	91.0	9.23
112695	173000	14.67	7.66	513	0.3	94.4	9.57
112695	180000	14.69	7.64	519	0.3	86.7	8.79
112695	183000	14.69	7.61	526	0.3	90.6	9.18
112695	190000	14.65	7.59	526	0.3	83.7	8.49
112695	193000	14.64	7.57	531	0.3	87.6	8.89
112695	200000	14.57	7.55	529	0.3	79.9	8.12
112695	203000	14.57	7.55	531	0.3	85.6	8.69
112695	210000	14.55	7.53	531	0.3	77.5	7.88
112695	213000	14.49	7.55	526	0.3	85.0	8.65
112695	220000	14.37	7.56	515	0.3	79.3	8.09
112695	223000	14.24	7.59	505	0.3	86.6	8.87
112695	230000	14.17	7.59	501	0.3	80.4	8.24
112695	233000	14.09	7.60	495	0.3	86.9	8.92
112795	0	14.01	7.62	485	0.2	81.8	8.41
112795	3000	13.93	7.63	482	0.2	88.6	9.13
112795	10000	13.83	7.68	477	0.2	85.7	8.85
112795	13000	13.73	7.71	473	0.2	93.2	9.64
112795	20000	13.63	7.75	467	0.2	89.0	9.24
112795	23000	13.55	7.77	465	0.2	95.9	9.97
112795	30000	13.46	7.77	462	0.2	90.3	9.40
112795	33000	13.37	7.78	460	0.2	97.0	10.12
112795	40000	13.28	7.78	459	0.2	90.4	9.45
112795	43000	13.20	7.80	457	0.2	97.8	10.24
112795	50000	13.14	7.74	460	0.2	87.1	9.14
112795	53000	13.12	7.69	463	0.2	91.0	9.54
112795	60000	13.12	7.62	470	0.2	80.3	8.43
112795	63000	13.15	7.59	475	0.2	84.1	8.82
112795	70000	13.23	7.55	487	0.2	74.0	7.75
112795	73000	13.30	7.51	498	0.3	77.6	8.11
112795	80000	13.28	7.49	503	0.3	70.3	7.34
112795	83000	13.28	7.49	507	0.3	75.7	7.91
112795	90000	13.28	7.47	511	0.3	68.9	7.20
112795	93000	13.33	7.47	517	0.3	74.9	7.82
112795	100000	13.43	7.46	522	0.3	68.5	7.13
112795	103000	13.53	7.47	528	0.3	75.5	7.84
112795	110000	13.50	7.47	528	0.3	68.0	7.07
112795	113000	13.48	7.49	517	0.3	77.7	8.09
112795	120000	13.41	7.48	514	0.3	69.2	7.21
112795	123000	13.38	7.52	507	0.3	79.1	8.25
112795	130000	13.35	7.56	500	0.3	76.2	7.95
112795	133000	13.30	7.59	495	0.3	84.6	8.84
112795	140000	13.43	7.71	486	0.2	86.0	8.96
112795	143000	13.41	7.79	481	0.2	97.1	10.12
112795	150000	13.32	7.81	479	0.2	91.1	9.51
112795	153000	13.28	7.89	475	0.2	102.1	10.67
112795	160000	13.43	8.00	471	0.2	101.8	10.60
112795	163000	13.48	7.85	479	0.2	100.0	10.41
112795	170000	13.46	7.71	486	0.2	86.4	8.99
112795	173000	13.46	7.68	492	0.2	90.9	9.46
112795	180000	13.60	7.63	503	0.3	81.8	8.49
112795	183000	13.71	7.60	514	0.3	86.2	8.92
112795	190000	13.71	7.58	518	0.3	79.0	8.18
112795	193000	13.73	7.57	524	0.3	84.0	8.69
112795	200000	13.74	7.55	528	0.3	77.0	7.96
112795	203000	13.74	7.54	531	0.3	82.5	8.53
112795	210000	13.76	7.52	533	0.3	75.6	7.82
112795	213000	13.73	7.52	533	0.3	80.7	8.35
112795	220000	13.69	7.52	532	0.3	74.0	7.66
112795	223000	13.61	7.53	525	0.3	80.3	8.33
112795	230000	13.48	7.54	513	0.3	73.7	7.67
112795	233000	13.40	7.55	508	0.3	80.6	8.40
112895	0	13.32	7.56	503	0.3	74.7	7.80
112895	3000	13.22	7.58	494	0.3	82.9	8.68
112895	10000	13.15	7.60	489	0.2	77.9	8.17
112895	13000	13.10	7.62	487	0.2	84.9	8.91
112895	20000	13.00	7.63	483	0.2	79.9	8.40
112895	23000	12.92	7.65	480	0.2	87.7	9.24
112895	30000	12.84	7.70	479	0.2	83.8	8.85
112895	33000	12.74	7.70	472	0.2	90.5	9.58
112895	40000	12.67	7.70	469	0.2	85.1	9.01
112895	43000	12.58	7.70	468	0.2	90.7	9.64

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond uS/cm	Salin ppt	DO %Sat	DO mg/l
112895	50000	12.48	7.70	466	0.2	84.1	8.95
112895	53000	12.44	7.66	469	0.2	86.9	9.26
112895	60000	12.41	7.66	469	0.2	80.4	8.57
112895	63000	12.43	7.62	475	0.2	83.9	8.94
112895	70000	12.49	7.61	477	0.2	77.5	8.25
112895	73000	12.53	7.58	483	0.2	81.2	8.64
112895	80000	12.61	7.52	493	0.2	71.3	7.56
112895	83000	12.64	7.51	501	0.3	76.2	8.08
112895	90000	12.66	7.50	504	0.3	69.2	7.34
112895	93000	12.71	7.49	509	0.3	75.1	7.95
112895	100000	12.81	7.49	517	0.3	68.5	7.24
112895	103000	12.89	7.49	523	0.3	75.5	7.96
112895	110000	12.99	7.48	529	0.3	69.1	7.27
112895	113000	12.99	7.48	530	0.3	75.2	7.91
112895	120000	13.00	7.48	528	0.3	68.7	7.22
112895	123000	12.99	7.49	526	0.3	74.7	7.86
112895	130000	12.95	7.52	521	0.3	70.9	7.46
112895	133000	12.92	7.54	515	0.3	79.6	8.38
112895	140000	12.94	7.60	507	0.3	77.4	8.15
112895	143000	12.94	7.63	503	0.3	85.6	9.02
112895	150000	12.99	7.75	497	0.3	87.2	9.17
112895	153000	13.05	7.92	492	0.2	99.7	10.47
112895	160000	13.05	8.15	484	0.2	104.2	10.94
112895	163000	13.02	7.96	488	0.2	103.1	10.84
112895	170000	12.97	7.90	484	0.2	96.3	10.13
112895	173000	12.97	7.93	484	0.2	102.7	10.81
112895	180000	13.00	7.94	487	0.2	96.8	10.18
112895	183000	13.02	7.75	494	0.2	93.6	9.85
112895	190000	13.02	7.66	501	0.3	81.8	8.60
112895	193000	13.04	7.61	505	0.3	85.7	9.01
112895	200000	13.10	7.58	514	0.3	76.8	8.06
112895	203000	13.17	7.56	521	0.3	81.4	8.53
112895	210000	13.18	7.54	526	0.3	74.3	7.78
112895	213000	13.18	7.53	528	0.3	79.8	8.36
112895	220000	13.18	7.53	531	0.3	72.8	7.63
112895	223000	13.18	7.52	532	0.3	78.3	8.21
112895	230000	13.15	7.51	531	0.3	71.5	7.49
112895	233000	13.09	7.51	528	0.3	77.4	8.12
112995	0	12.99	7.51	519	0.3	71.2	7.49
112995	3000	12.87	7.55	510	0.3	79.2	8.35
112995	10000	12.79	7.55	506	0.3	73.5	7.77
112995	13000	12.72	7.58	500	0.3	81.5	8.62
112995	20000	12.67	7.59	497	0.3	75.8	8.03
112995	23000	12.63	7.60	496	0.3	82.2	8.72
112995	30000	12.54	7.62	489	0.2	79.3	8.43
112995	33000	12.46	7.69	484	0.2	89.0	9.48
112995	40000	12.41	7.72	480	0.2	84.6	9.01
112995	43000	12.31	7.75	477	0.2	92.7	9.90
112995	50000	12.25	7.76	475	0.2	86.5	9.25
112995	53000	12.18	7.77	474	0.2	92.5	9.91
112995	60000	12.10	7.75	472	0.2	87.5	9.39
112995	63000	12.08	7.75	473	0.2	92.7	9.96
112995	70000	12.05	7.68	478	0.2	81.3	8.74
112995	73000	12.10	7.62	486	0.2	84.0	9.01
112995	80000	12.15	7.59	491	0.2	74.7	8.01
112995	83000	12.22	7.55	497	0.3	78.4	8.40
112995	90000	12.38	7.50	511	0.3	67.5	7.20
112995	93000	12.33	7.50	510	0.3	75.2	8.03
112995	100000	12.43	7.48	518	0.3	67.8	7.22
112995	103000	12.51	7.49	524	0.3	74.5	7.92
112995	110000	12.63	7.50	530	0.3	68.5	7.26
112995	113000	12.76	7.50	536	0.3	75.8	8.01
112995	120000	12.79	7.50	538	0.3	69.2	7.31
112995	123000	12.77	7.49	538	0.3	74.2	7.85
112995	130000	12.79	7.48	539	0.3	67.2	7.10
112995	133000	12.76	7.49	535	0.3	73.8	7.81
112995	140000	12.74	7.50	528	0.3	68.9	7.29
112995	143000	12.71	7.52	522	0.3	76.2	8.07
112995	150000	12.90	7.66	512	0.3	82.0	8.65
112995	153000	12.97	7.84	505	0.3	98.9	10.41
112995	160000	13.04	8.03	497	0.3	101.9	10.71
112995	163000	13.09	8.25	491	0.2	116.8	12.26
112995	170000	13.04	8.06	493	0.2	102.4	10.76
112995	173000	12.99	7.98	490	0.2	107.0	11.26
112995	180000	12.94	8.05	485	0.2	102.7	10.82
112995	183000	12.86	8.02	484	0.2	106.4	11.23
112995	190000	12.87	7.99	484	0.2	98.3	10.37
112995	193000	12.87	7.98	488	0.2	104.7	11.05

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond uS/cm	Salin ppt	DO %Sat	DO mg/l
112995	200000	12.89	8.01	489	0.2	99.8	10.52
112995	203000	12.87	7.91	494	0.2	102.3	10.79
112995	210000	12.86	7.76	504	0.3	87.6	9.25
112995	213000	12.84	7.66	512	0.3	88.3	9.32
112995	220000	12.84	7.62	515	0.3	80.0	8.44
112995	223000	12.82	7.60	521	0.3	83.6	8.83
112995	230000	12.87	7.54	529	0.3	73.7	7.78
112995	233000	12.79	7.55	521	0.3	81.4	8.60
113095	0	12.86	7.51	532	0.3	72.4	7.63

Figure 5. Dissolved oxygen measurements in Smith Canal from 3 to 6 December 1995.

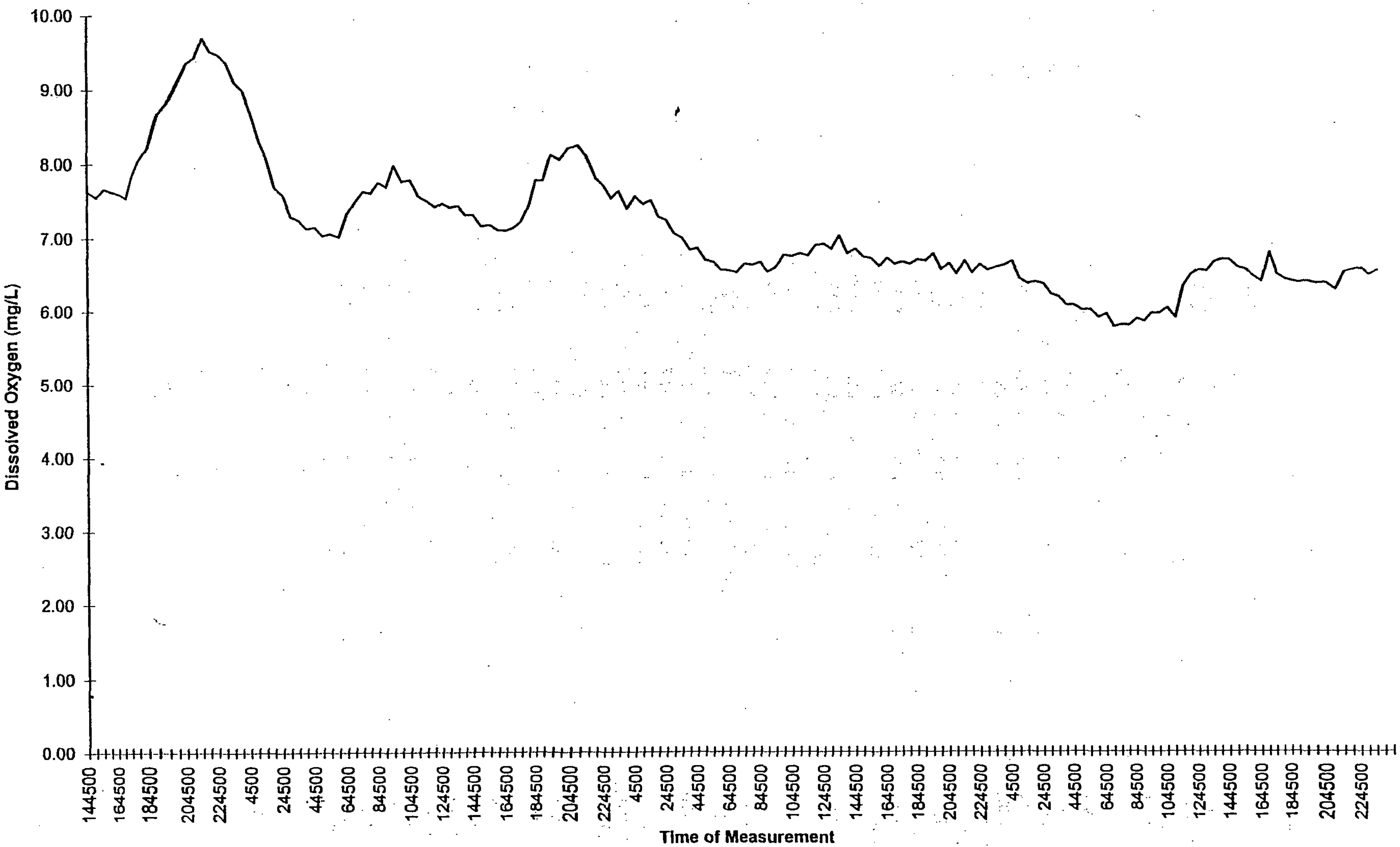


Table 5. Summary of water quality parameters measured in Smith Canal from 3 to 6 December 1995.

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond uS/cm	Salin ppt	DO %Sat	DO mg/l
120395	144500	12.71	7.22	563	0.3	72.1	7.63
120395	151500	12.67	7.24	559	0.3	71.3	7.55
120395	154500	12.72	7.24	564	0.3	72.4	7.66
120395	161500	12.79	7.24	570	0.3	72.1	7.62
120395	164500	12.71	7.24	559	0.3	71.8	7.60
120395	171500	12.66	7.25	552	0.3	71.1	7.54
120395	174500	12.64	7.28	544	0.3	74.0	7.85
120395	181500	12.64	7.31	540	0.3	75.9	8.05
120395	184500	12.64	7.33	536	0.3	77.4	8.20
120395	191500	12.64	7.37	530	0.3	81.6	8.65
120395	194500	12.66	7.39	529	0.3	83.2	8.81
120395	201500	12.66	7.44	522	0.3	85.7	9.09
120395	204500	12.61	7.46	517	0.3	88.1	9.35
120395	211500	12.61	7.49	514	0.3	88.9	9.43
120395	214500	12.58	7.52	510	0.3	91.2	9.69
120395	221500	12.54	7.50	508	0.3	89.5	9.51
120395	224500	12.49	7.49	505	0.3	88.9	9.46
120395	231500	12.46	7.47	504	0.3	87.9	9.36
120395	234500	12.53	7.43	509	0.3	85.5	9.09
120495	1500	12.54	7.42	509	0.3	84.5	8.98
120495	4500	12.61	7.37	517	0.3	81.8	8.67
120495	11500	12.64	7.34	524	0.3	78.4	8.31
120495	14500	12.67	7.30	529	0.3	76.1	8.06
120495	21500	12.71	7.27	537	0.3	72.4	7.67
120495	24500	12.71	7.25	540	0.3	71.6	7.58
120495	31500	12.74	7.23	547	0.3	69.0	7.29
120495	34500	12.74	7.22	547	0.3	68.4	7.24
120495	41500	12.76	7.22	549	0.3	67.4	7.13
120495	44500	12.74	7.21	554	0.3	67.6	7.15
120495	51500	12.77	7.21	552	0.3	66.6	7.03
120495	54500	12.76	7.20	550	0.3	66.8	7.06
120495	61500	12.74	7.20	546	0.3	66.4	7.02
120495	64500	12.67	7.23	534	0.3	69.2	7.33
120495	71500	12.64	7.26	526	0.3	70.6	7.49
120495	74500	12.64	7.26	523	0.3	71.9	7.62
120495	81500	12.63	7.27	520	0.3	71.7	7.60
120495	84500	12.61	7.28	517	0.3	72.9	7.74
120495	91500	12.61	7.28	516	0.3	72.4	7.68
120495	94500	12.59	7.30	512	0.3	75.1	7.97
120495	101500	12.69	7.28	516	0.3	73.3	7.76
120495	104500	12.79	7.28	522	0.3	73.6	7.78
120495	111500	12.90	7.27	530	0.3	71.7	7.56
120495	114500	12.99	7.25	540	0.3	71.3	7.50
120495	121500	13.04	7.25	546	0.3	70.6	7.42
120495	124500	13.10	7.24	554	0.3	71.2	7.47
120495	131500	13.10	7.25	548	0.3	70.7	7.42
120495	134500	13.20	7.24	558	0.3	71.0	7.44
120495	141500	13.22	7.23	563	0.3	69.9	7.31
120495	144500	13.27	7.23	569	0.3	70.1	7.32
120495	151500	13.27	7.21	572	0.3	68.6	7.17
120495	154500	13.30	7.21	574	0.3	68.7	7.18
120495	161500	13.35	7.20	579	0.3	68.2	7.12
120495	164500	13.30	7.21	569	0.3	68.1	7.11
120495	171500	13.35	7.22	572	0.3	68.6	7.15
120495	174500	13.30	7.22	563	0.3	69.2	7.23
120495	181500	13.32	7.26	554	0.3	71.3	7.44
120495	184500	13.33	7.28	547	0.3	74.5	7.78
120495	191500	13.32	7.29	544	0.3	74.6	7.78
120495	194500	13.33	7.32	538	0.3	77.8	8.12

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond uS/cm	Salin ppt	DO %Sat	DO mg/l
120495	201500	13.33	7.32	535	0.3	77.2	8.06
120495	204500	13.33	7.32	531	0.3	78.6	8.20
120495	211500	13.23	7.33	523	0.3	78.7	8.24
120495	214500	13.17	7.30	522	0.3	77.2	8.08
120495	221500	13.12	7.28	522	0.3	74.4	7.81
120495	224500	13.07	7.26	519	0.3	73.4	7.71
120495	231500	13.00	7.26	519	0.3	71.7	7.54
120495	234500	12.97	7.23	517	0.3	72.5	7.63
120595	1500	12.95	7.24	517	0.3	70.3	7.40
120595	4500	12.94	7.24	518	0.3	71.8	7.56
120595	11500	12.95	7.24	519	0.3	70.8	7.46
120595	14500	13.00	7.24	524	0.3	71.4	7.51
120595	21500	13.05	7.23	533	0.3	69.4	7.29
120595	24500	13.10	7.22	539	0.3	69.0	7.24
120595	31500	13.10	7.21	541	0.3	67.3	7.06
120595	34500	13.09	7.20	541	0.3	66.7	7.00
120595	41500	13.12	7.18	550	0.3	65.2	6.84
120595	44500	13.12	7.18	546	0.3	65.4	6.86
120595	51500	13.14	7.17	553	0.3	63.9	6.70
120595	54500	13.14	7.16	550	0.3	63.7	6.68
120595	61500	13.17	7.17	559	0.3	62.7	6.57
120595	64500	13.15	7.17	554	0.3	62.6	6.56
120595	71500	13.12	7.17	547	0.3	62.2	6.53
120595	74500	13.10	7.17	539	0.3	63.4	6.65
120595	81500	13.09	7.18	535	0.3	63.2	6.63
120595	84500	13.09	7.17	532	0.3	63.5	6.67
120595	91500	13.07	7.17	529	0.3	62.3	6.54
120595	94500	13.09	7.15	526	0.3	62.9	6.60
120595	101500	13.18	7.19	530	0.3	64.7	6.77
120595	104500	13.23	7.18	530	0.3	64.5	6.75
120595	111500	13.25	7.19	530	0.3	64.9	6.79
120595	114500	13.35	7.18	541	0.3	64.7	6.76
120595	121500	13.45	7.19	548	0.3	66.3	6.90
120595	124500	13.48	7.19	554	0.3	66.5	6.92
120595	131500	13.53	7.19	557	0.3	65.9	6.85
120595	134500	13.58	7.20	560	0.3	67.7	7.03
120595	141500	13.58	7.19	562	0.3	65.4	6.79
120595	144500	13.65	7.18	571	0.3	66.1	6.85
120595	151500	13.65	7.18	574	0.3	65.0	6.74
120595	154500	13.66	7.18	581	0.3	64.8	6.72
120595	161500	13.68	7.17	579	0.3	63.9	6.62
120595	164500	13.71	7.17	584	0.3	65.0	6.73
120595	171500	13.73	7.18	581	0.3	64.2	6.65
120595	174500	13.73	7.18	576	0.3	64.6	6.68
120595	181500	13.71	7.18	567	0.3	64.3	6.65
120595	184500	13.68	7.18	557	0.3	64.8	6.71
120595	191500	13.65	7.18	554	0.3	64.5	6.69
120595	194500	13.63	7.18	550	0.3	65.5	6.79
120595	201500	13.61	7.18	550	0.3	63.4	6.58
120595	204500	13.56	7.17	544	0.3	64.2	6.66
120595	211500	13.53	7.18	540	0.3	62.8	6.52
120595	214500	13.45	7.18	533	0.3	64.3	6.69
120595	221500	13.41	7.17	532	0.3	62.6	6.53
120595	224500	13.35	7.17	529	0.3	63.7	6.65
120595	231500	13.32	7.18	526	0.3	62.9	6.57
120595	234500	13.28	7.18	525	0.3	63.3	6.61
120695	1500	13.25	7.17	522	0.3	63.5	6.64
120695	4500	13.22	7.17	522	0.3	63.9	6.69
120695	11500	13.17	7.15	525	0.3	61.6	6.45
120695	14500	13.18	7.15	529	0.3	61.0	6.38
120695	21500	13.20	7.16	530	0.3	61.3	6.41
120695	24500	13.20	7.16	535	0.3	60.9	6.38
120695	31500	13.20	7.15	539	0.3	59.6	6.24

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond uS/cm	Salin ppt	DO %Sat	DO mg/l
120695	34500	13.23	7.14	545	0.3	59.3	6.20
120695	41500	13.22	7.13	551	0.3	58.1	6.09
120695	44500	13.20	7.13	551	0.3	58.2	6.09
120695	51500	13.23	7.14	559	0.3	57.5	6.02
120695	54500	13.20	7.13	559	0.3	57.6	6.03
120695	61500	13.22	7.13	563	0.3	56.6	5.92
120695	64500	13.20	7.13	565	0.3	57.0	5.97
120695	71500	13.22	7.13	565	0.3	55.4	5.79
120695	74500	13.17	7.11	559	0.3	55.6	5.82
120695	81500	13.12	7.12	553	0.3	55.4	5.81
120695	84500	13.10	7.12	544	0.3	56.3	5.90
120695	91500	13.10	7.13	542	0.3	56.0	5.87
120695	94500	13.10	7.13	538	0.3	57.0	5.98
120695	101500	13.15	7.13	538	0.3	57.1	5.98
120695	104500	13.27	7.14	540	0.3	57.9	6.05
120695	111500	13.25	7.12	540	0.3	56.6	5.92
120695	114500	13.33	7.16	541	0.3	60.8	6.35
120695	121500	13.53	7.18	549	0.3	62.7	6.51
120695	124500	13.60	7.18	558	0.3	63.4	6.58
120695	131500	13.66	7.18	562	0.3	63.3	6.56
120695	134500	13.73	7.17	568	0.3	64.6	6.68
120695	141500	13.88	7.19	574	0.3	65.2	6.72
120695	144500	13.83	7.18	573	0.3	65.0	6.71
120695	151500	13.84	7.18	573	0.3	64.1	6.61
120695	154500	13.88	7.17	588	0.3	63.8	6.58
120695	161500	13.88	7.17	586	0.3	62.9	6.49
120695	164500	13.88	7.16	592	0.3	62.3	6.42
120695	171500	13.98	7.19	594	0.3	66.2	6.81
120695	174500	13.93	7.17	589	0.3	63.3	6.52
120695	181500	13.91	7.17	586	0.3	62.6	6.45
120695	184500	13.86	7.17	575	0.3	62.2	6.42
120695	191500	13.78	7.17	563	0.3	62.0	6.40
120695	194500	13.74	7.17	559	0.3	62.1	6.42
120695	201500	13.73	7.17	556	0.3	61.8	6.39
120695	204500	13.73	7.17	555	0.3	61.9	6.40
120695	211500	13.71	7.17	552	0.3	60.9	6.30
120695	214500	13.69	7.18	547	0.3	63.1	6.54
120695	221500	13.68	7.19	543	0.3	63.5	6.57
120695	224500	13.66	7.18	541	0.3	63.6	6.59
120695	231500	13.66	7.18	539	0.3	62.8	6.50
120695	234500	13.65	7.18	536	0.3	63.3	6.56

Figure 6. Dissolved oxygen measurements in Smith Canal from 10 to 13 December 1995.

Table 6. Summary of water quality parameters measured in Smith Canal from 10 to 13 December 1995.

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond uS/cm	Salin ppt	DO %Sat	DO mg/l
121095	113500	13.17	6.84	575	0.3	39.9	4.18
121095	120500	13.17	6.84	572	0.3	40.6	4.25
121095	123500	13.18	6.85	570	0.3	42.6	4.46
121095	130500	13.20	6.87	571	0.3	41.0	4.29
121095	133500	13.22	6.87	571	0.3	42.8	4.48
121095	140500	13.23	6.86	572	0.3	40.9	4.27
121095	143500	13.28	6.87	579	0.3	44.9	4.69
121095	150500	13.30	6.89	584	0.3	44.5	4.64
121095	153500	13.30	6.88	591	0.3	46.5	4.86
121095	160500	13.30	6.89	596	0.3	44.6	4.65
121095	163500	13.30	6.88	598	0.3	45.8	4.79
121095	170500	13.30	6.89	604	0.3	44.7	4.66
121095	173500	13.32	6.88	612	0.3	47.2	4.93
121095	180500	13.32	6.88	615	0.3	45.0	4.70
121095	183500	13.30	6.88	613	0.3	46.3	4.84
121095	190500	13.28	6.88	612	0.3	44.3	4.63
121095	193500	13.28	6.87	611	0.3	46.0	4.81
121095	200500	13.23	6.88	608	0.3	44.6	4.66
121095	203500	13.25	6.86	605	0.3	45.1	4.71
121095	210500	13.20	6.87	597	0.3	42.6	4.45
121095	213500	13.20	6.86	593	0.3	43.3	4.54
121095	220500	13.17	6.87	588	0.3	41.4	4.34
121095	223500	13.17	6.87	587	0.3	42.9	4.49
121095	230500	13.17	6.88	586	0.3	40.5	4.24
121095	233500	13.15	6.86	582	0.3	42.2	4.42
121195	500	13.14	6.87	577	0.3	40.7	4.27
121195	3500	13.12	6.87	573	0.3	42.9	4.50
121195	10500	13.10	6.87	570	0.3	41.0	4.30
121195	13500	13.09	6.86	568	0.3	42.7	4.48
121195	20500	13.07	6.87	564	0.3	40.9	4.30
121195	23500	13.05	6.85	560	0.3	43.1	4.53
121195	30500	13.02	6.87	556	0.3	42.2	4.43
121195	33500	13.02	6.87	558	0.3	43.9	4.62
121195	40500	13.00	6.88	556	0.3	42.9	4.52
121195	43500	13.02	6.88	559	0.3	45.9	4.82
121195	50500	13.17	6.88	541	0.3	46.8	4.90
121195	53500	13.12	6.88	545	0.3	48.0	5.03
121195	60500	13.09	6.88	544	0.3	46.5	4.88
121195	63500	13.04	6.88	544	0.3	48.7	5.12
121195	70500	13.00	6.88	546	0.3	45.9	4.83
121195	73500	12.99	6.88	545	0.3	47.3	4.97
121195	80500	12.99	6.88	544	0.3	46.0	4.84
121195	83500	12.99	6.88	544	0.3	47.3	4.97
121195	90500	12.95	6.88	544	0.3	45.9	4.83
121195	93500	12.95	6.88	542	0.3	47.3	4.98
121195	100500	12.87	6.89	539	0.3	45.5	4.80
121195	103500	12.87	6.90	519	0.3	51.1	5.39
121195	110500	12.90	6.89	437	0.2	58.4	6.16
121195	113500	12.90	6.87	362	0.2	68.4	7.21
121195	120500	12.89	6.85	312	0.2	71.7	7.57
121195	123500	12.89	6.83	285	0.1	75.9	8.01
121195	130500	12.87	6.81	253	0.1	77.6	8.19
121195	133500	12.87	6.79	258	0.1	77.5	8.18
121195	140500	12.87	6.79	248	0.1	76.2	8.04
121195	143500	12.87	6.78	246	0.1	77.1	8.14
121195	150500	12.87	6.78	249	0.1	74.8	7.90
121195	153500	12.89	6.77	262	0.1	74.5	7.86
121195	160500	12.94	6.78	265	0.1	72.6	7.65
121195	163500	12.95	6.78	278	0.1	72.4	7.63

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond uS/cm	Salin ppt	DO %Sat	DO mg/l
121195	170500	12.94	6.79	294	0.1	68.9	7.26
121195	173500	12.94	6.77	284	0.1	70.3	7.41
121195	180500	12.92	6.77	292	0.1	67.4	7.11
121195	183500	12.94	6.78	318	0.2	65.2	6.87
121195	190500	12.94	6.78	334	0.2	62.1	6.54
121195	193500	12.92	6.79	346	0.2	63.3	6.67
121195	200500	12.92	6.78	341	0.2	60.8	6.41
121195	203500	12.92	6.75	327	0.2	62.4	6.58
121195	210500	12.89	6.69	272	0.1	63.2	6.67
121195	213500	12.82	6.66	239	0.1	67.0	7.08
121195	220500	12.84	6.62	198	0.1	68.9	7.28
121195	223500	12.92	6.59	168	0.1	73.9	7.79
121195	230500	12.94	6.56	161	0.1	71.9	7.58
121195	233500	12.95	6.53	153	0.1	73.5	7.74
121295	500	12.97	6.53	136.4	0.1	74.5	7.85
121295	3500	12.99	6.51	129.8	0.1	76.2	8.03
121295	10500	12.99	6.49	121.2	0	75.1	7.91
121295	13500	12.97	6.46	120.5	0	75.3	7.94
121295	20500	12.97	6.46	110.1	0	75.5	7.96
121295	23500	12.97	6.42	119.5	0	72.9	7.68
121295	30500	12.94	6.42	108.5	0	73.5	7.75
121295	33500	12.94	6.40	107.5	0	73.5	7.75
121295	40500	12.92	6.41	115	0	67.9	7.16
121295	43500	12.94	6.37	113.4	0	69.6	7.35
121295	50500	12.94	6.38	119.3	0	66.4	7.00
121295	53500	12.94	6.39	132.1	0.1	65.3	6.89
121295	60500	12.89	6.41	159	0.1	58.9	6.21
121295	63500	12.89	6.42	161	0.1	58.9	6.21
121295	70500	12.86	6.44	173	0.1	55.5	5.87
121295	73500	12.84	6.44	185	0.1	55.5	5.87
121295	80500	12.82	6.46	193	0.1	53.3	5.63
121295	83500	12.81	6.48	212	0.1	54.1	5.72
121295	90500	12.79	6.50	218	0.1	51.6	5.46
121295	93500	12.82	6.45	201	0.1	52.4	5.54
121295	100500	12.84	6.43	193	0.1	49.9	5.28
121295	103500	12.86	6.40	182	0.1	52.2	5.51
121295	110500	12.86	6.43	190	0.1	48.8	5.16
121295	113500	12.86	6.40	193	0.1	49.1	5.19
121295	120500	12.86	6.41	193	0.1	46.4	4.90
121295	123500	12.90	6.37	187	0.1	48.3	5.10
121295	130500	12.94	6.37	171	0.1	47.0	4.96
121295	133500	12.92	6.34	166	0.1	47.6	5.02
121295	140500	12.95	6.31	157	0.1	46.1	4.86
121295	143500	12.95	6.29	156	0.1	46.6	4.91
121295	150500	12.99	6.31	155	0.1	37.8	3.99
121295	153500	13.02	6.31	149	0.1	38.6	4.07
121295	160500	13.00	6.30	151	0.1	36.8	3.87
121295	163500	13.02	6.28	144.6	0.1	37.4	3.94
121295	170500	13.02	6.27	139.4	0.1	36.9	3.89
121295	173500	12.99	6.26	139.4	0.1	36.0	3.79
121295	180500	13.02	6.26	146.3	0.1	34.0	3.58
121295	183500	12.97	6.29	151	0.1	33.7	3.55
121295	190500	12.97	6.28	156	0.1	33.4	3.52
121295	193500	12.97	6.28	159	0.1	32.4	3.42
121295	200500	12.95	6.28	155	0.1	31.7	3.34
121295	203500	12.95	6.25	146	0.1	30.6	3.22
121295	210500	12.94	6.22	134	0.1	31.8	3.35
121295	213500	12.92	6.18	119.9	0	33.9	3.58
121295	220500	12.94	6.18	108.1	0	35.8	3.78
121295	223500	12.94	6.15	99.4	0	37.0	3.90
121295	230500	12.97	6.13	92.5	0	37.7	3.97
121295	233500	12.99	6.11	88.1	0	37.9	4.00
121395	500	13.00	6.09	84	0	38.5	4.06

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond uS/cm	Salin ppt	DO %Sat	DO mg/l
121395	3500	13.04	6.08	79.3	0	40.1	4.22
121395	10500	13.09	6.06	75.4	0	40.5	4.25
121395	13500	13.12	6.04	72.2	0	41.4	4.35
121395	20500	13.15	6.05	70.3	0	42.1	4.42
121395	23500	13.15	6.05	69.9	0	41.5	4.36
121395	30500	13.15	6.05	70.2	0	40.4	4.24

Figure 7. Dissolved oxygen measurements in Smith Canal from 15 to 18 December 1995.

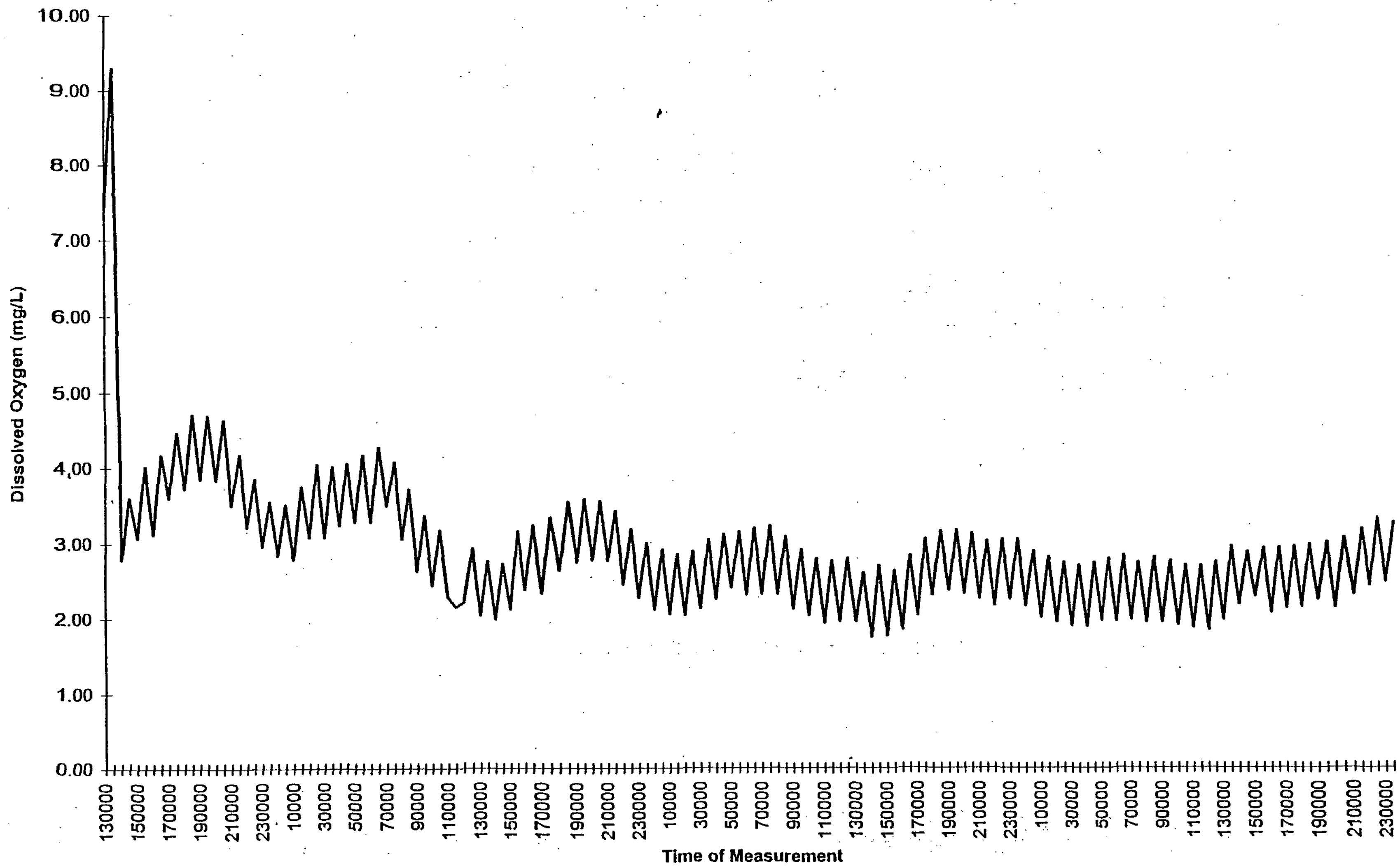


Table 7. Summary of water quality parameters measured in Smith Canal from 15 to 19 December 1995.

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond uS/cm	Salin ppt	DO %Sat	DO mg/l
121595	130000	16.79	8.23	512	0.3	76.5	7.41
121595	133000	18.01	8.21	514	0.3	98.4	9.30
121595	140000	12.35	6.67	79.7	0	26.1	2.79
121595	143000	12.41	6.37	77.9	0	33.8	3.61
121595	150000	12.43	6.38	75.3	0	28.9	3.08
121595	153000	12.43	6.39	74.9	0	37.7	4.02
121595	160000	12.43	6.39	74.6	0	29.3	3.13
121595	163000	12.41	6.39	73.8	0	39.1	4.17
121595	170000	12.41	6.37	72.2	0	33.8	3.61
121595	173000	12.40	6.38	71.4	0	41.9	4.47
121595	180000	12.36	6.37	71.1	0	34.9	3.73
121595	183000	12.35	6.38	69.9	0	44.0	4.71
121595	190000	12.30	6.40	69.9	0	35.9	3.85
121595	193000	12.28	6.40	69.9	0	43.8	4.69
121595	200000	12.25	6.37	69.8	0	35.8	3.84
121595	203000	12.23	6.37	70	0	43.2	4.64
121595	210000	12.20	6.37	72	0	32.8	3.51
121595	213000	12.22	6.38	74	0	38.9	4.17
121595	220000	12.18	6.39	74.7	0	30.0	3.22
121595	223000	12.17	6.42	75.9	0	35.9	3.85
121595	230000	12.15	6.40	76.8	0	27.6	2.96
121595	233000	12.12	6.40	79.2	0	33.1	3.55
121695	0	12.05	6.39	77.6	0	26.4	2.84
121695	3000	12.03	6.39	78.8	0	32.7	3.52
121695	10000	12.03	6.37	77.6	0	26.0	2.79
121695	13000	12.00	6.37	75.3	0	34.8	3.75
121695	20000	11.95	6.36	73.6	0	28.5	3.08
121695	23000	11.90	6.37	72.5	0	37.4	4.04
121695	30000	11.87	6.38	72.7	0	28.5	3.08
121695	33000	11.81	6.36	72.4	0	37.0	4.01
121695	40000	11.76	6.36	71.7	0	29.9	3.24
121695	43000	11.72	6.37	71.2	0	37.3	4.05
121695	50000	11.66	6.36	70.6	0	30.3	3.29
121695	53000	11.58	6.37	70.3	0	38.3	4.16
121695	60000	11.53	6.36	71.4	0	30.2	3.29
121695	63000	11.48	6.41	69.9	0	39.2	4.27
121695	70000	11.38	6.37	69.7	0	32.0	3.50
121695	73000	11.36	6.37	71.2	0	37.2	4.07
121695	80000	11.40	6.37	73.6	0	28.0	3.06
121695	83000	11.40	6.40	75.5	0	34.0	3.71
121695	90000	11.43	6.39	78.4	0	24.0	2.63
121695	93000	11.41	6.39	79.8	0	30.8	3.37
121695	100000	11.43	6.40	82.1	0	22.4	2.44
121695	103000	11.46	6.40	84	0	29.1	3.18
121695	110000	11.54	6.41	86.6	0	21.0	2.29
121695	113000	11.59	6.43	88.3	0	19.8	2.15
121695	120000	11.61	6.44	89.5	0	20.3	2.21
121695	123000	11.61	6.46	89.6	0	27.0	2.93
121695	130000	11.63	6.46	92	0	18.8	2.04
121695	133000	11.63	6.46	94.7	0	25.4	2.76
121695	140000	11.64	6.41	91.1	0	18.3	1.99
121695	143000	11.64	6.41	91.5	0	25.1	2.73
121695	150000	11.66	6.41	87.8	0	19.6	2.13
121695	153000	11.63	6.41	85.7	0	29.1	3.16
121695	160000	11.63	6.41	84.2	0	21.9	2.38
121695	163000	11.59	6.43	83.5	0	29.8	3.24
121695	170000	11.56	6.42	84.1	0	21.5	2.34
121695	173000	11.49	6.40	79.5	0	30.7	3.34
121695	180000	11.41	6.38	77	0	24.2	2.64

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond uS/cm	Salin ppt	DO %Sat	DO mg/l
121695	183000	11.31	6.38	75	0	32.4	3.55
121695	190000	11.25	6.37	74.4	0	25.1	2.75
121695	193000	11.17	6.38	74.2	0	32.7	3.59
121695	200000	11.13	6.37	73.7	0	25.3	2.78
121695	203000	11.10	6.42	73.9	0	32.4	3.56
121695	210000	11.09	6.38	72.9	0	25.2	2.77
121695	213000	11.05	6.40	75.3	0	31.1	3.43
121695	220000	11.04	6.40	78.1	0	22.3	2.46
121695	223000	11.07	6.41	79.6	0	29.0	3.19
121695	230000	11.10	6.40	82.1	0	20.7	2.28
121695	233000	11.12	6.44	85	0	27.3	3.00
121795	0	11.12	6.44	86.4	0	19.3	2.12
121795	3000	11.07	6.44	88.6	0	26.4	2.91
121795	10000	11.09	6.47	89.6	0	18.8	2.06
121795	13000	11.07	6.43	89.2	0	25.9	2.85
121795	20000	10.99	6.43	88.1	0	18.5	2.04
121795	23000	10.94	6.41	86.4	0	26.1	2.88
121795	30000	10.85	6.39	82.9	0	19.2	2.13
121795	33000	10.74	6.41	80.6	0	27.4	3.04
121795	40000	10.64	6.40	79.5	0	20.3	2.26
121795	43000	10.58	6.40	78.6	0	28.1	3.12
121795	50000	10.51	6.40	76.3	0	21.6	2.41
121795	53000	10.46	6.39	77.4	0	28.2	3.15
121795	60000	10.40	6.39	76.8	0	20.7	2.31
121795	63000	10.33	6.40	75.7	0	28.6	3.20
121795	70000	10.25	6.41	76.6	0	20.7	2.32
121795	73000	10.22	6.39	75	0	28.8	3.23
121795	80000	10.15	6.39	76.4	0	20.6	2.32
121795	83000	10.17	6.41	79.2	0	27.5	3.09
121795	90000	10.22	6.42	82.8	0	19.0	2.13
121795	93000	10.32	6.43	85.4	0	26.0	2.91
121795	100000	10.36	6.43	87.6	0	18.2	2.04
121795	103000	10.53	6.46	93.1	0	25.1	2.79
121795	110000	10.58	6.44	95.8	0	17.5	1.94
121795	113000	10.68	6.47	99.7	0	24.9	2.76
121795	120000	10.77	6.48	103.9	0	17.7	1.96
121795	123000	10.84	6.50	106.7	0	25.2	2.79
121795	130000	10.84	6.50	107.7	0	17.7	1.96
121795	133000	10.84	6.52	110.9	0	23.5	2.60
121795	140000	10.86	6.51	109.6	0	15.8	1.75
121795	143000	10.87	6.49	107.3	0	24.4	2.70
121795	150000	10.84	6.47	106.7	0	16.0	1.77
121795	153000	10.77	6.45	100.9	0	23.7	2.63
121795	160000	10.76	6.46	98.4	0	16.7	1.85
121795	163000	10.76	6.47	93.1	0	25.6	2.83
121795	170000	10.73	6.46	92.4	0	18.4	2.04
121795	173000	10.77	6.44	86.5	0	27.6	3.05
121795	180000	10.77	6.42	84.7	0	20.8	2.31
121795	183000	10.77	6.43	83.1	0	28.6	3.16
121795	190000	10.76	6.41	81.5	0	21.4	2.37
121795	193000	10.73	6.42	81.5	0	28.6	3.17
121795	200000	10.71	6.42	81.6	0	21.0	2.33
121795	203000	10.66	6.42	80.9	0	28.2	3.13
121795	210000	10.63	6.42	81	0	20.3	2.26
121795	213000	10.58	6.46	82.2	0	27.2	3.03
121795	220000	10.55	6.41	80.6	0	19.5	2.17
121795	223000	10.51	6.43	80.7	0	27.4	3.05
121795	230000	10.53	6.43	82.7	0	20.2	2.25
121795	233000	10.53	6.43	83.8	0	27.4	3.05
121895	0	10.53	6.44	86	0	19.3	2.16
121895	3000	10.55	6.48	89.5	0	25.9	2.89
121895	10000	10.55	6.48	94.4	0	18.0	2.01
121895	13000	10.50	6.48	94.6	0	25.2	2.81

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond uS/cm	Salin ppt	DO %Sat	DO mg/l
121895	20000	10.50	6.47	94.9	0	17.5	1.95
121895	23000	10.48	6.50	95.3	0	24.5	2.74
121895	30000	10.48	6.47	96.6	0	17.1	1.90
121895	33000	10.51	6.49	105.8	0	24.2	2.70
121895	40000	10.46	6.46	97.9	0	16.9	1.89
121895	43000	10.44	6.46	93.2	0	24.5	2.74
121895	50000	10.40	6.44	89.7	0	17.7	1.97
121895	53000	10.38	6.44	87.8	0	25.0	2.79
121895	60000	10.37	6.45	87.8	0	17.5	1.96
121895	63000	10.35	6.43	86.6	0	25.3	2.83
121895	70000	10.32	6.42	86.9	0	17.7	1.98
121895	73000	10.31	6.44	87	0	24.4	2.74
121895	80000	10.30	6.42	85.2	0	17.4	1.95
121895	83000	10.27	6.44	86.1	0	25.0	2.81
121895	90000	10.31	6.46	87.8	0	17.4	1.95
121895	93000	10.35	6.48	91.5	0	24.7	2.76
121895	100000	10.37	6.48	94.7	0	17.1	1.91
121895	103000	10.40	6.51	99.7	0	24.1	2.70
121895	110000	10.48	6.53	108.3	0	16.8	1.87
121895	113000	10.50	6.52	114.7	0	24.1	2.69
121895	120000	10.48	6.52	110.2	0	16.5	1.84
121895	123000	10.51	6.54	120.4	0	24.6	2.75
121895	130000	10.56	6.57	128.3	0.1	17.8	1.98
121895	133000	10.64	6.61	144.6	0.1	26.6	2.96
121895	140000	10.66	6.62	151	0.1	19.6	2.18
121895	143000	10.62	6.59	143.1	0.1	25.9	2.88
121895	150000	10.68	6.60	153	0.1	20.6	2.29
121895	153000	10.61	6.57	134.9	0.1	26.3	2.93
121895	160000	10.55	6.54	122.7	0.1	18.6	2.07
121895	163000	10.51	6.54	114.5	0	26.4	2.94
121895	170000	10.46	6.51	108.4	0	19.1	2.13
121895	173000	10.46	6.51	103.4	0	26.5	2.96
121895	180000	10.43	6.49	102.7	0	19.2	2.15
121895	183000	10.40	6.50	101	0	26.7	2.98
121895	190000	10.32	6.46	91	0	20.1	2.25
121895	193000	10.28	6.46	89.9	0	26.9	3.01
121895	200000	10.27	6.46	90.1	0	19.1	2.14
121895	203000	10.24	6.47	88.6	0	27.3	3.07
121895	210000	10.27	6.45	88.8	0	20.6	2.31
121895	213000	10.28	6.47	88.8	0	28.5	3.19
121895	220000	10.32	6.47	89.1	0	21.7	2.43
121895	223000	10.33	6.46	89.5	0	29.7	3.33
121895	230000	10.30	6.49	89.1	0	22.1	2.48
121895	233000	10.28	6.49	89	0	29.2	3.27
121995	0	10.24	6.48	91.8	0	21.0	2.36

CDM Camp Dresser & McKee

Technical Memorandum

Assessment of Water Quality Data From Smith Canal

July 27, 1999

Prepared for:

City of Stockton
Stormwater Division
2500 Navy Drive
Stockton, CA 95206

San Joaquin County
Department of Public Works/Stormwater
1810 E. Hazelton Avenue
Stockton, CA 95205

Prepared by:

Camp Dresser & McKee Inc.
2151 River Plaza Drive, Suite 200
Sacramento, CA 95833

APPENDIX B-2

Technical Memorandum
Assessment of Water Quality Data From Smith Canal

1.0 Introduction

1.1 Overview of Program

A series of water quality monitoring studies were conducted in the Smith Canal to identify the causes of the observed water quality problems in the Canal. The water quality in the Smith Canal has been reported to be poor, especially after wet-weather events. Both continuous monitoring and grab sampling were performed at selected locations. This technical memorandum presents the results of an analysis conducted on monitoring data. The analysis was conducted in order to gain further insight into the occurrence and causes of low dissolved oxygen (DO) levels and other water quality problems within the Canal.

1.2 Background

The Smith Canal is a dead-end slough with its confluence at the San Joaquin River. The Canal receives inflow from storm water discharges generated in the surrounding urban areas of Stockton during wet-weather events, along with tidal inflows from the San Joaquin River, groundwater, and rain falling directly in the Canal.

Dead-end sloughs or canals are very susceptible to water quality problems, particularly low DO levels. Without a significant inflow of clean water to flush out the system, any pollutant carried in is allowed to exert its influence for an extended period of time. The settleable fractions of these pollutants will be susceptible to periodic re-suspension resulting from surges of storm water inflows. This is probably true for the Smith Canal.

The water quality in Smith Canal was monitored at five locations. At two of these locations, continuous water quality meters were installed for a period of one year, starting in October of 1997. Measurements were collected every 20 minutes for water depth, water temperature, DO, specific conductivity, and turbidity. Two sets of grab samples from the water column were collected at thee stations on a single day and analyzed for several pollutants and indicator parameters.

A recent modeling study of Smith Canal concluded the observed DO depressions were caused from the oxygen demand exerted from organic material generated during rain events. The primary sources of this organic material were storm water loads and the re-suspension of both bottom sediments in Smith Canal and sediments deposited in the storm sewers. For one storm event, the modeling found the DO levels recovered within five days following a rain event. The upstream terminal point of the Canal experienced the worst water quality impacts, while the impacts decreased in the downstream portions as the Canal neared its confluence with the San Joaquin River.

1.3 Memorandum Organization

This memorandum is organized as follows:

- Section 2 discusses the existing database and modifications that were performed to the database for this study.
- Section 3 summarizes the assessment of the field data performed for this study.
- Section 4 presents conclusions.

Appendices contain the following additional information summarizing the analyses of the water quality data from the Smith Canal:

- Appendix A includes summary tables of continuous water quality data.
- Appendix B includes box and whisker plots summarizing continuous water quality data.
- Appendix C includes frequency of occurrence graphs for selected parameters.
- Appendix D provides time series plots of data from the Pershing Avenue Bridge station.
- Appendix E provides time series plots of data from the Smith Canal Pedestrian Bridge station.

2.0 Field Data

2.1 Continuous Water Quality Data

Continuous recording water quality meters were installed for a period of one year at two locations along the Smith Canal. The first location was at the Pershing Avenue Bridge and the second location was at the pedestrian bridge that crosses Smith Canal just downstream of Interstate 5. The Pershing Avenue station represents water quality conditions in the upper portion of the Canal and the Smith Canal Pedestrian Bridge station represents conditions in the lower portion of the Canal.

Both meters were installed in October of 1997. Measurements were collected every 20 minutes for water depth, water temperature, DO levels, specific conductivity, and turbidity. More than 20,000 measurements were collected for each parameter at each station over the 12 month monitoring period.

The meters were serviced every two to four weeks based on a review of the data. The servicing appeared to include uploading the recorded data, along with cleaning and re-calibrating the units. The data were entered into a database maintained by the City of Stockton.

The database of the continuous water quality data provided to CDM from the City of Stockton appeared to contain only the raw data collected from the continuous monitors. No evidence was found in the database that quality assurance or quality control (QA/QC) procedures had been erformed on the data after the data had been entered into the database. None of the data provided had been flagged to identified their quality.

CDM did perform cursory QA/QC checks on the data but not a detailed review as directed by the City. These checks discovered some problems in the database and several modifications were performed. The problems and resulting modifications included:

1. After May 17, 1998, the database listed field measurements in categories for other parameters. For example, the depth measurements were included under the pH category and DO measurements were included under the water depth category. DO, water depth, pH, and turbidity were all affected. Consequently, the data after this point made little sense.

   To correct this problem, all the data after May 17, 1998 that were listed under DO were re-classified as turbidity data. Depth data were re-classified as DO data, pH data were re-classified as depth data, and turbidity data were re-classified as pH data.

2. The data recorded during the times when the monitors were serviced and re-calibrated were included in the database on several occasions. These data were removed from the database for this study because they did not represent water quality conditions in Smith Canal. For example, portions of the data recorded on June 18, 1998 and August 20, 1998 were removed.

3. All data with negative values were not included in the database used for this study. Negative values were probably the result of calibration drift.

4. A review of time series plots revealed additional data that did not match trends found in both previous and future data at the same station. These data were also removed from the database for this study. These data included:

   - Water depth and specific conductivity data from the Smith Canal Pedestrian Bridge station for the period of November 20, 1997 to December 5, 1997;
   - DO, water depth, and specific conductivity data from the Pershing Avenue Bridge station for the period of November 20, 1997 to December 5, 1997;
   - Water depth data from the Smith Canal Pedestrian Bridge and Pershing Avenue Bridge stations for the period of December 18, 1997 to January 8, 1998; and
   - DO data from the Pershing Avenue Bridge station for the period of March 13, 1998 to March 28, 1998.

5. Trends in the specific conductivity data were highly variable throughout the monitoring period at both stations. Conductivity varied between 100 to 700 umhos/cm. This is a very wide range for conductivity in a river system. Although most of the data were included in the analysis for this study, the overall quality of these data were suspect.

6. Other discrepancies were found in the dataset, especially in the DO data. On occasion, the trends in the recorded data would change over time or after the meter had been serviced. The data were included in the dataset for this study. Standard quality assurance and quality control procedures must be implemented during all field monitoring programs to ensure quality and all data flagged to identify problems.

2.2 Other Water Quality Data

Water quality data from one round of dry weather sampling was provided for this study. This survey included three stations located on Smith Canal: SC-57 at Legion Park, SC-56 at Buena Vista Avenue, and SC-55 at Shirmuzu and Ryde Avenue. The survey was conducted on July 22, 1998 and samples were analyzed for total copper, MBAS, and total phenols. Field measurements were performed for pH, water temperature, and chlorine. Samples from SC-56 were also analyzed for cadmium, chromium, nickel, and lead, and specific conductivity. None of the data provided had been flagged to identify any quality assurance or quality control problems.

2.3 Precipitation

Precipitation data from the National Weather Service station located at Stockton Municipal Airport were used to represent local conditions at Smith Canal for this study. Continuous hourly precipitation record for the period of October 1997 to October 1998 was compiled from data published by the National Climatic Data Center.

3.0 Assessment of Water Quality Conditions

3.1 Methodology

The first step in the analysis of the continuous water quality data was to combine the hourly precipitation records with the water quality data. Time series plots were generated for the precipitation, DO, water temperature, water depth, pH, and specific conductivity data collected at both the Pershing Avenue and Smith Canal Pedestrian Bridge stations. Individual time series plots of each parameter were stacked together. Individual stacked plots each represent a one week period. A total of 52 stacked plots were generated for each station for the year long monitoring period.

Each weekly plot was reviewed and any problems in the data were noted. The database was modified based on the results of this review, as discussed in Section 2.1. The stacked plots were revised using the corrected database and printed once again. These final plots are included in Appendix D (Pershing Avenue station) and Appendix E (Smith Canal Pedestrian Bridge station).

The next step was to divide the continuous data into two categories representing dry and wet conditions. This was performed to assess the impacts that these conditions had on water quality. This was accomplished by reviewing the stacked plots for the occurrence of substantial rainfall amounts (e.g., greater than 0.1 inches over 12 hours). Responses of the various other parameters to the rainfall were also noted. Wet weather periods were classified as those periods where rainfall occurred and instream water quality remained clearly impacted. For example, a rainfall event might cause a drop in the DO concentrations or a rise in water depths. The wet-weather period was considered the period from the start of the rain event to the point in time when the DO or depth recovered back to near pre-event levels. Once all the wet-weather periods had been identified by date, the remaining periods of time were considered dry conditions.

water. This demand might come from sediment oxygen demand, decomposition of organic material, and plant respiration.

For most of the year, the water quality objectives for the San Joaquin, including Smith Canal, is 5.0 mg/L for DO. For the fall months of September through November, the objective increases to 6.0 mg/L. Figure C-3 indicates the reported DO levels at the Pershing Avenue station were below 5 mg/L for 50% of the time and below 6 mg/L for 65% of the time. Reported DO levels at the Smith Canal Pedestrian Bridge station were below 5 mg/L for 20% of the time and below 6 mg/L for 40% of the time. These results should only be viewed as possible trends due to the unknown quality of the data.

Specific conductivity levels were higher at the Smith Canal Pedestrian Bridge station than at the Pershing Avenue station. This difference might indicate an impact on water quality in the Canal from the tidal inflows coming up from the San Joaquin River.

Mean turbidity levels were higher at the Pershing Avenue station. However, the median values, minimum and maximum values, and typical ranges (25^{th} and 75^{th} percentiles) were more comparable between the two stations. The higher turbidity in the upper portion might be related to the considerable storm water loads this portion of the Canal receives during wet weather events. Water quality objectives for turbidity have been established at 150 NTUs for the San Joaquin River system. Table A-1 shows the turbidity at the Pershing Avenue Bridge station typically ranges between 20 and 60 NTUs and between 18 and 35 NTUs at the Smith Canal Pedestrian Bridge station. Peak levels did exceed the 150 NTU standard at both monitoring stations.

3.3 Seasonal Impacts

Analyzing the continuous data on a seasonal basis found differences in the water quality among the different periods of the year. Table A-2 in Appendix A summarizes the continuous data for each of the four quarters for the Pershing Avenue Bridge station. Table A-3 summarizes the continuous data for the Smith Canal Pedestrian Bridge station. A clearer understanding of season differences can be seen in the box and whisker plots presented in Appendix B. The figures show the distribution of data for each of the four seasons: October – December 1997 (Q4), January – March (Q1), April – June (Q2), and July – September (Q3). Figures B-1, B-2, and B-3 in Appendix B present data from the Pershing station and Figures B-4, B-5, B-6 present data from the Smith Canal Pedestrian Bridge station.

Figures B-1 and B-4 show the distribution of depth data. Both figures show a similar seasonal trend. Depths were lowest in the Q4 1997, increased during Q1 1998 and decreased during each of the next two quarters, Q2 1998 and Q3 1998. This trend followed typical seasonal flow patterns in California rivers. The highest flows occur during the winter and spring periods in response to rainfall and snow melt and the lowest flows occur in the summer and fall after the wet season and most of the snow had melted. Flow depths might be higher for this entire period in response to El Nino weather conditions that caused higher than usual rainfall and snowfall amounts.

The water temperatures followed expected seasonal trends at both continuous stations. The highest temperatures occurred in the summer (July – September) and the lowest temperatures during the winter season (January – March) as demonstrated in Figures B-2 and B-5 in Appendix B.

DO levels remained relatively equal for all four three-month periods at the Pershing Avenue station, as shown in Figure B-3. The mean values ranged from 4.1 to 5.4 mg/L. The group of data with the lowest overall values was from the October – December 1997 (Q4) period. The DO values varied more on a seasonal basis at the Smith Canal Pedestrian Bridge station. The lowest values occurred during the Q4 1997 period, as they had at the Pershing station. The highest values occurred during the period of April through June (Q2) 1998.

DO levels are expected to be higher during periods when the water temperature is cold and lower during period when the water is warm. The DO saturation level is temperature dependent and the colder the water, the more oxygen can be dissolved. Neither Figure B-3 nor Figure B-6 shows this trend in the Canal. The DO levels were also expected to be lower during the wet-weather season that ran from November 1997 to May 1998 (a portion of Q4, all of Q1, and a portion of Q2). During wet weather events, storm water runoff discharged to the Canal included an organic load that created an additional demand for the DO. This trend is not shown in either figure. Possibly, the increased demand for oxygen offset the higher DO saturation during colder temperatures.

The DO data from the Pershing Avenue station indicated DO levels might exceed the water quality objectives throughout the year. The mean DO values were below 5 mg/L for Q4 1997 and Q2 1998, while the mean values were only 5.4 mg/L for Q1 1998 and Q3 1998. Only data from Q4 1997 at the Smith Canal Pedestrian Bridge station had a mean value below 5 mg/L. For the rest of the year, mean values ranged from 7.2 to 8.9 mg/L.

The boxes in Figure B-3 are longer than the boxes in Figure B-6, which indicates the range of DO values from the Pershing Avenue station were more variable (e.g., lower low values and higher high values). This variation could be caused by higher photosynthetic activity in the portion of the Canal near the Pershing Avenue station.

During the day aquatic plants produce more oxygen through photosynthesis than they consume through respiration. DO levels increase during the day and peak in the late afternoon or early evening. At night, the plants produce no oxygen yet it continues to be consumed through plant respiration. This consumption reduces the level of oxygen throughout the night, with the lowest levels occurring near dawn. This daily fluctuation of DO, known as a diurnal, is a natural occurrence in most lake and river systems. However, wide the fluctuations in the daily DO (> 5 mg/L) can indicate excessive plant growth. Waterbodies located in urban areas are prone to excessive plant growth because the nutrients required by the plants are often carried in with the storm water. Therefore, the presence of a wide diurnal variation in the DO levels may be used to indicate a nuisance plant or nutrient loading problem.

Reviewing the time series plots in Appendices D and E, diurnal trends can be seen in the DO data at both continuous stations, not just at the Pershing Avenue station as indicated by the box plots. The diurnal variation was most prevalent for the period of April to September 1998 (pages 29 – 48 in Appendices D-3 and E-3), the period of most sunlight and higher temperatures. The diurnal variation peaked during June, July and August, the height of summer. The daily variation in the DO levels was as high as 10 mg/L at the Pershing Avenue station, if the meter was measuring the DO correctly. The peak variations were less at the Smith Canal Pedestrian Bridge station, peaking at 8 mg/L in a single day. These wide variations indicate the Canal supports a dense population of

A few individual rain events did provide an opportunity for the response of the water quality to be evaluated. These events occurred on November 10, 1997, March 23, 1998 and May 28, 1998. (Refer to pages 7, 26, and 35 in Appendices D-3 and E-3.)

Water quality in the Canal does respond to wet-weather events, but the responses tend to occur over a number of days, as opposed to a few hours. For example, the lowest DO levels occurred one to two days after the start of a rain event. A first flush response would cause a substantial change in a matter of hours. The quiescent conditions of the Canal might be the reason for this gradual response pattern. The only parameters to show a definite response to rain events were DO and specific conductivity. Also, the response at the Smith Canal Pedestrian Bridge station was less dramatic than at the Pershing Avenue Bridge station based on the recorded data. These are the same trends noted in the Smith Canal modeling study conducted for the City in 1998.

Water quality data from one round of dry weather sampling indicated very little. Each of the three stations was sampled twice on July 22, 1998, once in the morning and once in the afternoon. Most of the results for copper, total phenols, and field chlorine appeared to be below the reporting limits. Results of the field pH were within the range measured by the two continuous meters on the same day, 7.0 to 8.4. However, the field temperature readings were lower than the measurements recorded by the continuous meters. The water temperature recorded by the continuous monitors ranged from 26 to 29 °C. The grab measurements ranged from 23 to 26 °C. Results of the MBAS analyses ranged from 0.26 to 0.67 mg/L. The levels were comparable among the three stations. The additional metal analyses conducted at SC-58 did not detect any concentrations above the reporting limits for cadmium, chromium, nickel, and lead.

4.0 Conclusions

1. Results presented in this technical memorandum need to be qualified because the accuracy, precision, representativeness, completeness, and comparability of the data applied to this study has not been documented. How close the data represents the actual water quality conditions in Smith Canal is unknown. The City of Stockton and San Joaquin County should consider including a quality assurance and quality control component with all future field monitoring programs to ensure the quality of the data can be documented for all users.

2. The DO levels appeared to be consistently below the saturation level of oxygen in water. Such a trend indicates a greater demand is exerted on the oxygen than can be replaced through reaeration, photosynthesis, and inflow of oxygenated water. This demand may come from sediment oxygen demand, decomposition of organic material, and plant respiration.

3. The compiled data indicated DO levels were consistently lower at the upstream Pershing Avenue Bridge station than at the downstream Smith Canal Pedestrian Bridge station. DO levels at both stations appeared to drop below the water quality objective established for the San Joaquin River system of 5 mg/L for DO.

4. The large diurnal variations found in the DO data appear to indicate the Canal has an aquatic plant growth problem. Storm water discharges are probably a substantial source of the nutrients required to maintain these plants.

5. Expected differences in water quality were found between wet and dry conditions for water depth, temperature, pH, specific conductivity, and turbidity with water quality generally worse during wet weather.

6. The DO levels at the two continuous stations appeared to be lower during wet conditions than during dry conditions.

7. The El Nino weather pattern that occurred during the monitoring period increased the frequency and volume of wet weather events. Water quality in the Smith Canal was influenced by wet conditions for long periods of time, up to several weeks.

8. The response of water depth, temperature, and pH to wet weather events was gradual and could not be detected through visual observations of the time series plots. Statistical analyses indicated differences in the data between the two weather conditions.

9. The response of DO, specific conductivity, and turbidity to wet weather events also appeared to be gradual, but substantial enough to be observed in the time series plots. This gradual or slow response may be caused by the quiescent flow conditions in the Canal.

10. In general, results of the recent water quality modeling study of Smith Canal were similar to the data assessment presented in this technical memorandum. The water quality model was preliminarily calibrated to the first storm event (November 10, 1997) during the Smith Canal monitoring program. Therefore, the same water quality trends found in the data had to be simulated by the model in order to demonstrate the accuracy of the model. However, the modeling study only investigated water quality impacts during this single wet-weather event. Whereas, this data assessment also addressed water quality under dry weather conditions and a variety of wet weather events, seasonal variations in water quality, possible imbalances between oxygen demand and reaeration, and the wide diurnal variations in daily DO levels which indicated excessive plant growth and nutrient loading.

Table A-1
Summary Water Quality Measurements
at Pershing Avenue and Smith Canal Pedestrian Bridges
Full Monitoring Period

Station	Parameter	Temperature	Specific Conductivity	Dissolved Oxygen	Depth	pH	Turbidity
		(C)	(umhos/cm)	(mg/L)	(ft)	(SU)	(ntu)
Pershing	Mean	18	289	4.92	3.07	7.4	108
	Median	18	262	4.92	3.09	7.2	34
	Min	5	27	0.00	0.00	6.4	-2
	Max	33	709	15.1	7.65	9.2	1380
	Std. Dev.	7	153	2.78	1.31	0.6	245
	25th Percentile	12	197	2.77	2.13	6.9	20
	75th Percentile	24	355	6.90	3.99	7.8	60
	Count	23740	22750	21853	21221	23742.0	15704
Smith Canal Bridge	Mean	18	366	6.96	3.15	7.5	29
	Median	18	322	6.54	3.14	7.4	26
	Min	6	1	0.30	-0.05	6.8	-42
	Max	32	917	17.3	8.26	9.3	1310
	Std. Dev.	6	157	2.52	1.41	0.5	47
	25th Percentile	12	248	5.40	2.13	7.2	18
	75th Percentile	22	453	8.48	4.09	7.7	35
	Count	24141	23146	24157	23157	24137.0	16091

Table A-2
Statistics for Pershing Avenue Bridge Station
Seasonal Summary

Period	Parameter	Temperature	Specific Conductivity	Dissolved Oxygen	Depth	pH
		(C)	(umhos/cm)	(mg/L)	(ft)	(SU)
Q4 1997	Mean	14	428	4.17	2.18	7.3
	Median	14	552	4.05	2.23	7.0
	Min	5	82	0.00	-0.04	6.4
	Max	25	709	15.07	4.78	8.9
	Std. Dev.	5	200	2.90	1.13	0.6
	25th Percentile	11	222	1.81	1.27	6.8
	75th Percentile	18	602	6.09	3.11	7.7
	Count	6470	5480	5799	4507	6472.0
Q1 1998	Mean	13	170	5.37	3.94	7.0
	Median	12	150	5.15	3.95	6.9
	Min	7	35	0.03	0.87	6.5
	Max	20	467	10.16	7.65	8.8
	Std. Dev.	3	107	1.83	1.29	0.4
	25th Percentile	11	71	4.09	2.98	6.8
	75th Percentile	14	250	6.52	4.85	7.1
	Count	5853	5853	4669	5297	5853.0
Q2 1998	Mean	21	235	4.89	3.11	7.3
	Median	21	240	4.59	3.16	7.3
	Min	14	137	0.00	0.58	6.5
	Max	29	329	14.34	5.82	9.0
	Std. Dev.	3	35	3.19	1.10	0.5
	25th Percentile	18	210	2.20	2.31	6.9
	75th Percentile	23	261	7.36	3.95	7.6
	Count	6376	6376	6344	6376	6376.0
Q3 1998	Mean	27	343	5.43	2.93	7.9
	Median	28	322	5.55	2.95	7.9
	Min	20	244	0.10	0.47	6.7
	Max	33	449	14.71	5.65	9.2
	Std. Dev.	3	57	2.62	1.14	0.5
	25th Percentile	25	295	3.48	2.04	7.5
	75th Percentile	29	402	7.34	3.80	8.3
	Count	5010	5010	5010	5010	5010.0

Table A-3
Statistics for Smith Canal Pedestrian Bridge Station
Seasonal Summary

Period	Parameter	Temperature	Specific Conductivity	Dissolved Oxygen	Depth	pH
		(C)	(umhos/cm)	(mg/L)	(ft)	(SU)
Q4 1997	Mean	15	567	4.63	2.64	7.3
	Median	14	572	4.91	2.46	7.3
	Min	6	1	0.30	-0.05	6.8
	Max	25	917	9.99	8.06	8.5
	Std. Dev.	4	106	1.48	1.74	0.2
	25th Percentile	11	516	3.58	1.33	7.2
	75th Percentile	18	608	5.81	3.51	7.4
	Count	6435	5440	6431	5451	6431
Q1 1998	Mean	12	332	7.23	3.86	7.3
	Median	11	302	6.57	3.89	7.2
	Min	7	75	3.14	0.52	6.8
	Max	20	908	17.31	8.26	9.0
	Std. Dev.	3	164	2.24	1.29	0.4
	25th Percentile	11	221	5.84	2.93	7.1
	75th Percentile	13	373	8.61	4.75	7.4
	Count	6279	6279	6279	6279	6279
Q2 1998	Mean	19	255	8.92	3.13	7.7
	Median	19	259	8.80	3.19	7.5
	Min	14	196	2.81	0.47	6.9
	Max	28	328	16.15	5.78	9.3
	Std. Dev.	2	28	2.45	1.08	0.5
	25th Percentile	17	233	7.06	2.34	7.4
	75th Percentile	21	276	10.66	3.97	8.0
	Count	5498	5498	5498	5498	5498
Q3 1998	Mean	25	320	7.35	2.87	7.8
	Median	26	340	7.25	2.88	7.7
	Min	19	162	1.27	0.46	6.9
	Max	32	426	14.02	5.59	9.2
	Std. Dev.	2	72	1.70	1.13	0.5
	25th Percentile	24	253	6.24	1.98	7.4
	75th Percentile	27	379	8.34	3.76	8.2
	Count	5897	5897	5917	5897	5897

Table A-4
Summary Water Quality Measurements under Wet and Dry Conditions at Pershing Avenue Bridge Station

Period	Parameter	Temperature	Specific Conductivity	Dissolved Oxygen	Depth	pH	Turbidity
		(C)	*(umhos/cm)*	*(mg/L)*	*(ft)*	*(SU)*	*(ntu)*
Wet Weather	Mean	14	199	3.81	3.38	6.9	131
	Median	13	194	3.67	3.41	6.9	38
	Min	6	35	0.00	-0.04	6.4	-2
	Max	24	708	13.75	7.65	9.0	1370
	Std. Dev.	4	119	2.54	1.40	0.3	277
	25th Percentile	11	110	1.91	2.41	6.8	19
	75th Percentile	17	240	5.32	4.35	7.0	75
	Count	11664	10674	10442	9573	11666.0	11049
Dry Weather	Mean	23	368	5.94	2.82	7.8	55
	Median	24	310	5.95	2.86	7.7	29
	Min	5	27	0.06	-0.04	6.7	-1
	Max	33	709	15.07	5.82	9.2	1380
	Std. Dev.	6	135	2.60	1.17	0.5	130
	25th Percentile	19	269	4.21	1.94	7.4	22
	75th Percentile	27	429	7.83	3.70	8.1	42
	Count	12076	12076	11411	11648	12076.0	4655

Table A-5
Summary Water Quality Measurements under Wet and Dry Conditions at Smith Canal Pedestrian Bridge

Period	Parameter	Temperature	Specific Conductivity	Dissolved Oxygen	Depth	pH	Turbidity
		(C)	(umhos/cm)	(mg/L)	(ft)	(SU)	(ntu)
Wet Weather	Mean	14	357	6.47	3.47	7.3	31
	Median	13	286	6.24	3.50	7.2	28
	Min	6	1	0.30	0.00	6.8	-42
	Max	24	886	15.99	8.26	9.3	1310
	Std. Dev.	4	171	2.56	1.45	0.4	50
	25th Percentile	11	245	4.76	2.47	7.1	20
	75th Percentile	16	467	8.06	4.46	7.4	37
	Count	12089	11102	12085	11105	12085.0	11467
Dry Weather	Mean	22	374	7.44	2.85	7.7	25
	Median	22	358	6.91	2.84	7.5	21
	Min	6	9	1.27	0.00	6.9	9
	Max	32	917	17.31	8.06	9.3	1303
	Std. Dev.	5	143	2.37	1.30	0.5	38
	25th Percentile	18	252	5.81	1.89	7.4	16
	75th Percentile	26	407	8.83	3.73	8.0	29
	Count	12052	12044	12072	12052	12052.0	4624

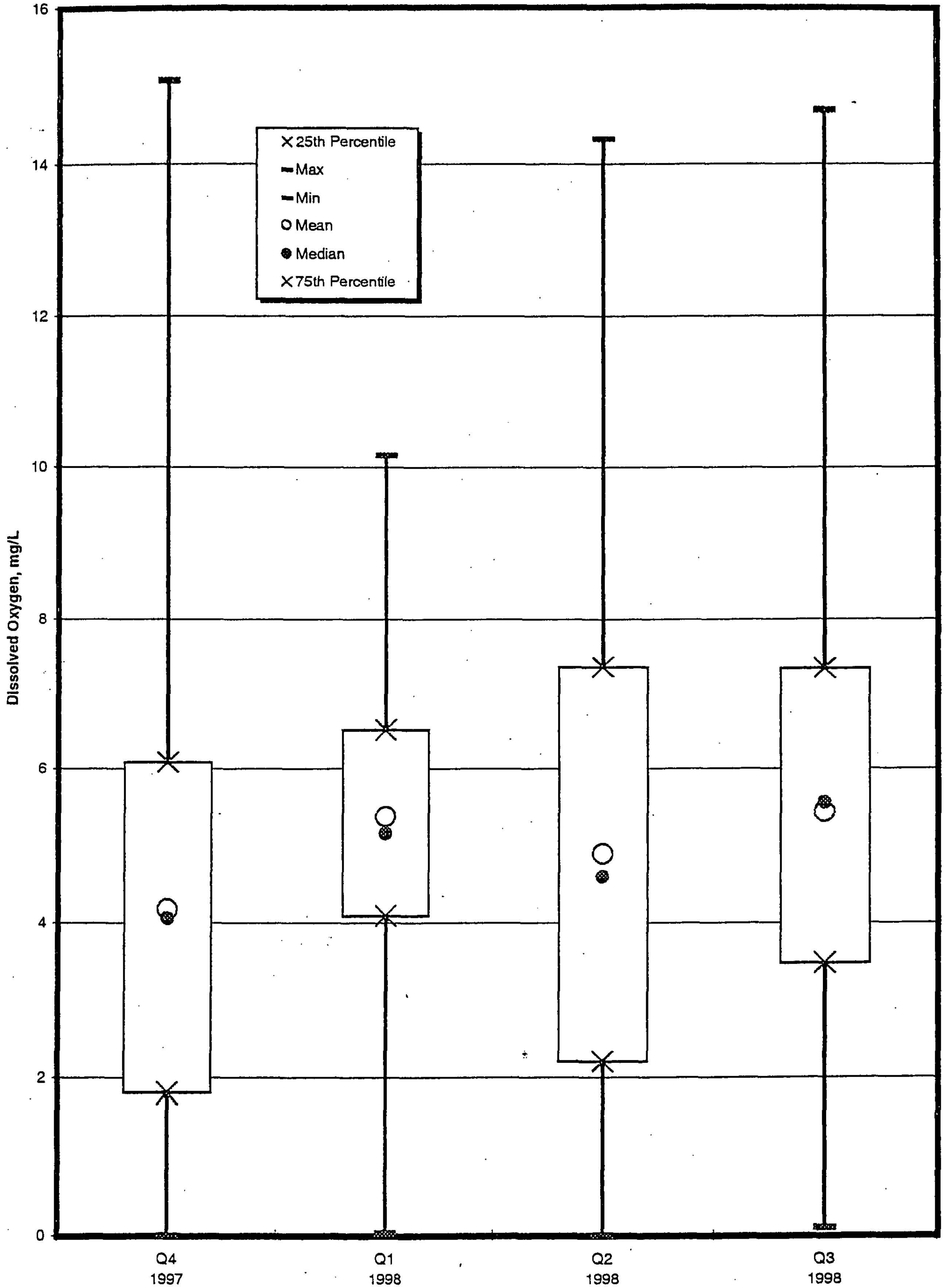


Figure B-3
Seasonal Data Distribution Plot
Dissolved Oxygen at Pershing Avenue Bridge Station

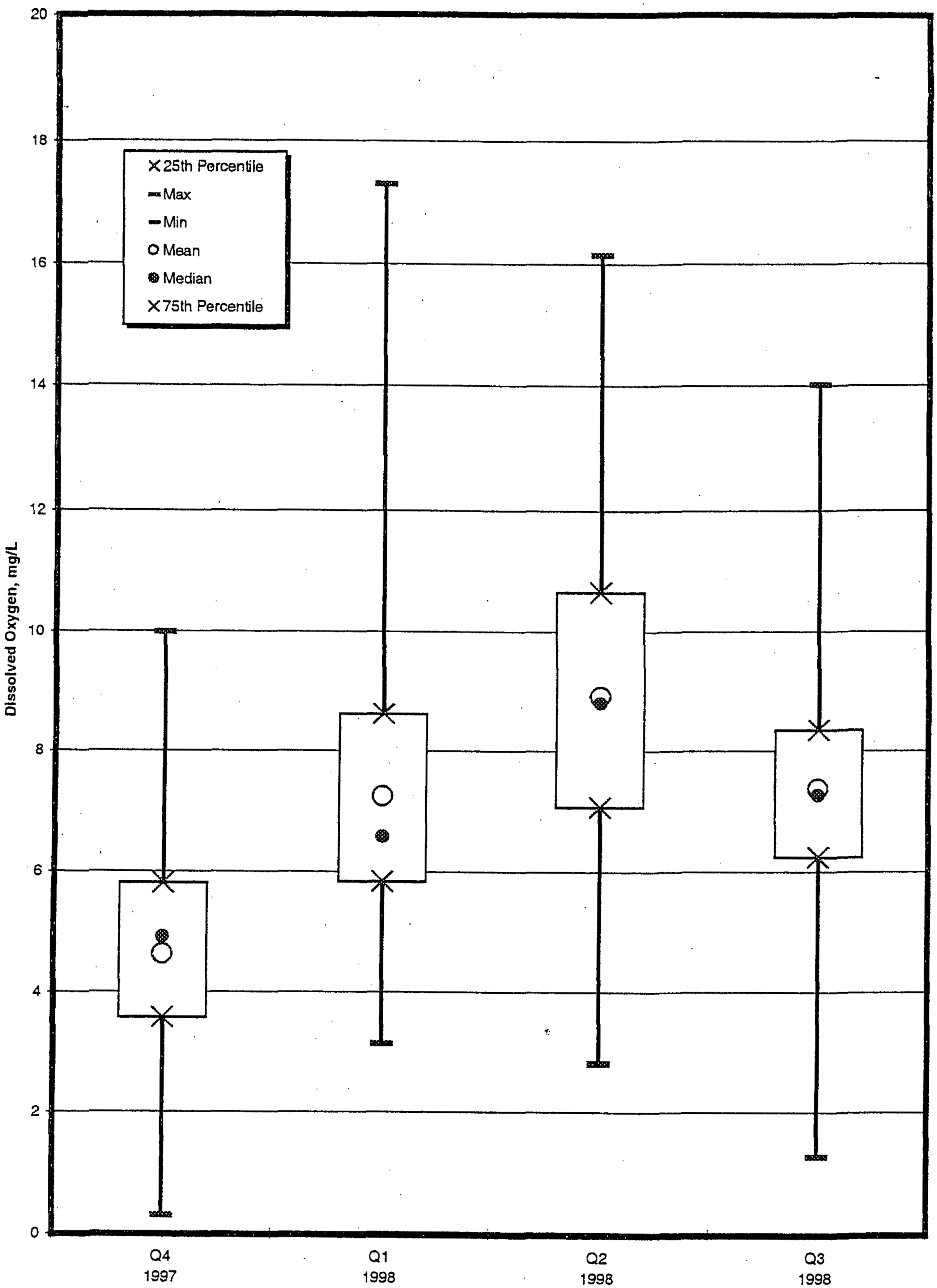


Figure B-6
Seasonal Data Distribution Plot
Dissolved Oxygen at Smith Canal Pedestrian Bridge

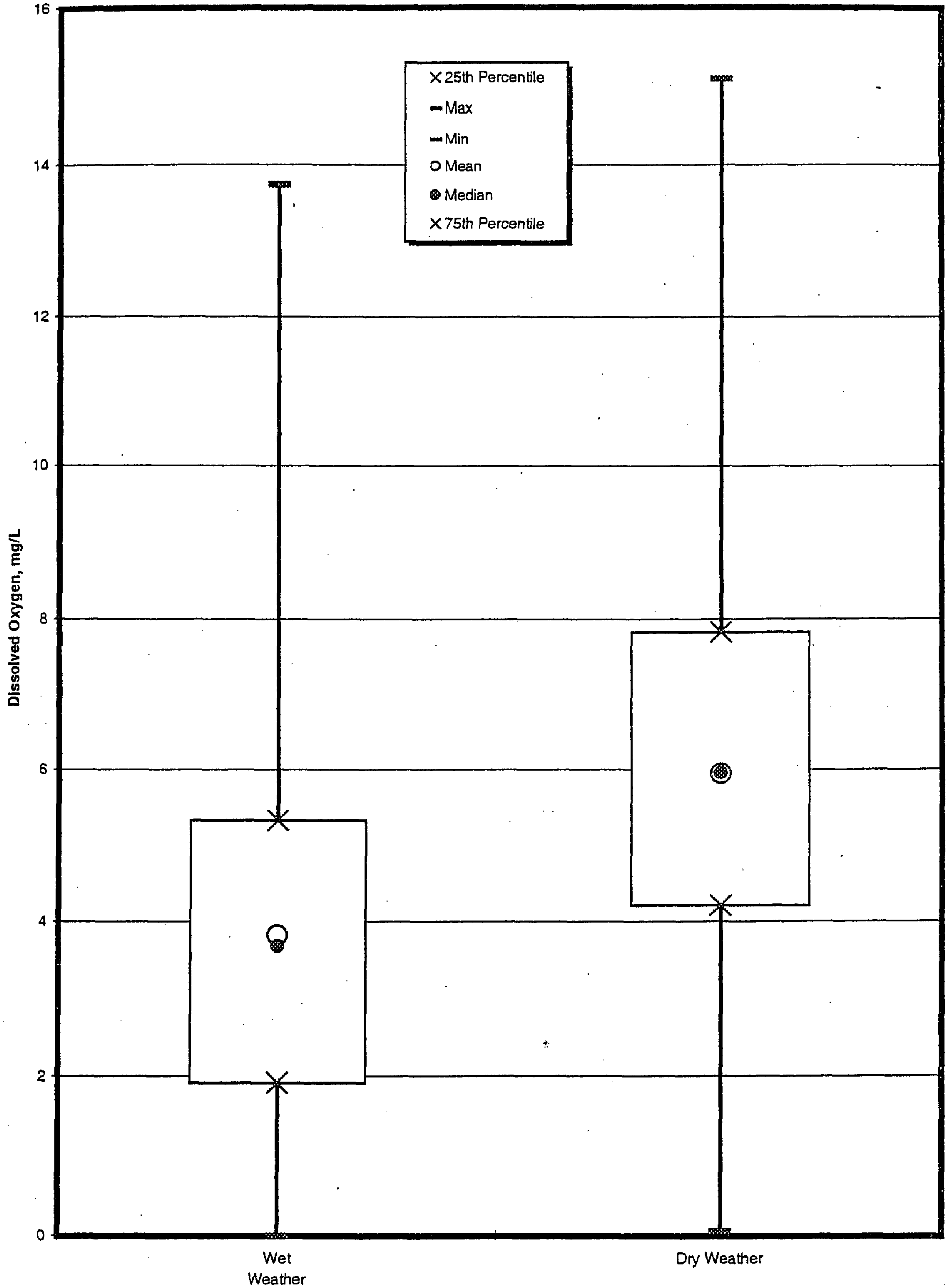


Figure B-7
Wet/Dry Data Distribution Plot
Dissolved Oxygen at Pershing Avenue Station

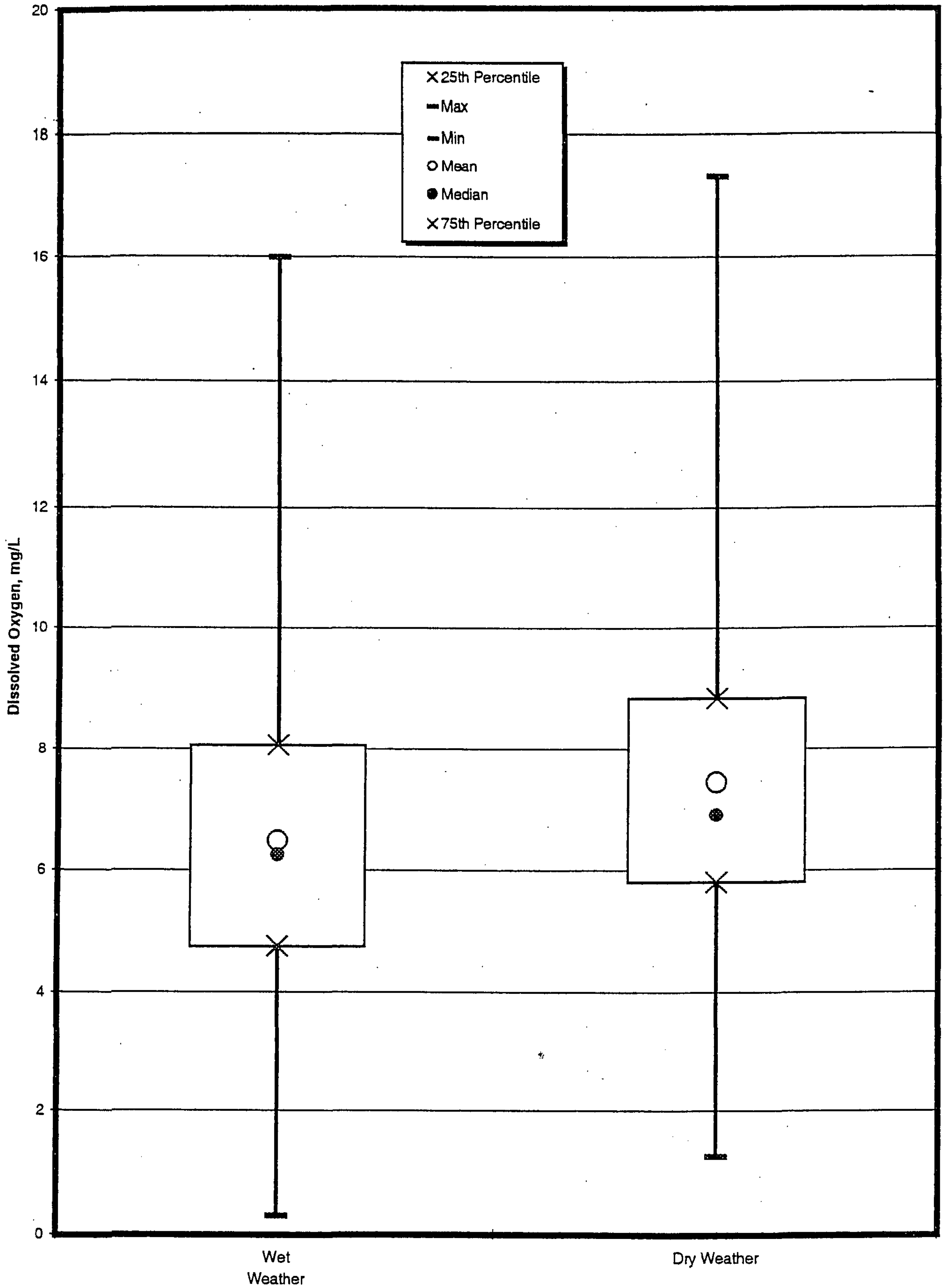


Figure B-8
Wet/Dry Data Distribution Plot
Dissolved Oxygen at Smith Canal Pedestrian Bridge

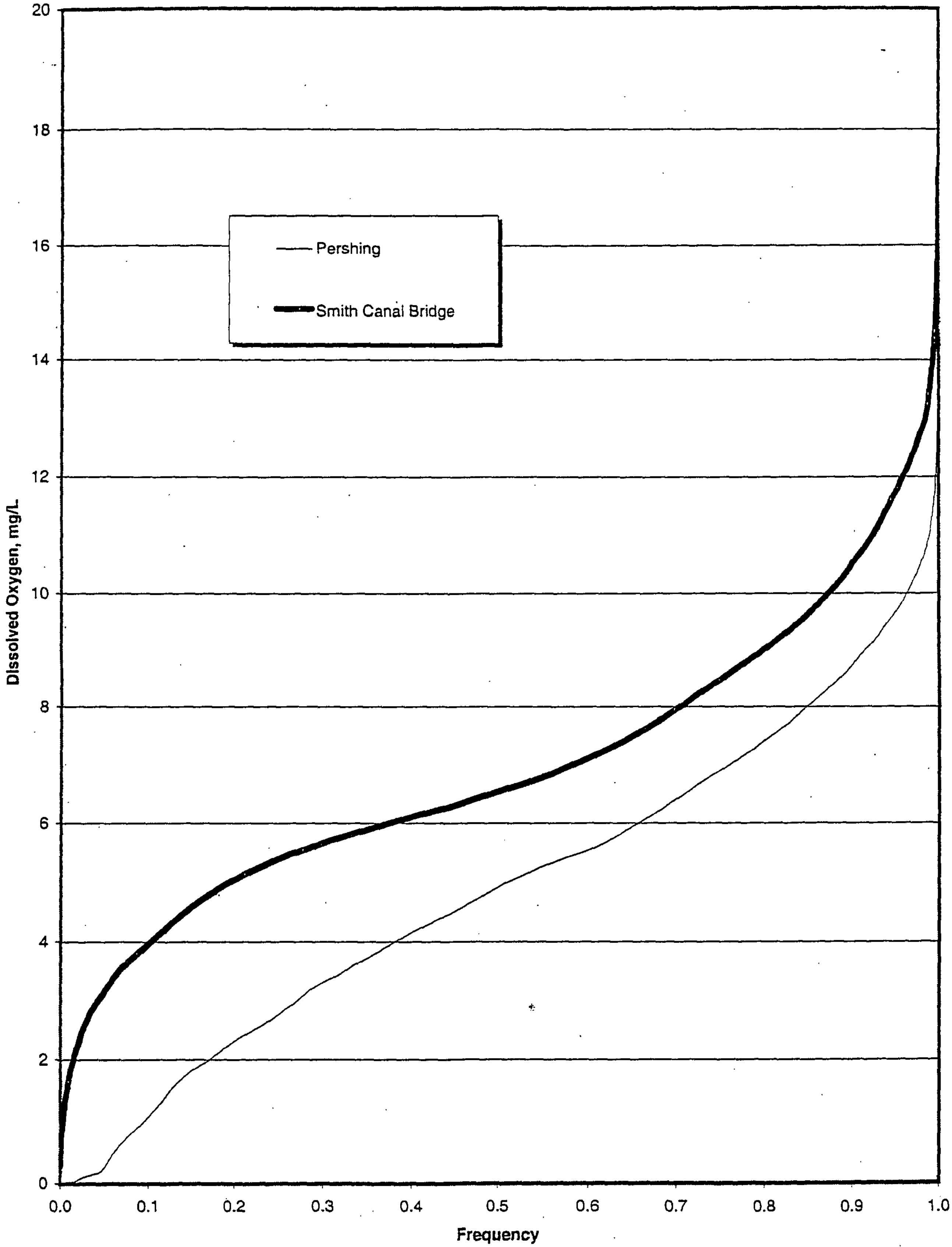


Figure C-3
Full Period Frequency Distribution
Dissolved Oxygen

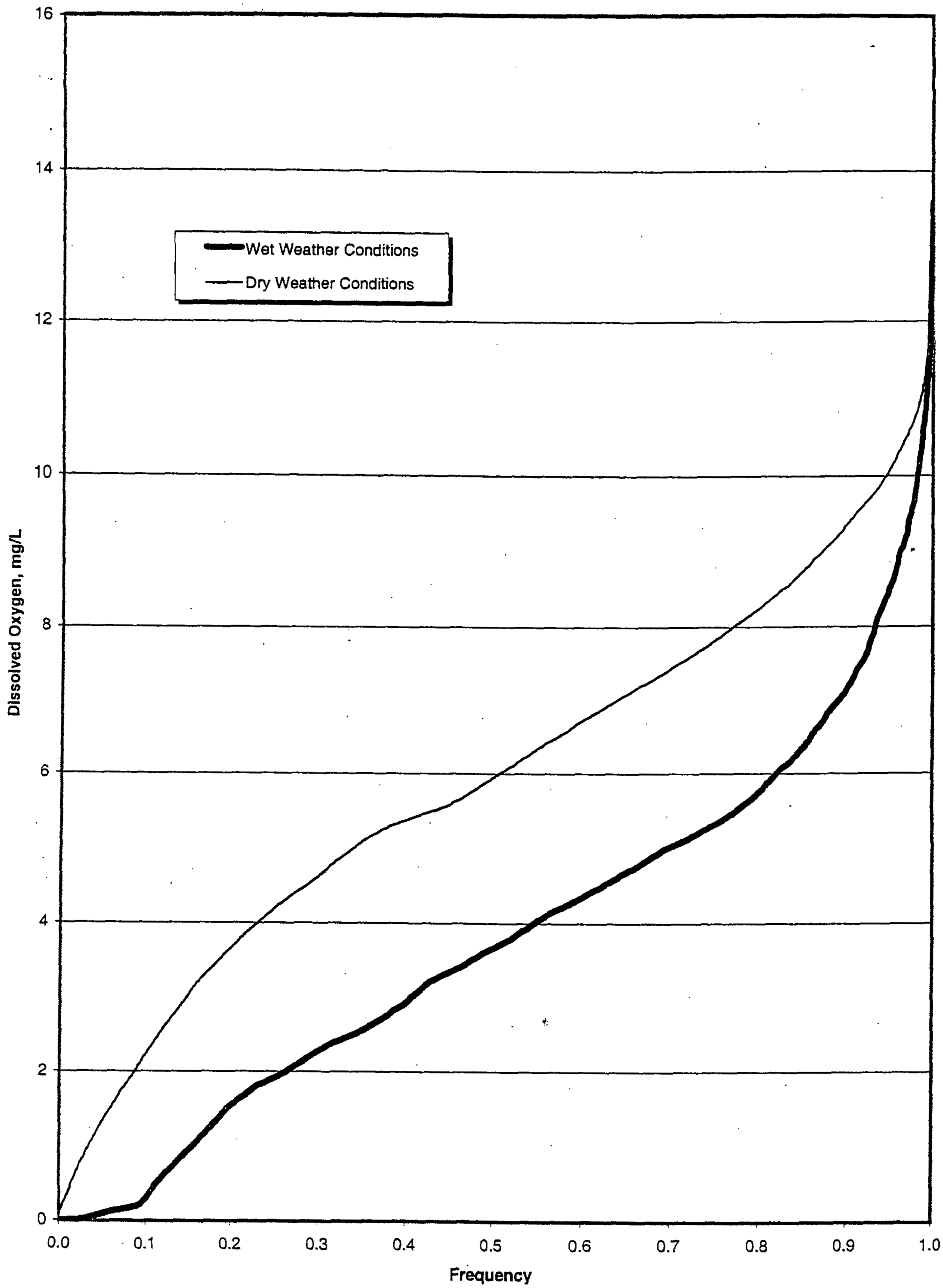


Figure C-4
Wet/Dry Frequency Distribution
Dissolved Oxygen at Pershing Avenue Bridge Station

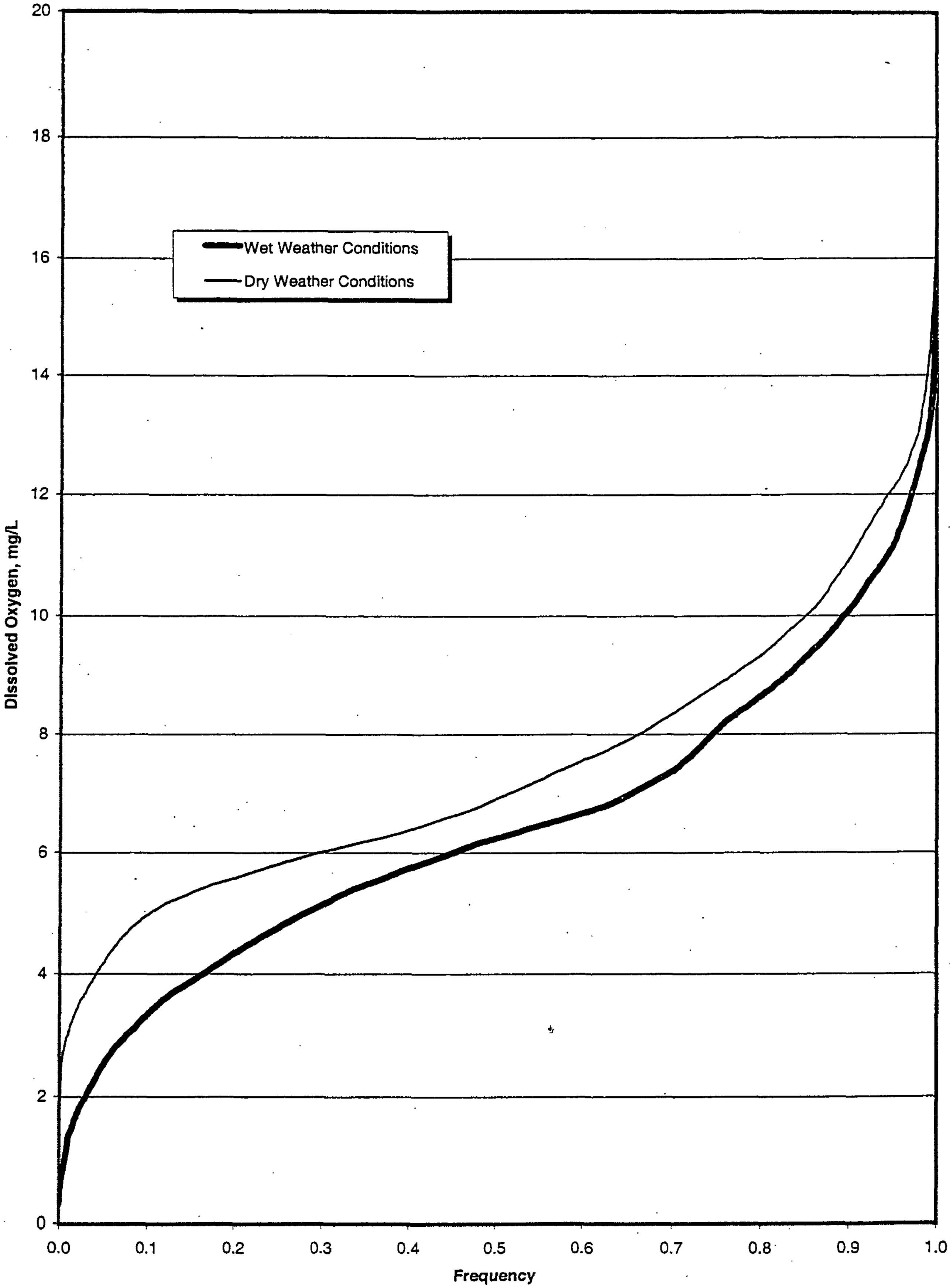
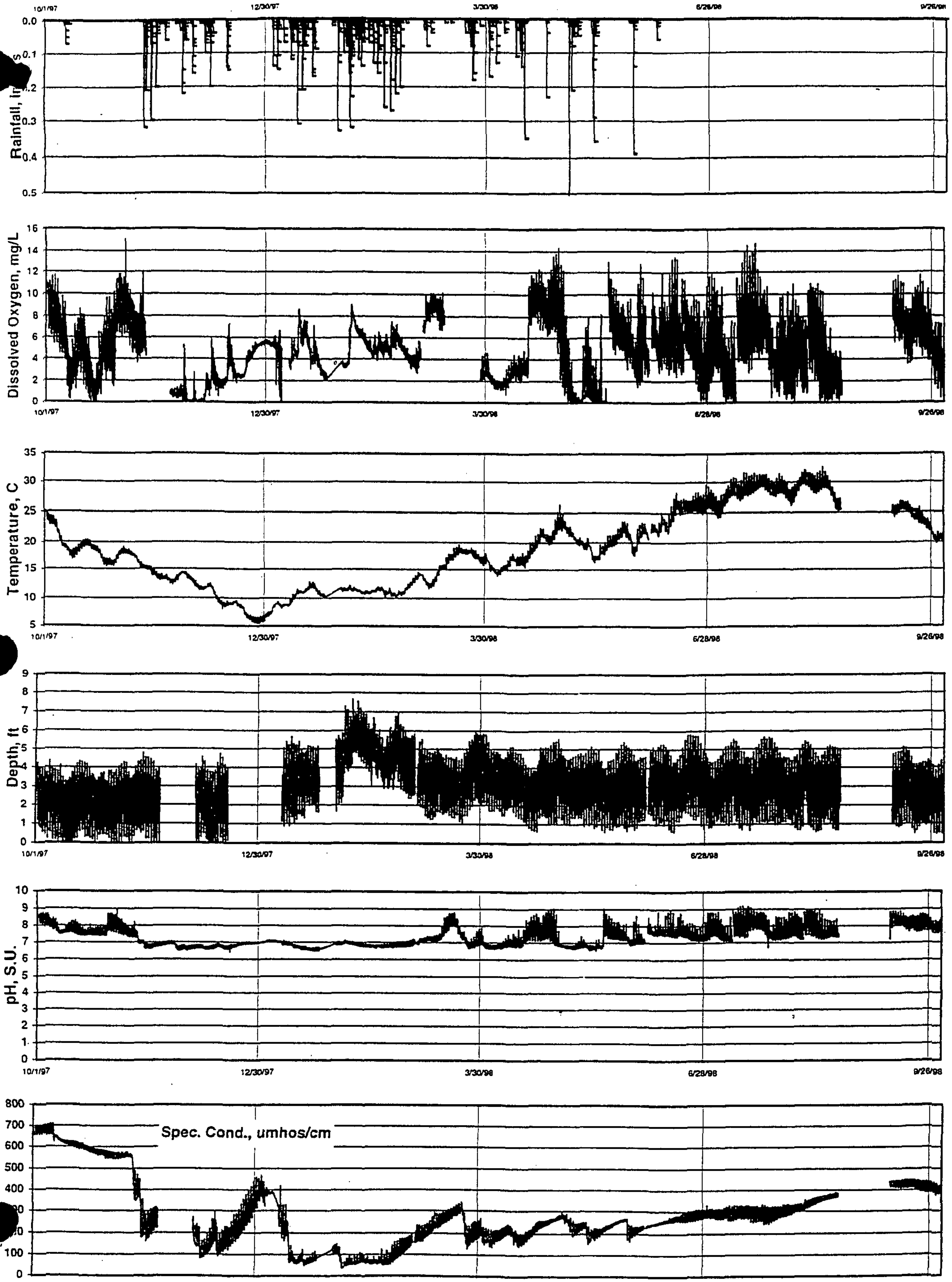
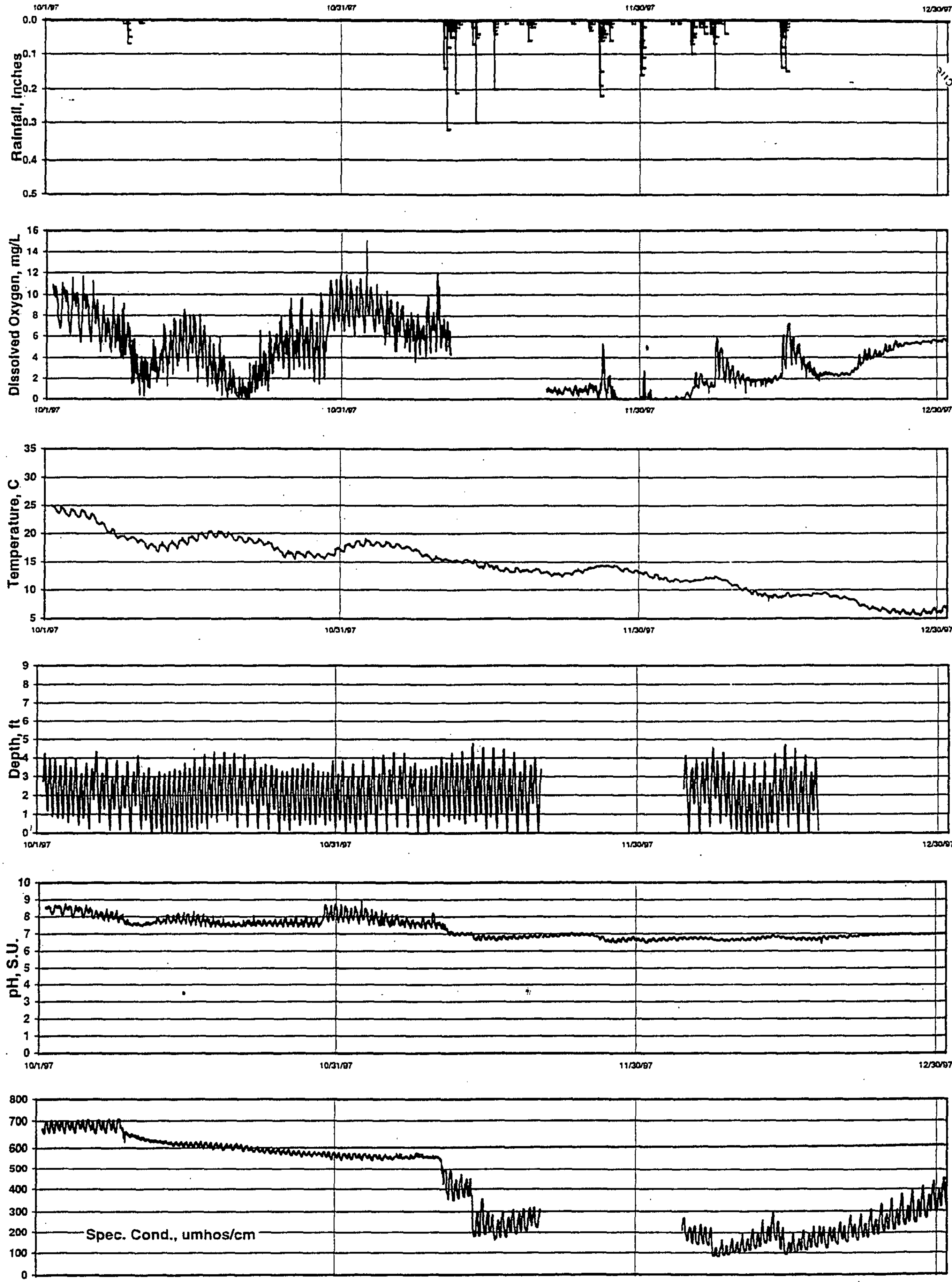


Figure C-5
Wet/Dry Frequency Distribution
Dissolved Oxygen at Smith Canal Pedestrian Bridge Station

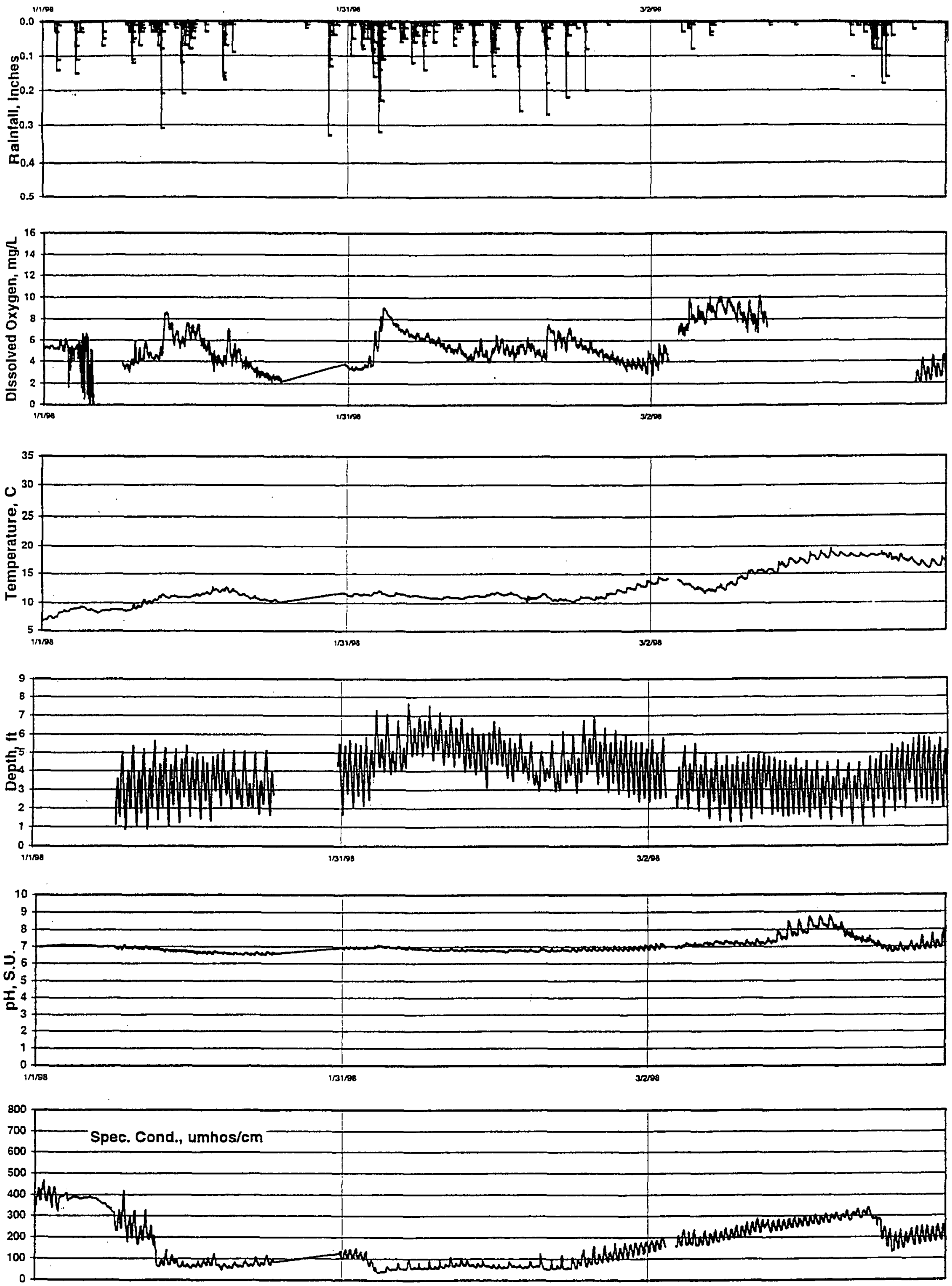
Smith Canal Continuous Water Quality Data for Pershing



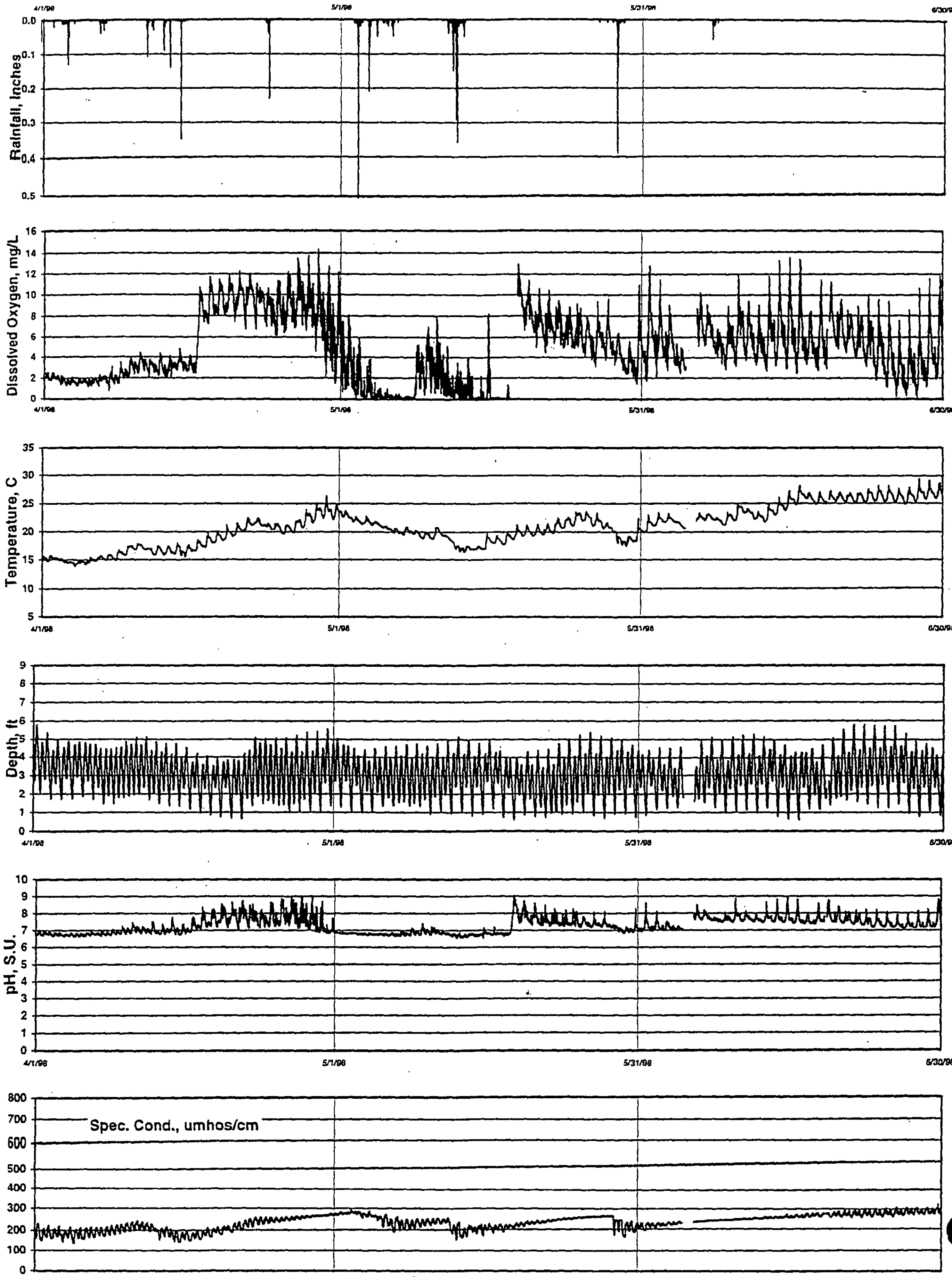
Smith Canal Continuous Water Quality Data for Pershing



Smith Canal Continuous Water Quality Data for Pershing



Smith Canal Continuous Water Quality Data for Pershing

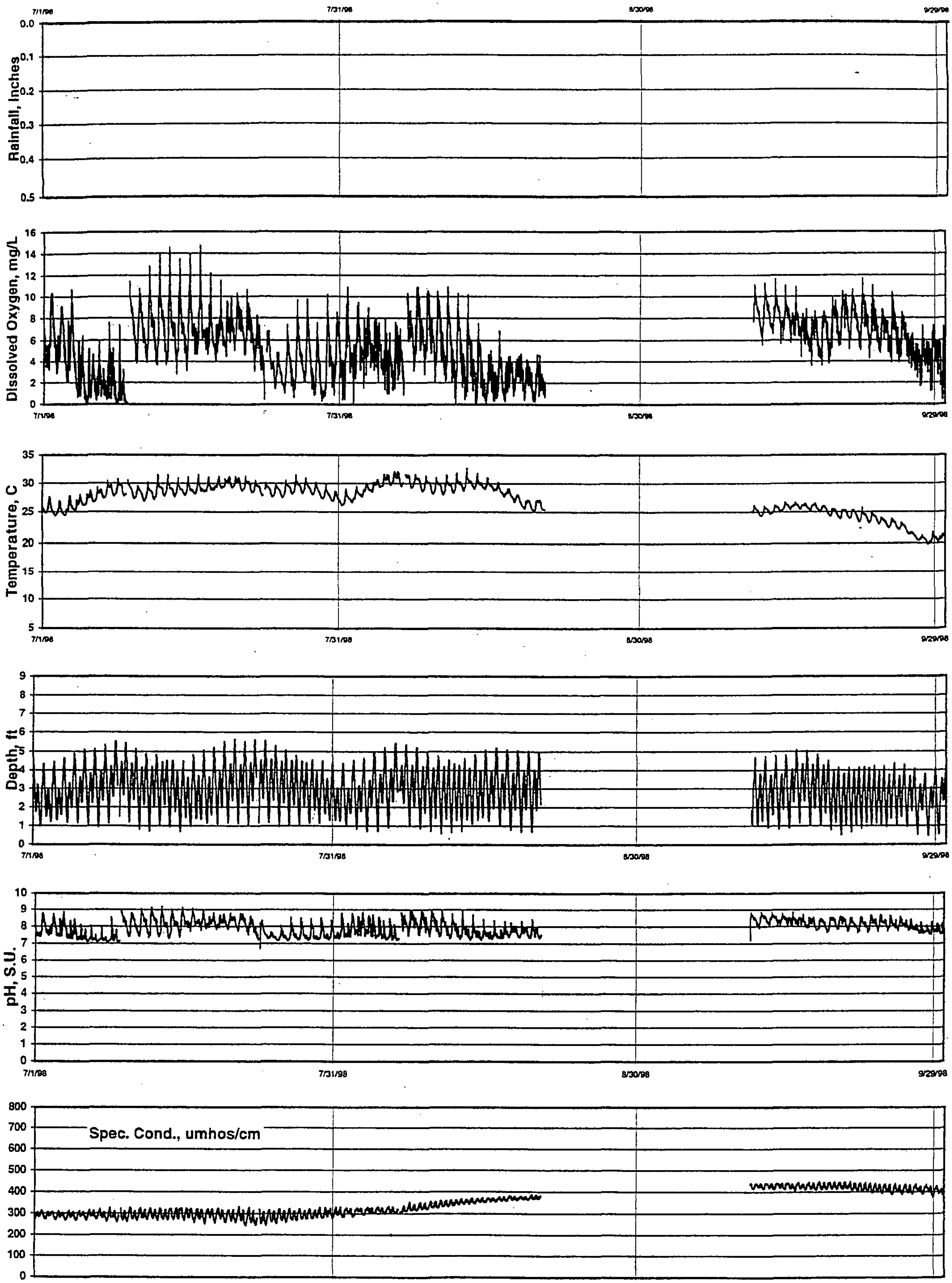


Date and Time Printed: 7/12/99 8:08 PM

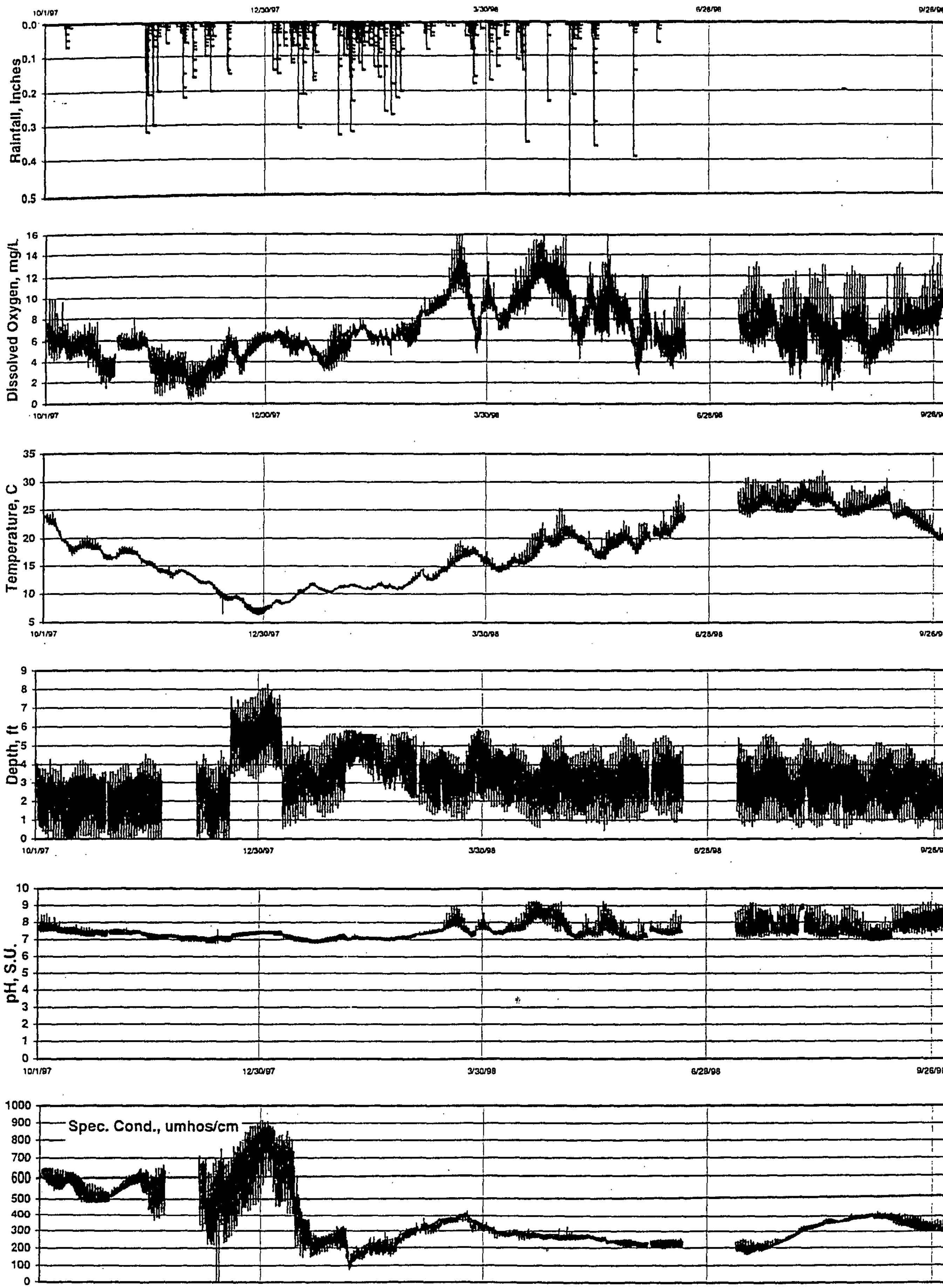
City of Stockton, California

Q2 1998

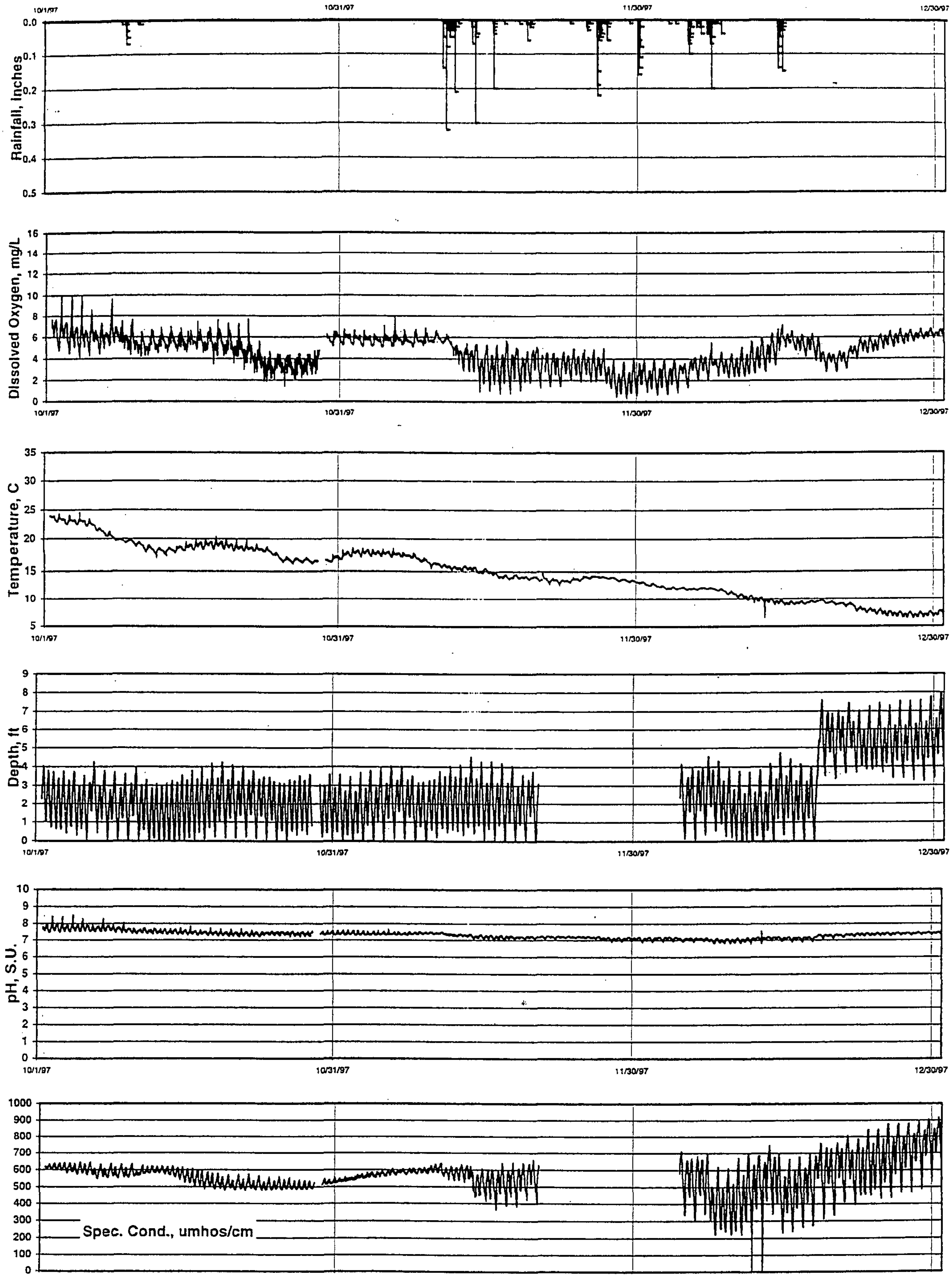
Smith Canal Continuous Water Quality Data for Pershing



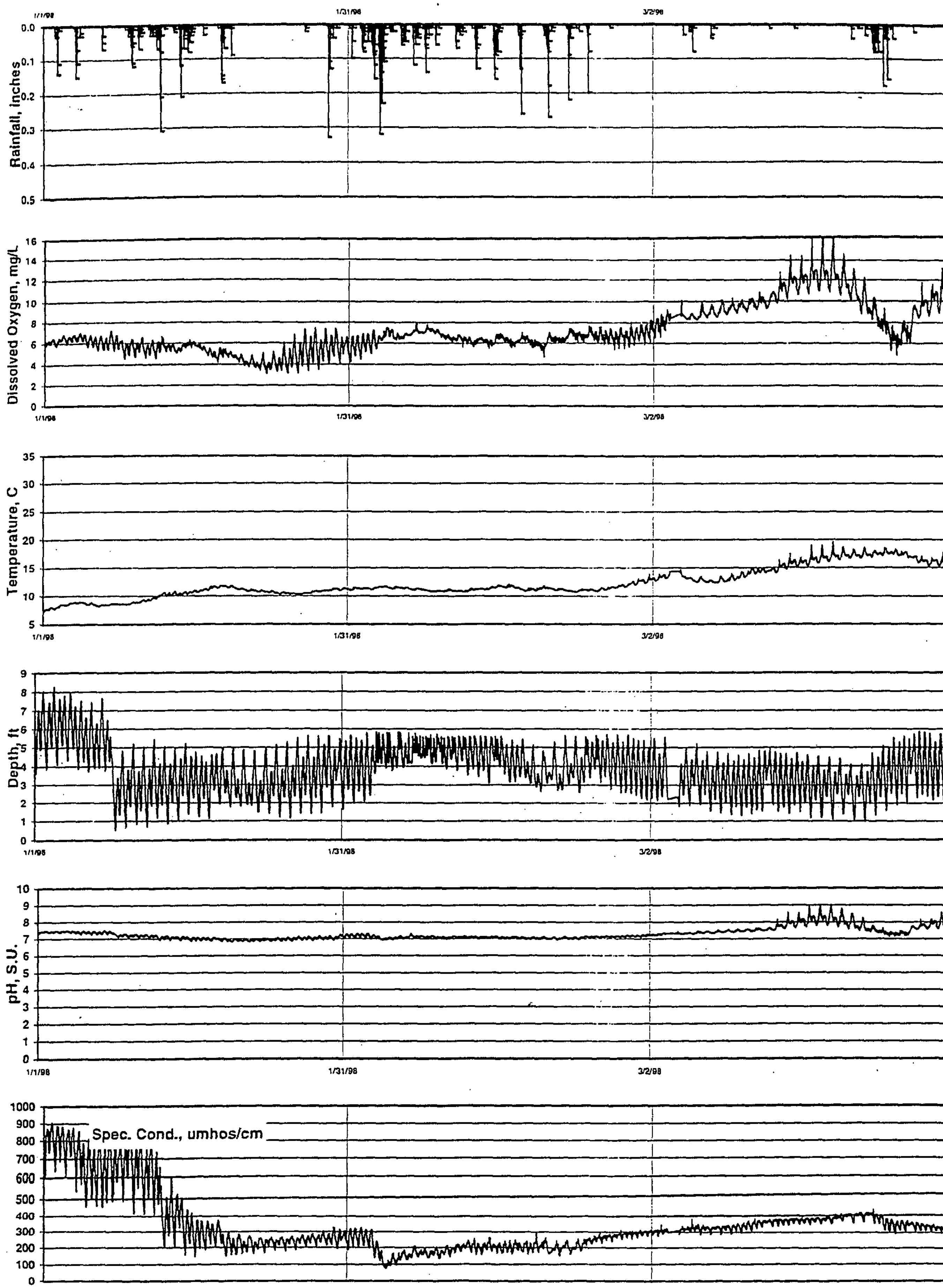
Smith Canal Continuous Water Quality Data for Smith Canal Bridge



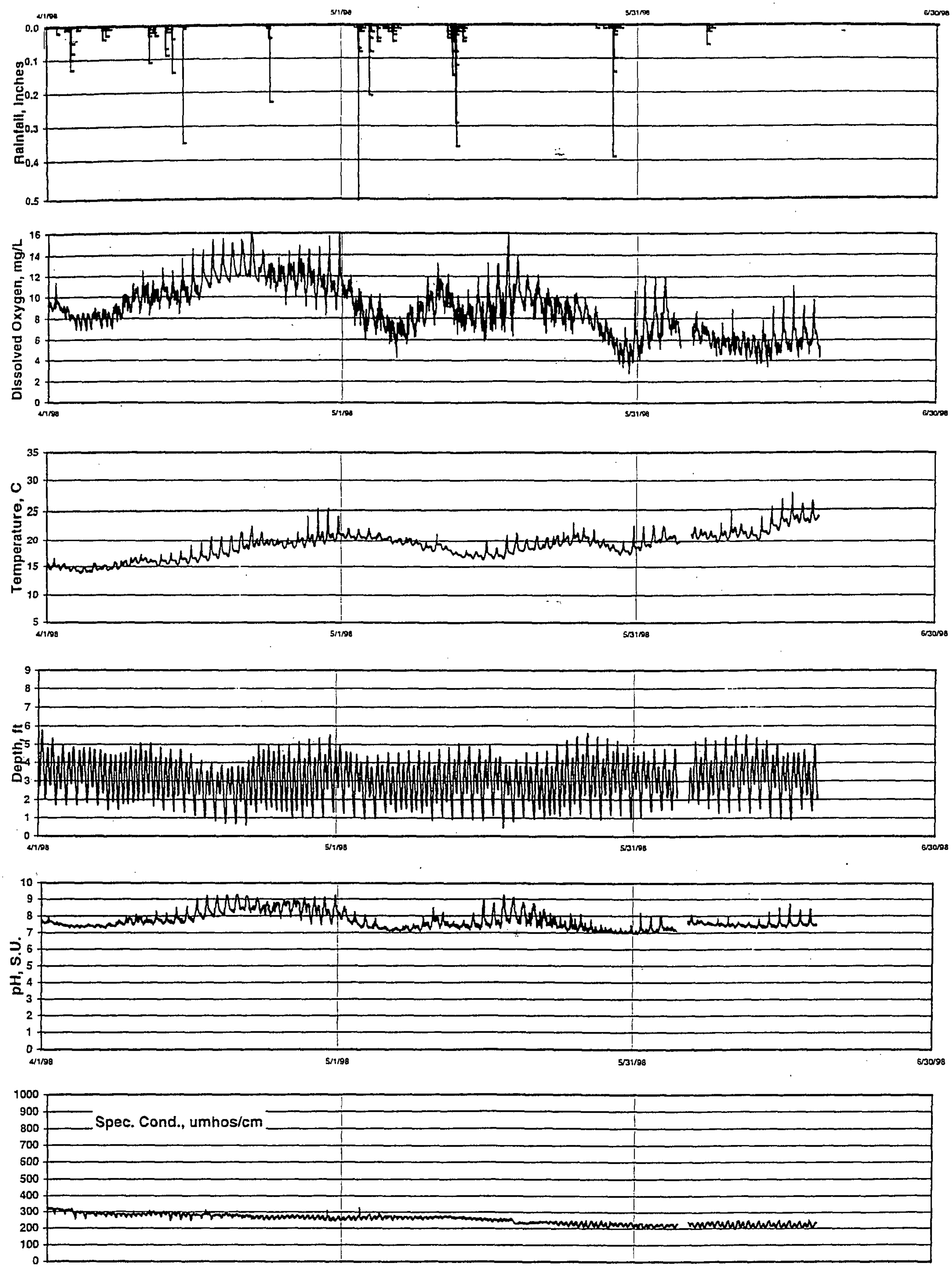
Smith Canal Continuous Water Quality Data for Smith Canal Bridge



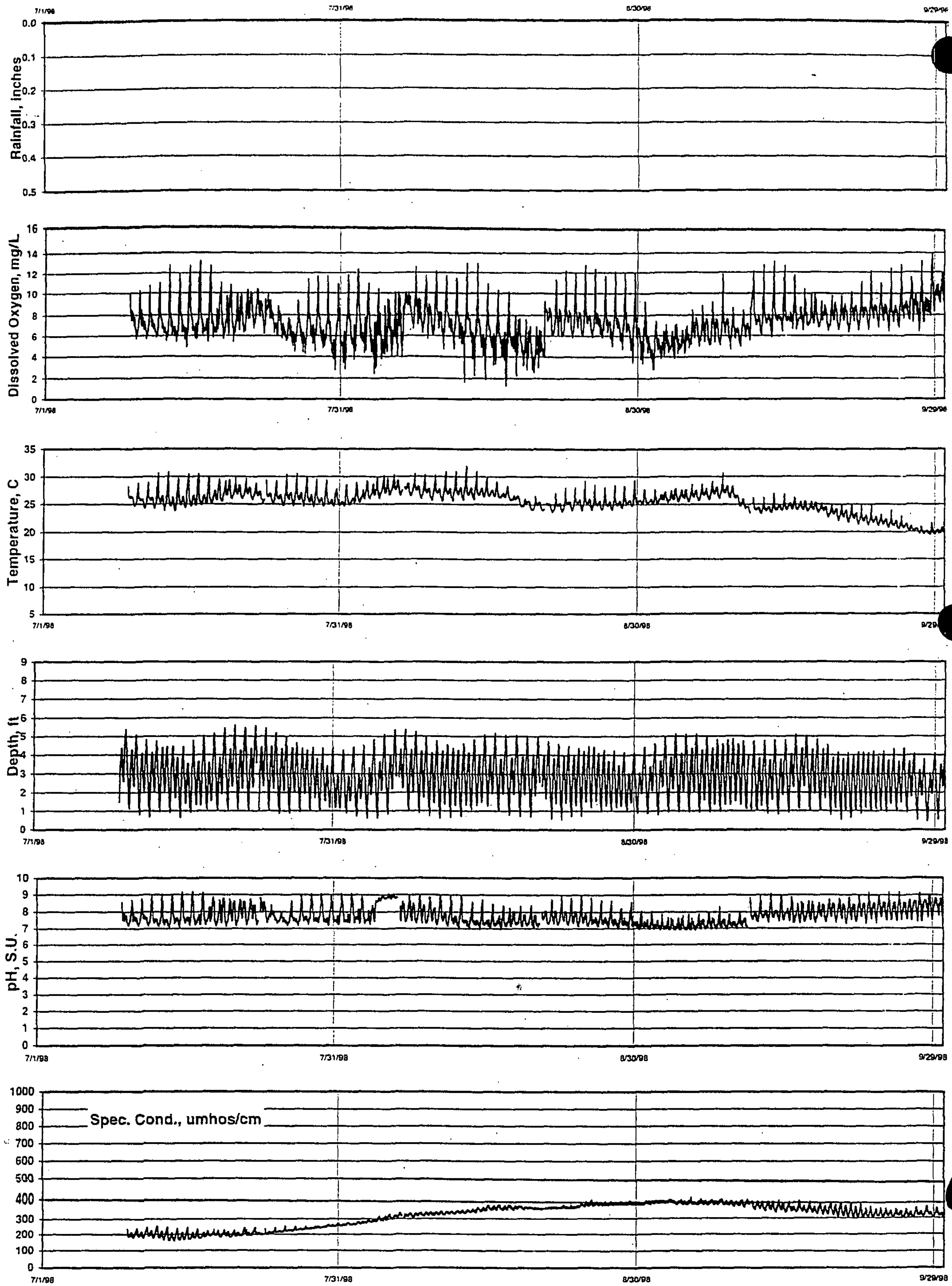
Smith Canal Continuous Water Quality Data for Smith Canal Bridge



Smith Canal Continuous Water Quality Data for Smith Canal Bridge



Smith Canal Continuous Water Quality Data for Smith Canal Bridge



Date and Time Printed: 7/12/99 8:45 PM *City of Stockton, California* Q3 1998

PHIL

CITY OF STOCKTON

DEPARTMENT OF MUNICIPAL UTILITIES
2500 NAVY DRIVE
STOCKTON, CA 95206-1191
(209) 937-8750
FAX (209) 937-8708

March 17, 1999

Patricia H. Leary, P.E.
Associated Water Resources Control Engineer
California Regional Water Quality Control Board
3443 Routier Road, Suite A
Sacramento, CA 95827-3098

CITY OF STOCKTON SMITH CANAL MONITORING PROGRAM REPORT

Pursuant to the City of Stockton's communications with the California Regional Water Quality Control Board, the above mentioned report is hereby presented. The City of Stockton, San Joaquin County, and CALTRANS District 10 have jointly sponsored this program.

The proposed twelve month data gathering project has been completed, computer model was calibrated and the data was evaluated. We would appreciate a meeting to discuss these findings at your earliest convenience.

Questions concerning the City's Storm Water Management Program should be directed to Glen D. Birdzell, Deputy Director Municipal Utilities/Stormwater; Municipal Utilities Department, 2500 Navy Drive, Stockton, CA 95206-1191; telephone (209) 937-8734.

MORRIS L. ALLEN
DIRECTOR OF MUNICIPAL UTILITIES

Glen D. Birdzell

GLEN D. BIRDZELL
DEPUTY DIRECTOR MUNICIPAL UTILITIES/STORMWATER

MLA:GDB:sa

Attachment

cc: Dale Steel, P.E. CALTRANS District 10
Manual Lopez, Deputy Director/County of San Joaquin
Morris Allen, Director of Municipal Utilities
emc: Gary Ingraham, Assistant City Manager

RECEIVED
SACRAMENTO
CVRWQCB
99 MAR 19 ... 1:57

T:\STORMWAT\RGLBOARD\SMITH\FINALRPT.WPD

PHL

CITY OF STOCKTON

DEPARTMENT OF MUNICIPAL UTILITIES
2500 NAVY DRIVE
STOCKTON, CA 95206-1191
(209) 937-8750
FAX (209) 937-8708

March 17, 1999

Patricia H. Leary, P.E.
Associated Water Resources Control Engineer
California Regional Water Quality Control Board
3443 Routier Road, Suite A
Sacramento, CA 95827-3098

CITY OF STOCKTON SMITH CANAL MONITORING PROGRAM REPORT

Pursuant to the City of Stockton's communications with the California Regional Water Quality Control Board, the above mentioned report is hereby presented. The City of Stockton, San Joaquin County, and CALTRANS District 10 have jointly sponsored this program.

The proposed twelve month data gathering project has been completed, computer model was calibrated and the data was evaluated. We would appreciate a meeting to discuss these findings at your earliest convenience.

Questions concerning the City's Storm Water Management Program should be directed to Glen D. Birdzell, Deputy Director Municipal Utilities/Stormwater; Municipal Utilities Department, 2500 Navy Drive, Stockton, CA 95206-1191; telephone (209) 937-8734.

MORRIS L. ALLEN
DIRECTOR OF MUNICIPAL UTILITIES

Glen D. Birdzell

GLEN D. BIRDZELL
DEPUTY DIRECTOR MUNICIPAL UTILITIES/STORMWATER

MLA:GDB:sa

Attachment

cc: Dale Steel, P.E. CALTRANS District 10
Manual Lopez, Deputy Director/County of San Joaquin
Morris Allen, Director of Municipal Utilities
emc: Gary Ingraham, Assistant City Manager

T:\STORMWAT\RGLBOARD\SMITH\FINALRPT.WPD

Technical Report

Application of Stockton's Water Quality Model to Evaluate Stormwater Impact on Smith Canal

Prepared for

Storm Water Management Program
Municipal Utilities Department
City of Stockton

Attention: Mr. Glen Birdzell
Deputy Director Municipal Utilities/Stormwater

Submitted by

Carl W. Chen, P.E.
Wangteng Tsai

Systech Engineering, Inc.
3180 Crow Canyon Place, Suite 260
San Ramon, CA 94583

February 23, 1999

Phone: 510-355-1780
Fax: 510-355-1778

Executive Summary

An application of Stockton's Water Quality Model was made to evaluate the reason for dissolved oxygen depression in Smith Canal after the stormwater input. Data compiled includes Smith Canal cross sections, SBOD measurement, stormwater pumping, mean event concentration of stormwater, and water quality collected in Smith Canal, effluent characterisitics of the City's Regional Wastewater Control Facility, and water quality monitored in the San Joaquin River for the period, extended from June to November of 1997. In order to track the DO during storm events, the model were modified to include scouring, resuspension, and redeposition of sediment. The oxygen demand of suspended sediment was incoporated into the model. The modified model simulated the rise and fall of suspended sediment, BOD, and dissolved oxygen in Smith Canal. The patterns follow those of observed turbidity, BOD, and dissolved oxygen.

The BOD in stormwater runoff ranged from 12 to 19 mg/l. The BOD loading from stormwater could not cause the observed DO depression in Smith Canal. The cause for DO depression was due to the scouring and resuspension of sediment from the channel bottom and also from the scouring and resuspension of sediment from storm sewers. The DO in Smith Canal recovered from the DO depression more than 5 days after the storm. During this period, the suspended sediment was redeposited to the channel bottom. The amount of suspended sediment escaped to the San Joaquin River was small.

In terms of dissolved oxygen, the terminal point of Smith Canal at Legion Park was most severely impacted by the stormwater input. The impacted area decreased toward the confluence with the San Joaquin River. If dissolved oxygen was the cause of fish kills, the impacted fish would be those resided in Smith Canal, not those in the San Jaoquin River.

Table of Content

List of Figures

List of Tables

Chapter 1

INTRODUCTION

BACKGROUND

Smith Canal is a dead end slough connected to the San Joaquin River. It receives stormwater inflow from an urban area of the City of Stockton. During or soon after storm events, the water quality in the canal was so deteriorated that fish kills were reported.

To address the water quality problems in Smith Canal, the City conducted a monitoring program to measure stormwater input and water quality responses in the canal. This is a preliminary study, initiated to apply the City's Water Quality Model to the data set and to help explain the impacts of stormwater on the water quality of Smith Canal.

OBJECTIVE AND SCOPE

The objective of the study is to determine the causes of DO drops, which are believed to kill fish in Smith Canal. The tool to be used for such a determination is the City's Water Quality Model. The model has recently been enhanced to include the simulation of temperature, nutrients, algae, and their effects on DO. The enhanced version will be used in this study.

The scope of work included the following tasks:

1. Systech compiled, from the City of Stockton, the data of Smith Canal cross sections, stormwater pumping, mean event concentration of stormwater, and water quality collected in Smith Canal during the storm events. Systech also compiled effluent data for the City's Regional Wastewater Control Facility, and water quality monitored in the San Joaquin River for the period, extended from June to November 1997.

2. From other sources, Systech compiled tidal data at the lower boundary of the San Joaquin River, the stream flow at the upper boundary of the San Joaquin River and the meteorological data of Stockton Airport. The data period was from June to November 1997.

3. Systech used the compiled data to prepare input to the City's Water Quality Model of San Joquin River. Systech compared the model result to the water quality monitored in the main stem of the San Joaquin River for the entire period of June to November 1997 to ensure that the model remained calibrated.

4. Systech evaluated the dynamic behaviors of dissolved oxygen occurred in the Smith Canal before and during the storm event. Based on the analysis, Systech provided an explanation of how stormwater input deteriorated the dissolved oxygen in the Smith Canal and whether the stormwater impacts extended from the Smith Canal to the main stem of the San Joaquin River.

Chapter 2

STUDY AREA

SMITH CANAL

Figure 1 shows a map of urban watershed tributary to Smith Canal. As shown, Smith Canal is a dead end slough connected to the main stem of the San Joaquin River near Rough and Ready Island.

South of Smith Canal, another dead end slough, the Stockton Channel, enters the San Joaquin River. The Stockon Channel extends from downtown Stockton to the confluence of the San Joaquin River.

The Stockton Port is located at the confluence of Stockton Channel and the San Joaquin River. To support ocean going ships, this section of Stockton Channel, including the turning basin, was dredged.

In term of water movement, the San Joaquin River flows from South, turns around the Rough and Ready Island, and moves to the northwest direction. Downstream of Rough and Ready Island, the San Joaquin River meets the tides from San Francisco Bay. The water in this region, including Smith Canal, is therefore tidally influenced.

TRIBUTARY AREA

The urban watershed tributary to Smith Canal can be divided into 11 catchments, as shown in Figure 1. The land uses in each of these catchments are presented in Table 1.

The total drainage area is 144 million square feet or 3,300 acres. The land uses are 50% residential, 18% commercial, and 26% street. The institutional and industrial uses occupy the remaining 6%..

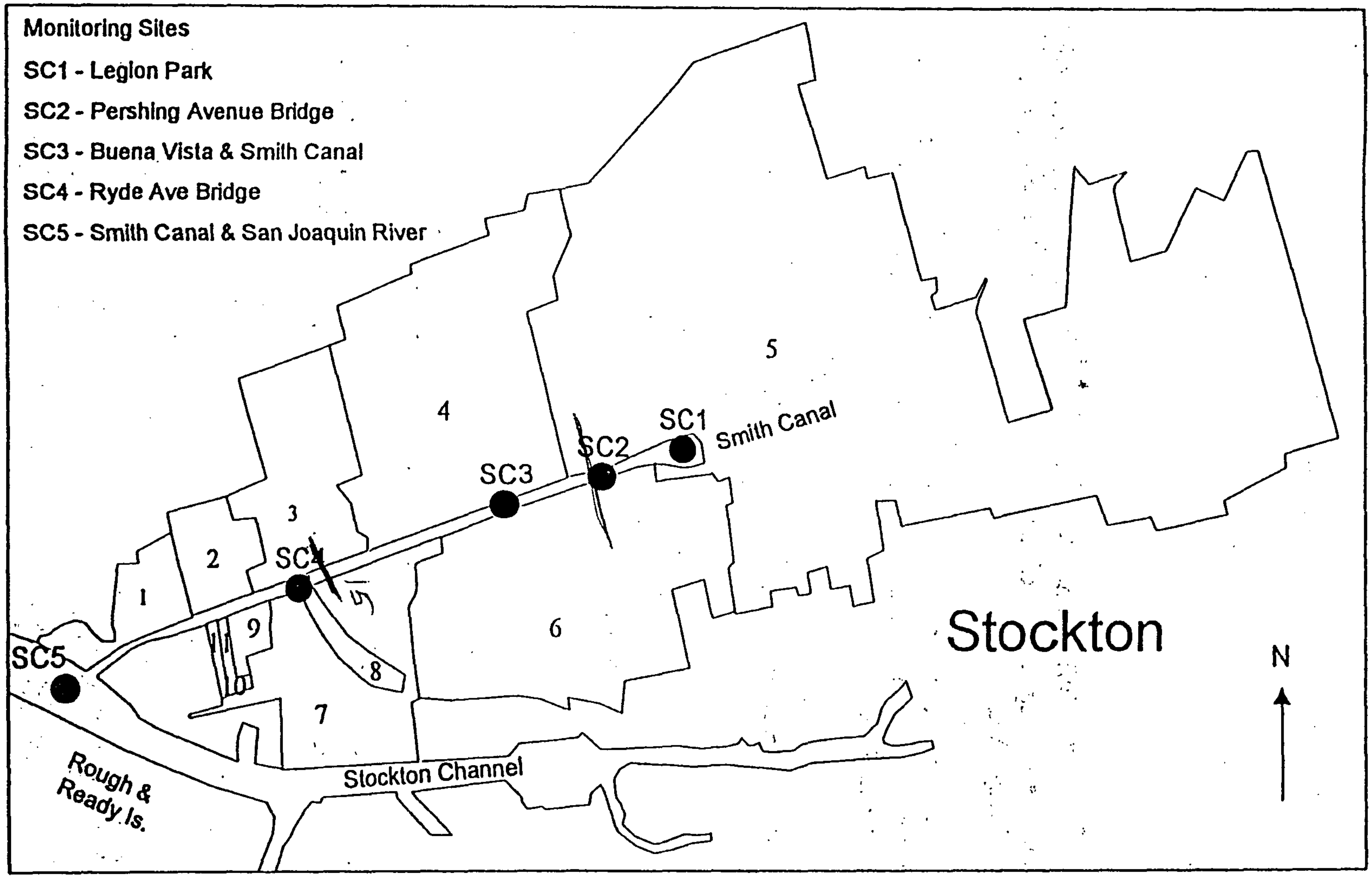


Figure 1. The Vicinity Map of Smith Canal

Table 1.

Land Uses of Catchments Tributary to Smith Canal

Catchment Number	Area sq. ft	Residential percent	Commercial percent	Institutional percent	Industrial percent	Street percent
1	2522757	70	16	0	0	14
2	2561088	75	5	0	0	20
3	7231269	49	18	0	0	32
4	18544676	64	11	0	2	22
5	81526824	41	22	10	1	26
6	21278582	56	11	3	0	29
7	8577073	53	25	0	0	22
8	925590	0	0	0	0	100
9	740300	78	0	0	0	22
10	342960	67	2	0	0	31
11	244210	60	0	0	0	39

NONPOINT SOURCE POLLUTION

The City of Stockton initiated a stormwater sampling program. Stormwater samples were collected at 5 stations. Table 2 presents the monitoring sites, their drainage area, and land use characteristics.

Table 2.

Stormwater Sampling Locations
and Land Use Characteristics

Monitoring Site	Drainage Area	Land Use
West Lane at Calveraa River	169	Commercial/Residential
W. Pacific Industrial Park at Duck Creek	343	Industrial/partial develop
Sutter Street at Calveras River	360	Old single residential homes
Kelley Drive at Mosher Slough	533	Newer residential homes
Thornton Road at Mosher Slough	102	Moderate old residential

The mean event concentrations of various constituents in stormwater are summarized in Table 3. Because the constituent concentrations are highly variable, the median values were selected for the mean event concentrations.

Table 3.

Median Mean Event Concentrations of Various Constituents in the Stockton Stormwater

Constituents	Units	Residential (n=30)	Commercial (n=11)	Industrial (n=10)
Hardness	mg/l	21	17	39
TSS	mg/l	51	89	211
TDS	mg/l	65	52	101
BOD	mg/l	13	12	19
Coliform	MPN/100	1.45e5	1.09e5	1.07e5
Fecal	MPN/100	2.45e4	1.66e4	9.37e3
TKN	mg/l	2.1	2.0	2.7
Nitrate	mg/l	0.46	0.55	0.82
Total N	mg/l	2.61	2.52	3.59
Ammonia-N	mg/l	0.54	0.73	0.70
Total P	mg/l	0.36	0.35	0.67

The drainage area lower than the water surface of Smith Canal. For that reason, the stormwaters from catchments are drained to 3 sumps at Ryde Avenue, Buena Vista, and Legion Park. Pumps are used to lift stormwaters and discharge them to SC4, SC3 and SC1, respectively as shown in Figure 1. The pumping record for the storm occurring on November 10-14, 1997 is presented in Figure 2.

Based on the land use data shown in Table 1 and the mean event concentrations shown in Table 3, the total nonpoint load for the storm occurring on November 10-14, 1997 was calculated. The results are presented in Table 4 and plotted in Figure 3.

The stormwater nonpoint loads are shown to enter Smith Canal principally via the Legion Park pumping station. This is because the Legion Park pump station services a very large drainage area with a mixed residential, commercial and institutional land uses.

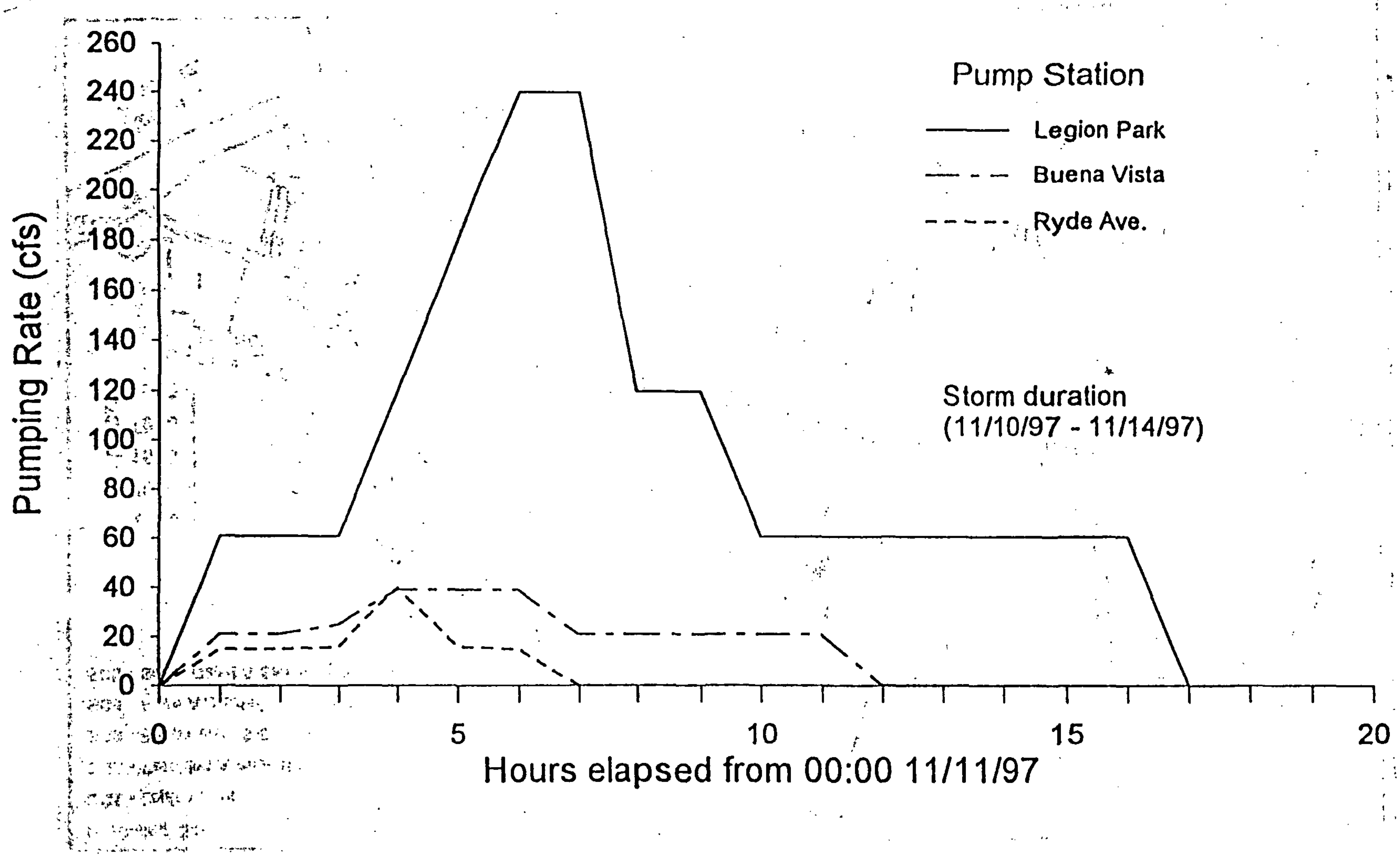


Figure 2. Record of Stormwater Pumping to Smith Canal

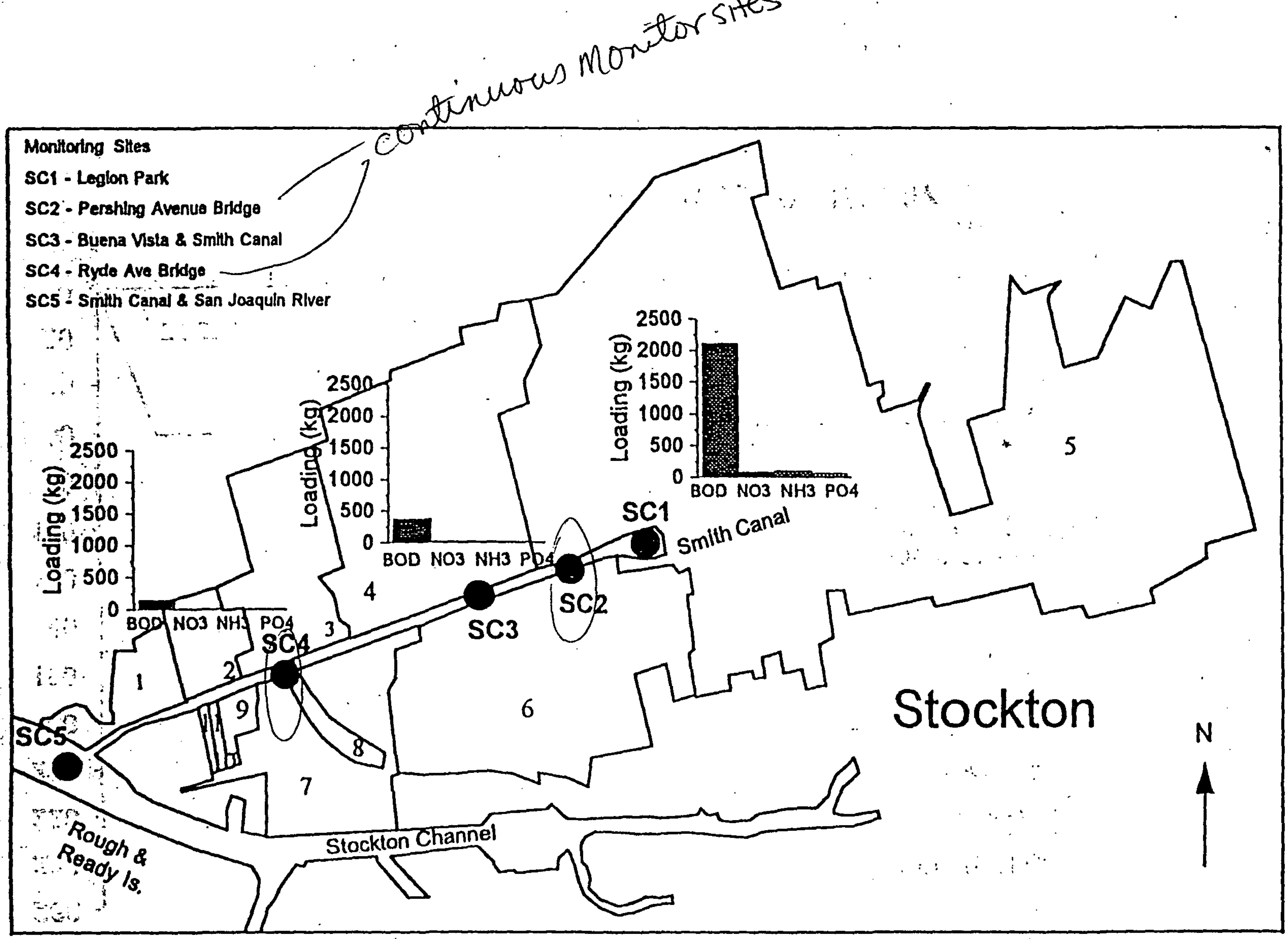


Figure 3. Nonpoint Source Loads to Smith Canal

8

Table 4

Calculated

Nonpoint Source Loads for the Storm of November 10-14, 1997

Constituents	Ryde Ave SC4	Buena Vista SC3	Legion Park SC1
Flow (cubic feet)	424,400	1,040,400	5,875,200
BOD (kg)	150	373	2,113
NO3N (kg)	6	15	81
NH3N (kg)	7.5	17.9	99
PO4P (kg)	4.2	10.6	59
TSS (kg)	710	1,802	9,383

WATER QUALITY IN SMITH CANAL

The City of Stockton installed two sensor arrays, one at Pedestrian Bridge and the other at Pershing Avenue Bridge. The sensors continuously recorded dissolved oxygen, water temperature, pressure (water depth), specific conductivity, and turbidity of the water in Smith Canal. The results are presented in Appendix A. A preliminary review of the data indicated that the equipments were sometimes malfunctioned. To analyze the data would require more time and effort than it is available in this project.

The water quality in Smith Canal was measured at SC1, SC2, SC3, and SC4 during the storm of November 10 to 14, 1997. Figures 4-6 presents the time varying concentrations of turbidity, BOD and DO at various stations after the stormwater input.

The data showed that the pollutant concentrations increased after the stormwater inflow. The increase was highest at SC1, decreasing toward SC4. In term of dissolved oxygen, the highest DO depression occurred at SC1.

After the storm passed, the pollutant concentrations decreased with time. The DO also recovered gradually from the large DO depression.

CHANNEL CROSS SECTIONS

The channel geometry is an important input to the model. Two river cross sections were measured in Smith Canal. Figure 7 presents the channel cross section at the Pedestrian Bridge on Ryde Avenue. Figure 8 presents the channel cross section at Pershing Avenue.

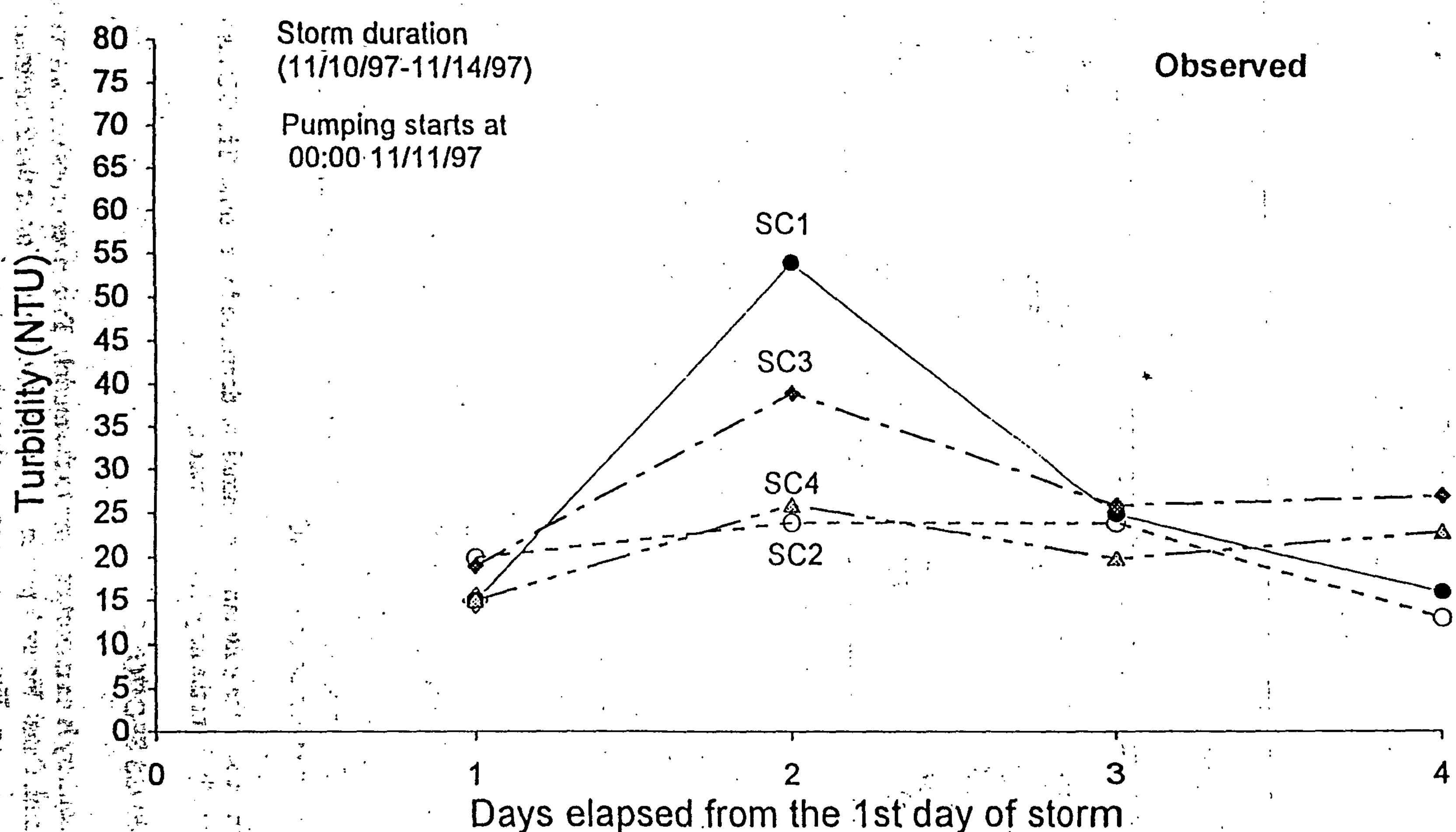


Figure 4. Turbidity in Smith Canal After the Storm of November 10-14, 1997

Table 4
Calculated
Nonpoint Source Loads for the
Storm of November 10-14, 1997

Constituents	Ryde Ave SC4	Buena Vista SC3	Legion Park SC1
Flow (cubic feet)	424,400	1,040,400	5,875,200
BOD (kg)	150	373	2,113
NO3N (kg)	6	15	81
NH3N (kg)	7.5	17.9	99
PO4P (kg)	4.2	10.6	59
TSS (kg)	710	1,802	9,383

WATER QUALITY IN SMITH CANAL

The City of Stockton installed two sensor arrays, one at Pedestrian Bridge and the other at Pershing Avenue Bridge. The sensors continuously recorded dissolved oxygen, water temperature, pressure (water depth), specific conductivity, and turbidity of the water in Smith Canal. The results are presented in Appendix A. A preliminary review of the data indicated that the equipments were sometimes malfunctioned. To analyze the data would require more time and effort than it is available in this project.

The water quality in Smith Canal was measured at SC1, SC2, SC3, and SC4 during the storm of November 10 to 14, 1997. Figures 4-6 presents the time varying concentrations of turbidity, BOD and DO at various stations after the stormwater input.

The data showed that the pollutant concentrations increased after the stormwater inflow. The increase was highest at SC1, decreasing toward SC4. In term of dissolved oxygen, the highest DO depression occurred at SC1.

After the storm passed, the pollutant concentrations decreased with time. The DO also recovered gradually from the large DO depression.

CHANNEL CROSS SECTIONS

The channel geometry is an important input to the model. Two river cross sections were measured in Smith Canal. Figure 7 presents the channel cross section at the Pedestrian Bridge on Ryde Avenue. Figure 8 presents the channel cross section at Pershing Avenue.

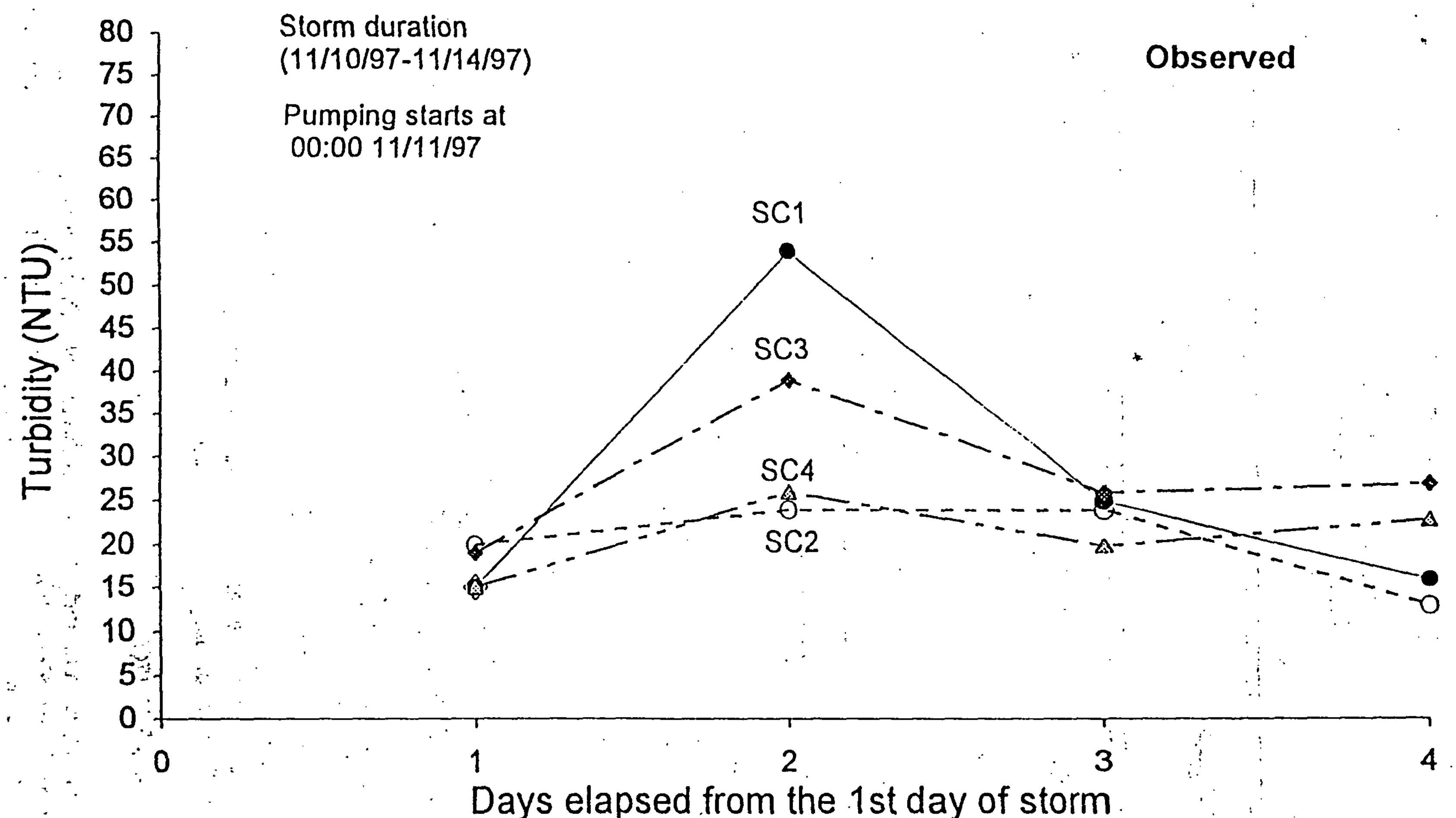


Figure 4. Turbidity in Smith Canal After the Storm of November 10-14, 1997

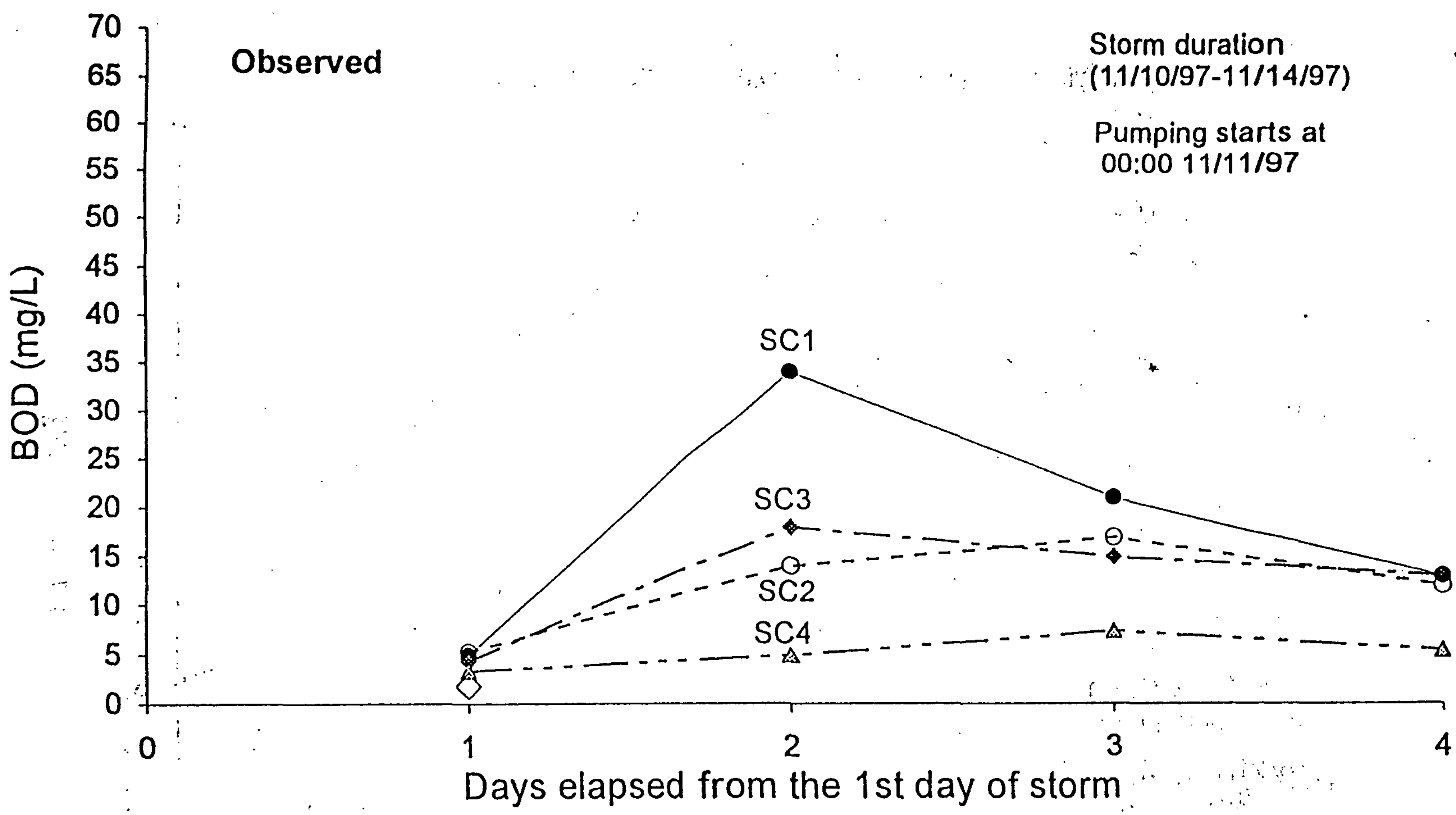


Figure 5. BOD in Smith Canal After the Storm of November 10-14, 1997

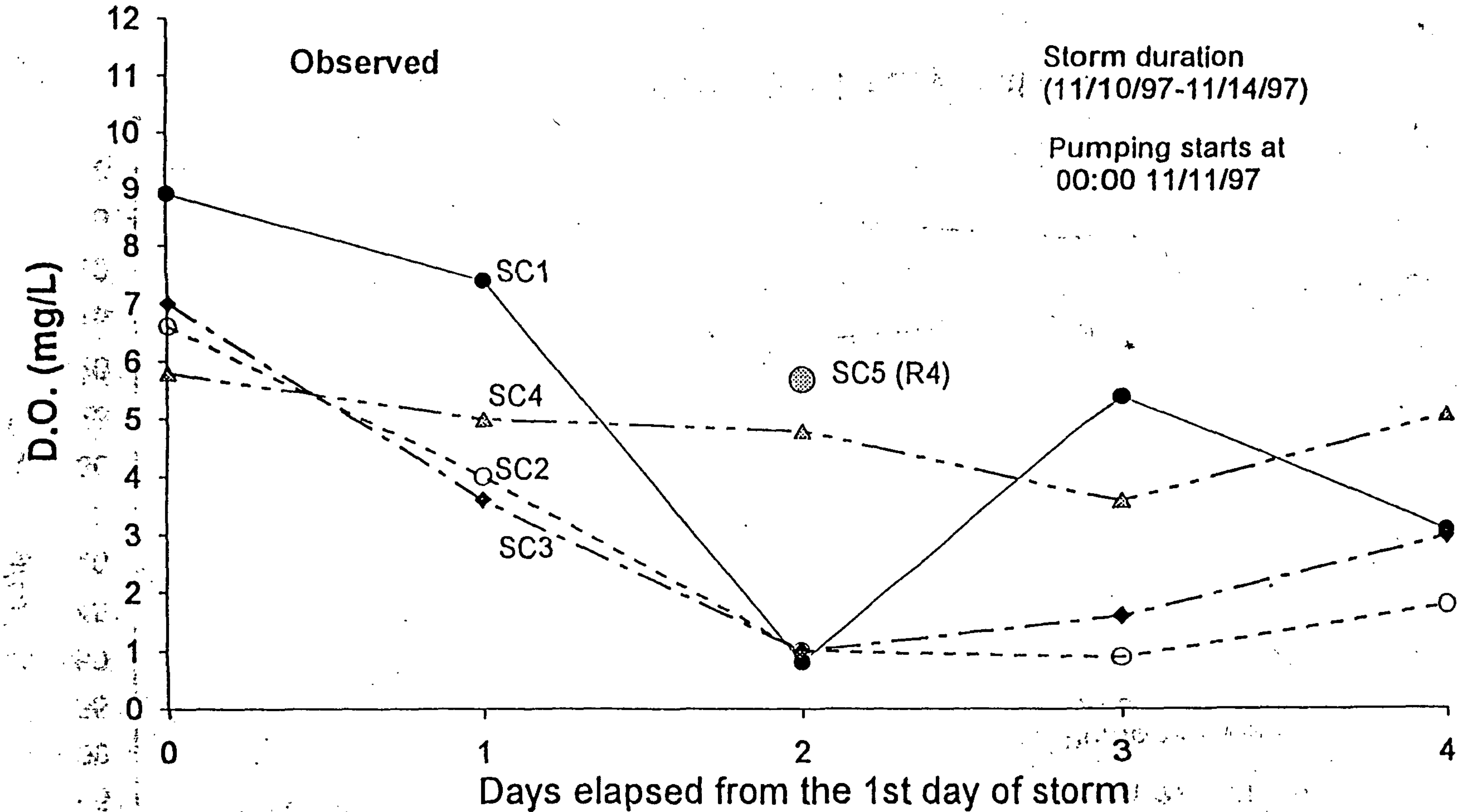


Figure 6. DO in Smith Canal After the Storm of November 10-14, 1997

Where?

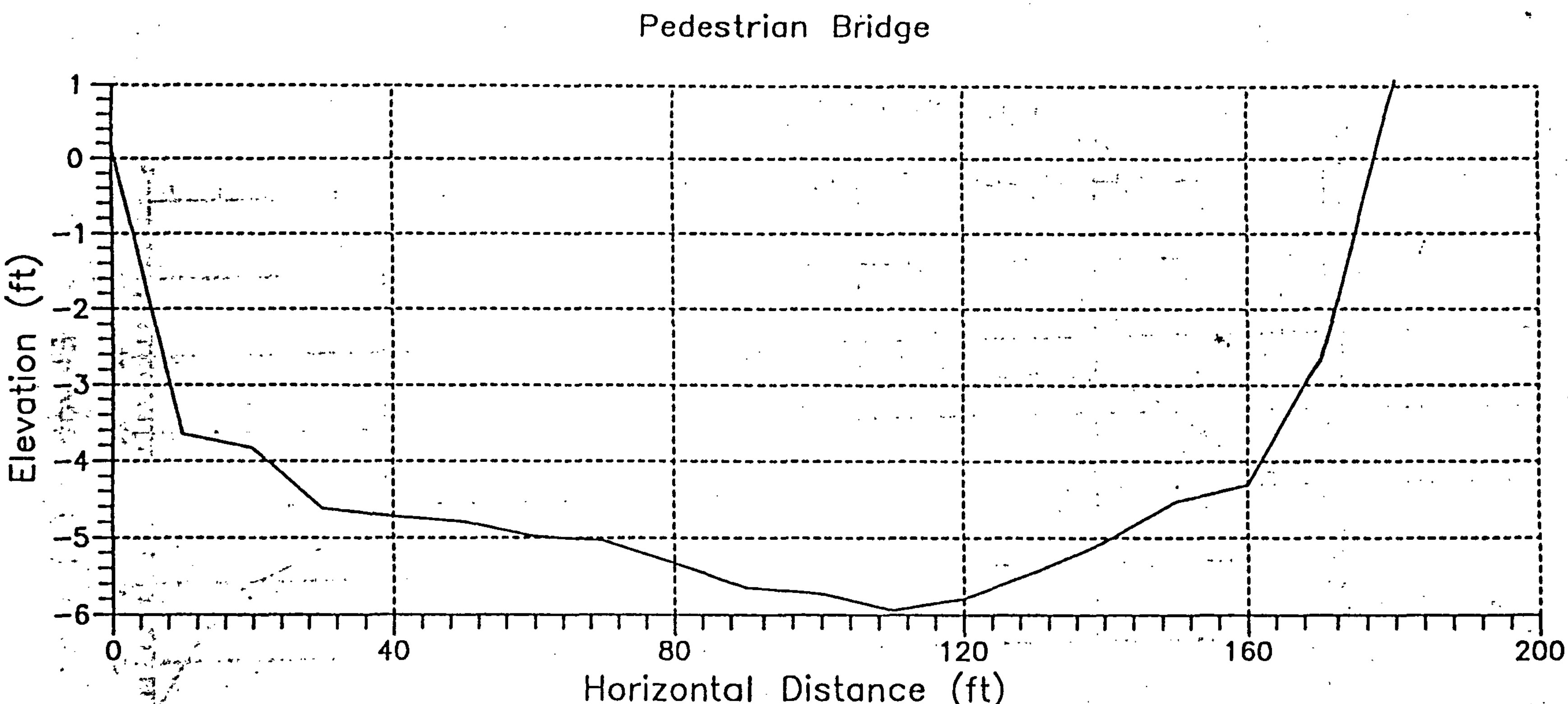


Figure 7. Channel Cross Section at Pedestrian Bridge

SC-2?

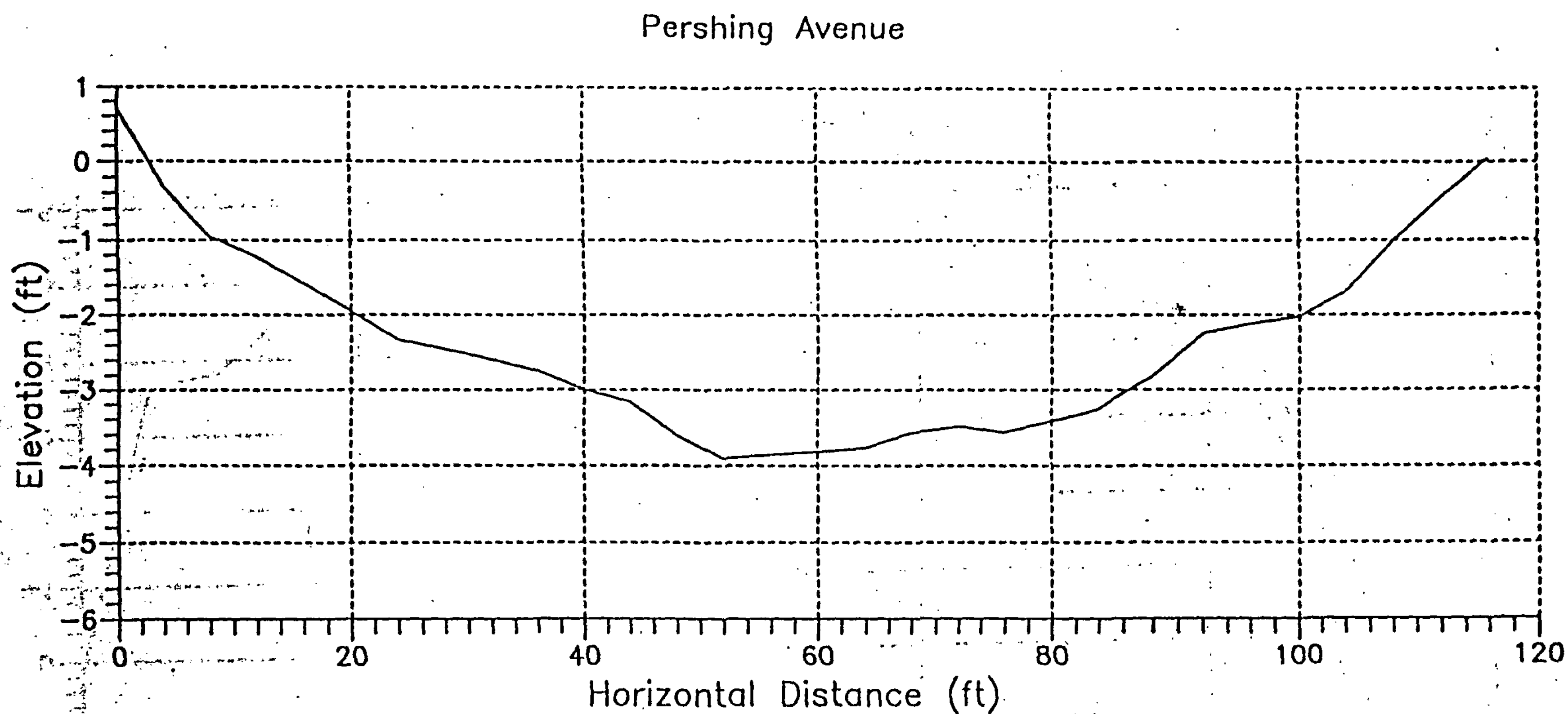


Figure 8. Channel Cross Section at Pershing Avenue

SEDIMENT BOD

To measure sediment BOD, the City of Stockton contracted with Kinnetic Laboratories, Inc. to obtain sediment cores at two locations: one at the Pedestrian Bridge and the other at the Pershing Avenue crossing. At each location, 3 sediment cores were taken along a transect across the channel: one in the middle, one in the south and one in the north.

The top 5 cm of the core was dissected as the top sample (TOP) and the section from 6 to 10 cm of the core was dissected for the bottom sample (BOT). There are 6 mud samples at Pedestrian Bridge crossing (PS-1TOP, PS-1BOT, PS-2TOP, PS-2BOT, PS-3TOP and PS-3BOT) and 6 mud samples at Pershing Avenue crossing (PA-1TOP, PA-1BOT, PA-2TOP, PA-2BOT, PA-3TOP and PA-3BOT). Appendix A presents the sampling log sheet provided by Kinnetic Laboratories, Inc. ?

The mud samples were analyzed for solid content, immediate oxygen demand (IDOD) and 5-day biochemical oxygen demand (SBOD). The results are presented in Table 5.

Table 5

Sediment BOD Measured in Smith Canal

[mg O_2 demand/kg mud]

Sample	IDOD (mg/kg)		SBOD (mg/kg)		Total Solids
	wet	dry	wet	dry	
9/18/97					
PA-1TOP	240	560	1200	2800	0.424
PA-1BOT	240	570	930	2200	0.419
PA-2TOP	340	910	1300	3500	0.37
PA-2BOT	250	630	1300	3200	0.394
PA-3TOP	280	1000	1700	5900	0.289
PA-3BOT	270	840	1700	4800	0.317
PS-1TOP	270	680	1500	3800	0.392
PS-1BOT	250	580	1500	3300	0.441
PS-2TOP	250	650	1400	3600	0.386
PS-2BOT	330	740	1500	3400	0.444
PS-3TOP	200	410	1100	2300	0.485
PS-3BOT	160	230	1100	1500	0.696
11/25/97					
PA-1TOP	190	520	1100	2800	0.373
PA-1BOT	170	390	1100	2400	0.436
PA-2TOP	250	740	1200	3600	0.333
PA-2BOT	250	670	1300	3400	0.381
PA-3TOP	220	710	1500	4900	0.318
PA-3BOT	230	570	1200	2900	0.403

PS-1TOP	230	650	960	2700	0.361
PS-1BOT	240	640	1100	2600	0.421
PS-2TOP	170	510	1000	3100	0.337
PS-2BOT	170	400	900	2100	0.429
PS-3TOP	170	330	1100	2000	0.53
PS-3BOT	110	170	850	1300	0.674
6/22/98					
PA-1TOP	240	590	1300	3200	0.413
PA-1BOT	230	500	1100	2400	0.457
PA-2TOP	440	1400	1400	4200	0.327
PA-2BOT	350	930	1200	3300	0.378
PA-3TOP	360	950	1300	3500	0.386
PA-3BOT	170	360	950	2000	0.473
PS-1TOP	220	560	1100	2900	0.389
PS-1BOT	240	540	1600	3600	0.44
PS-2TOP	180	440	1200	2900	0.411
PS-2BOT	170	360	1000	2100	0.472
PS-3TOP	160	320	1200	2300	0.513
PS-3BOT	130	210	1200	2100	0.603

As shown in the table, the measured values are in milligram of oxygen demand per kilogram of dry mud. However, the SBOD is parameterized by gram of oxygen demand per square feet per day. So, an unit conversion must be performed. The calculation for the unit conversion is described below.

Basis?

It is assumed that the top 5 centimeter of sediment consumes dissolved oxygen. For the top sample collected at the Pershing Avenue crossing (PA-1TOP), the SBOD was 2800 mg/kg of dry mud. The solid fraction of the mud was 0.424. The volume for one kilogram of mud is:

Volume = (1 kg of mud) / (250 kg/m3 x 0.424) in cubic meter

For a 5 cm thickness of the mud, this volume of mud can be spread to an area:

Area = Volume / 0.05 = 0.1887 in square meter

Area = 2.03 in square feet

The SBOD of 2800 mg/kg was measured in 5 days. On a per day basis, SBOD equals to 560 mg/kg-day. The SBOD on a per square feet basis can be calculated as follow:

SBOD = 560 mg/kg-day x 1 kg / 2.03 square feet
SBOD = 0.28 g/square feet per day.

METEOROLOGY

Mean air temperature, dew point temperature, wind speed, and rainfall are also input data to the model. The meteorological data was compiled from Stockton Airport station and plotted in Figure 9.

OTHER DATA

The effluent data was compiled from Stockton's Regional Wastewater Treatment Facility. The data included the daily flow and concentrations of BOD, ammonia, nitrate, phosphate, and other constituents discharged to the San Joaquin River.

Monitoring data measured at 8 stations (R1 through R8) was also compiled from the City of Stockton. The data was used to check against the simulation results.

The river flows at Vernalis, the records of rock barrier operation at the head of Old River, and pumping rates at Tracy Pump were compiled from the Department of Water Resources. The data was used to calculate the river flow passed Stockton.

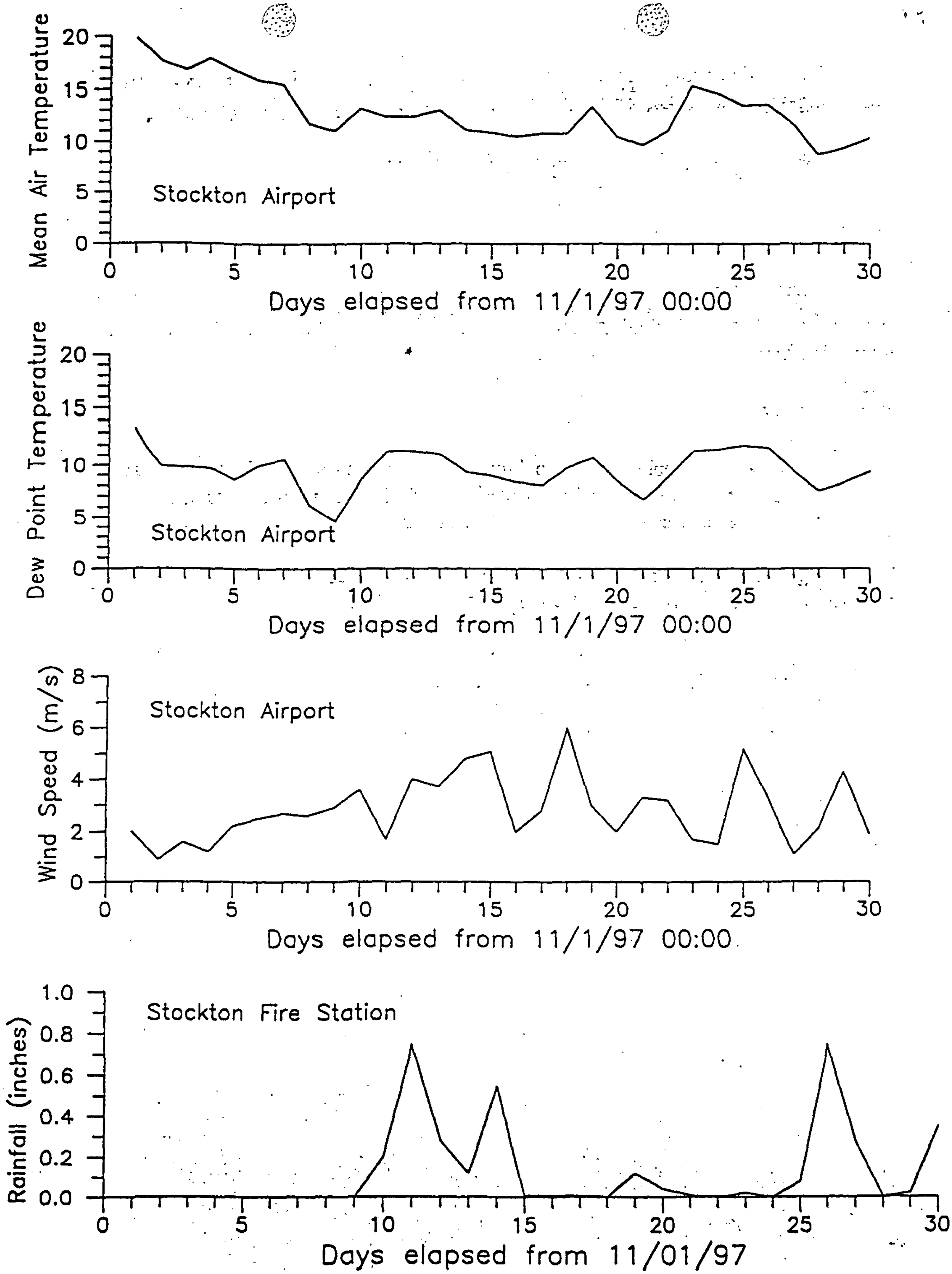


Figure 9. Meteorology at Stockton Airport

Chapter 3

MODEL SIMULATION

MODEL ENHANCEMENT

To simulate the stormwater effect, it is necessary to make modifications to the City's water quality model. It is necessary to add the features of scouring of sediment from the bed, the transport and deposition of scoured particles, and the bed load transport of sediment at the bottom. It is also necessary to add the BOD of scoured particles into the sink term of dissolved oxygen.

The equations for scouring, deposition, and transport of sediment have previously been incorporated into the model version, used to evaluate the transport and fate of copper discharged to San Francisco Bay (Chen, Leva, and Oliveri 1996). They are incorporated into the City's water quality model for the Smith Canal application. These equations are derived after a careful reviews of literature contained in ANSWERS (Beasely and Higgins 1991) and Graf (1971).

In the model, the sediment contains clay, silt, and sand fractions. Scouring is assumed to occur when the flow velocity exceeds a critical value:

$$V_{CR} = \sqrt{25 * 0.65 g d^{0.8} D^{0.2}}$$

where V_{CR} = critical velocity; g = acceleration due to gravity (9.81 m/s^2); d = particle diameter; and D = water depth. The rate of scouring is:

$$S = K A_W (V_{AVE} - V_{CR})^b$$

where S = scouring rate in kg/s; K = a calibration parameter; A_W = area of the wetted channel bed; V_{AVE} = average flow velocity in m/s; V_{CR} = critical velocity; b = a calibration parameter.

The scoured clay, silt, and sand are assumed to be subjected to transport and dispersion like any other constituents. They can also settle according to their settling velocities. Since sand has a very high settling velocity, the scoured sand may be re-deposited to the bed very quickly.

The bed load transport is assumed to occur only on the sand fraction. The bed load transport capacity of sand is a function of the shear velocity, shear stress, Reynolds Number, and critical shear stress:

$$V^* = \sqrt{gDS}$$

$$Y = \frac{V^{*2}}{(\gamma - 1)gd}$$

$$NR = \frac{V^* d}{\nu}$$

$$Y_{CR} = f(N_R)$$

where V* = shear velocity in m/s; g = acceleration due to gravity; D = hydraulic radius (water depth) in m; Y = shear stress; γ = specific gravity of the soil particles; d = diameter of soil particles in m, N_R = Reynolds Number; ν = kinematic viscosity of water in m^2/s; and Y_{CR} = critical shear stress, taken from Shield Diagram (Graf 1971).

The bed load transport capacity of sand is calculated according to Yalin equation,

$$T_f = P_S \gamma \rho_w d V^* W$$

$$PS = 0.635\Delta[1 - \frac{\ln(1+\Sigma)}{\Sigma}$$

$$\Delta = \frac{Y}{Y_{CR}} - 1$$

$$\Sigma = 2.45\rho - 0.4\Delta\sqrt{Y_{CR}}$$

where ρ_w = density of water in kg/m3 and W = wetted perimeter of channel in m. The value of $\Delta = 0$ when Y is less than Y_{CR}.

The scouring of sand is compared to the bed load transport capacity. The eroded sand in excess of T_f is immediately re-deposited to the bed. If the scoured sand is less than T_f, the sand may remain in suspension.

To account for the oxygen demand from the scoured mud, it is assumed that the fresh scour exerts an oxygen demand:

$$IOD = aC_s$$

where IOD = immediate oxygen demand in mg/l; a = rate coefficient; C_S = concentration of the freshly scoured sediment in mg/l. The suspended sediment remained in suspension will also exert an oxygen demand:

$$BOD_{SS} = bC_{SS}$$

where BOD_{SS} = oxygen demand exerted by suspended sediment in solution; b = rate coefficient; C_{SS} = concentration of suspended sediment.

For the lack of data, the a-value for IOD was assumed to be 0.015. The b-value for BOD was assumed to be 0.0015. reasonable?

FUNCTIONAL TESTING

A functional test of model was performed after the model modification. Everything appeared to function properly, except the response of dissolved oxygen. Figure 10 presents the dissolved oxygen response obtained during the functional test. The model showed that the dissolved oxygen depression was too small as compared to the observed data shown in Figure 6. As a result, the dissolved oxygen recovered in Smith Canal 3 days after the storm, which was too fast according to the observed data.

It was reasoned that the problem was caused by the low estimate of suspended sediment load in the stormwater input. The suspended sediment load shown in Table 4 was based on stormwater samples collected on land, before entering the storm sewers. Upon entry to the storm sewers, the water may pick up suspended sediment, that has been accumulated at the bottom of storm drain.

Without the direct measurement of water quality in the effluent of stormwater pumps, the equations for the carrying capacity of suspended sediment were used to estimate the suspended sediment loads: Should have sampled this

$$C_{clay} = 0.0027Q^{1.5}$$

$$C_{silt} = 0.0018Q^{1.5}$$

$$C_{sand} = 0.00072Q^{1.5}$$

where C_{clay} = input of clay particles in the stormwater in kg/s; C_{silt} = input of silt particles in the stormwater in kg/s; C_{sand} = input of sand particles in the stormwater in kg/s; and Q = flow rate of stormwater in cfs.

It was assumed that the suspended sediment scoured from storm sewers would have the same sediment BOD as those scoured from the bottom of Smith Canal.

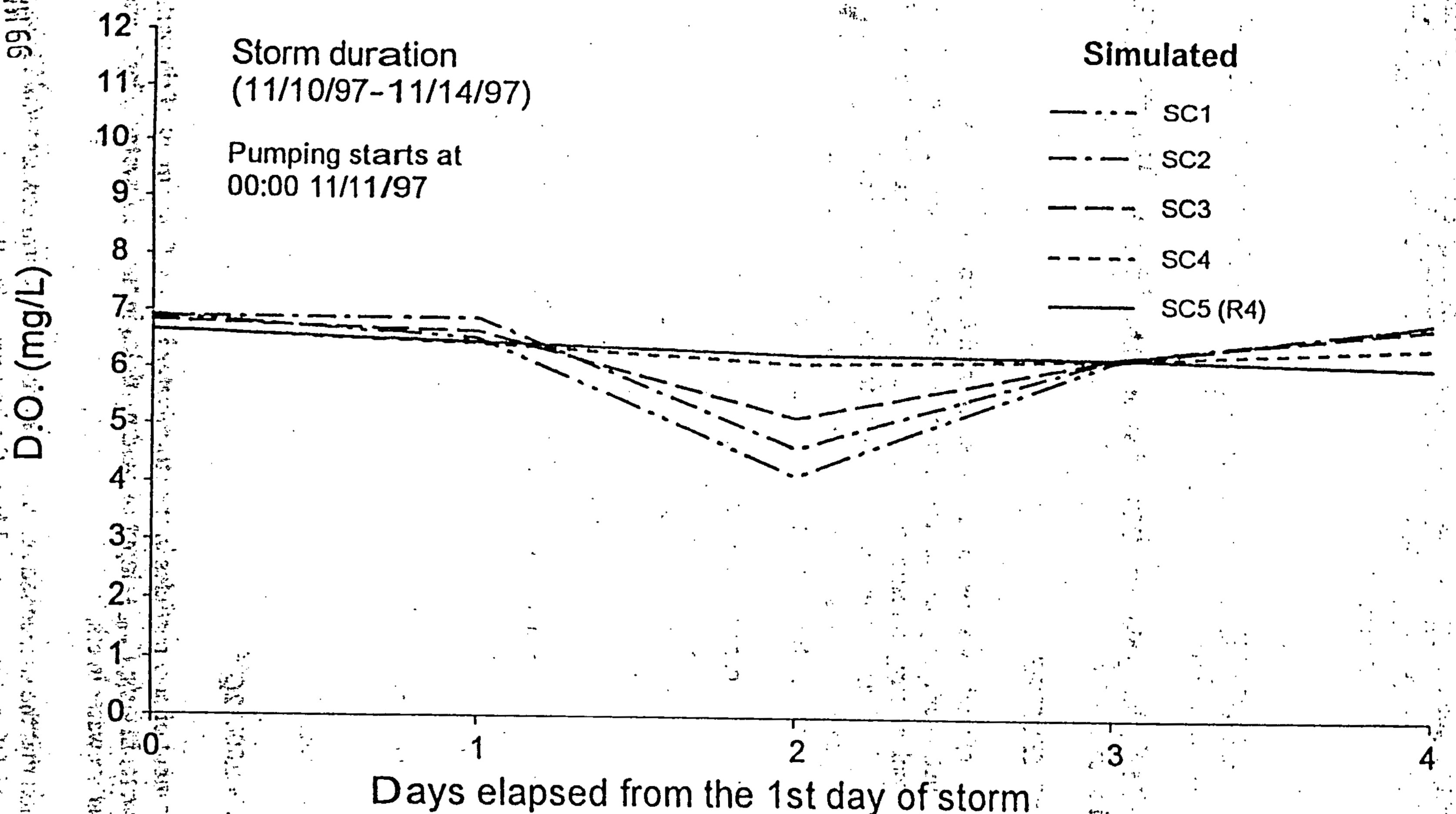


Figure 10. Simulated DO Without SS in Storm Sewers

SAN JOAQUIN RIVER SIMULATION

The first step in the model simulation was to check whether the water quality model could simulate the water quality conditions in the San Joaquin River for 1997. The simulated water temperature are compared to the observed in Appendix B. The simulated dissolved oxygen are compared to the observed in Appendix C.

The results indicate that the model was tracking the observed data throughout the period of June to November 1997 at monitoring stations from R1 to R8. Since no model coefficients have been re-adjusted since the last calibration, this should be considered as another verification of the model.

SUSPENDED SEDIMENT SIMULATION

Figure 11 presents the simulated suspended particle concentrations in Smith Canal after the storm of November 10-14, 1997. The rise and fall patterns of suspended sediment follow those of observed turbidity shown in Figure 4. The highest concentration occurs at SC1, decreasing toward SC5, consistent with the turbidity data.

However timing is slightly off. The model shows that the peak concentrations would occur in less than 24 hours. Unfortunately, the sampling was made only once a day. It could have missed the time of peak concentrations.

The simulated concentrations of suspended sediment show an order of magnitude increase, whereas observed turbidity increased only 5 to 6 times at SC1. The over predictions of suspended sediment is clear, even if we account for the fact that sampling might have missed the peak concentration and also that turbidity and suspended sediment might not have a linear relationship.

The over prediction of suspended sediment might have been caused by the over prediction of suspended sediment load from stormwater input. In the model, we might have compensated the over prediction of suspended sediment by assigning an order of magnitude lower BOD exertion rate of suspended sediment.

BOD SIMULATION

Figure 12 presents the simulated BOD concentrations after the storm in Smith Canal. Compared to the observed BOD shown in Figure 5, the simulated BOD was about two times of the observed.

The over predictions of BOD were caused by the over predictions of suspended sediment. The problem can be overcome with new data.

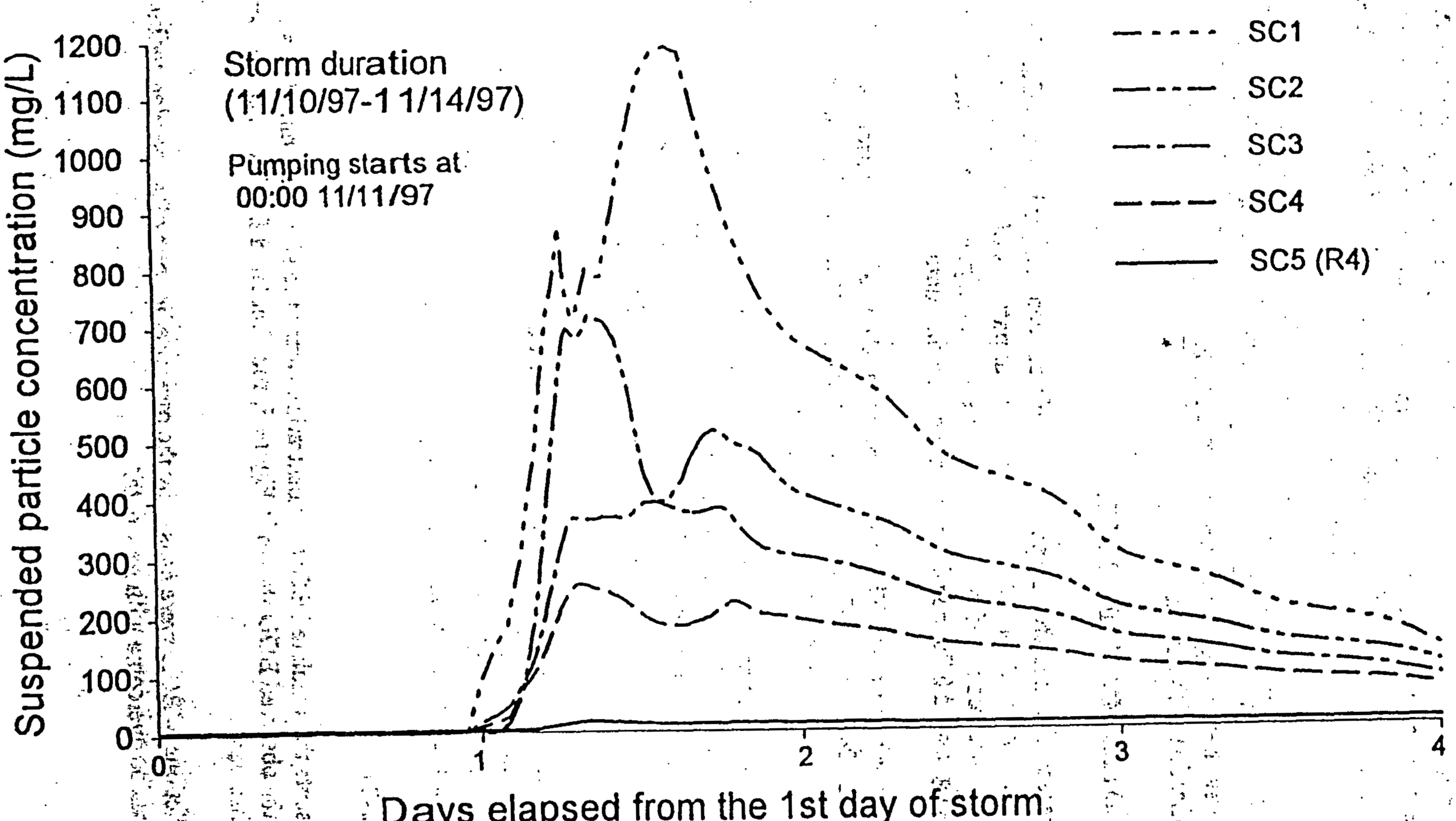


Figure 11. Simulated SS after the Storm of November 10-14, 1997

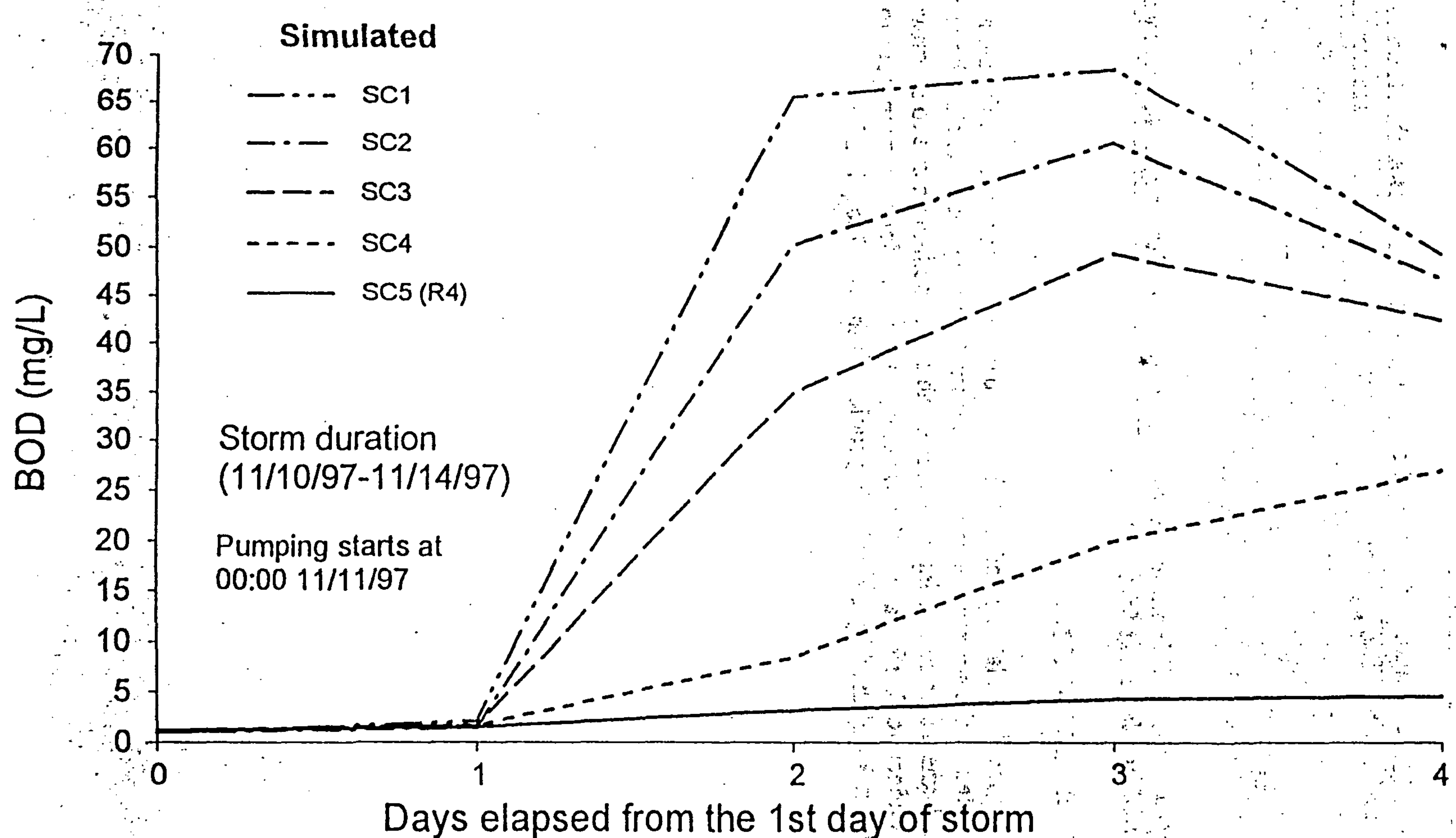


Figure 12. Simulated BOD after the Storm of November 10-14, 1997

DISSOLVED OXYGEN SIMULATION

Figure 13 presents the simulated dissolved oxygen in Smith Canal after the storm of November 10-14, 1997. The patterns of DO depression and DO recovery are similar to the observed shown in Figure 6. For the observed, we could not explain why the dissolved oxygen at SC1 had higher concentration than SC2 or SC3 before the stormwater input. We could not explain why the dissolved oxygen at SC1 would jump up on the 3rd day and drop down on the 4th day of the storm.

In all, it appears that the DO did not recover in the 4th day of the storm. The recovery was slowest at SC1 and fastest at SC4.

GENERAL OBSERVATION

Based on the model simulations and the observed data, SC1 appears to be the most severely affected by the stormwater input. This is the tip of the dead end slough which received the highest stormwater input. The rise and fall of pollutants due to stormwater input was confined to Smith Canal. The water quality impact does not propagate to SC5, which is station R4 of the City's monitoring station on the San Joaquin River.

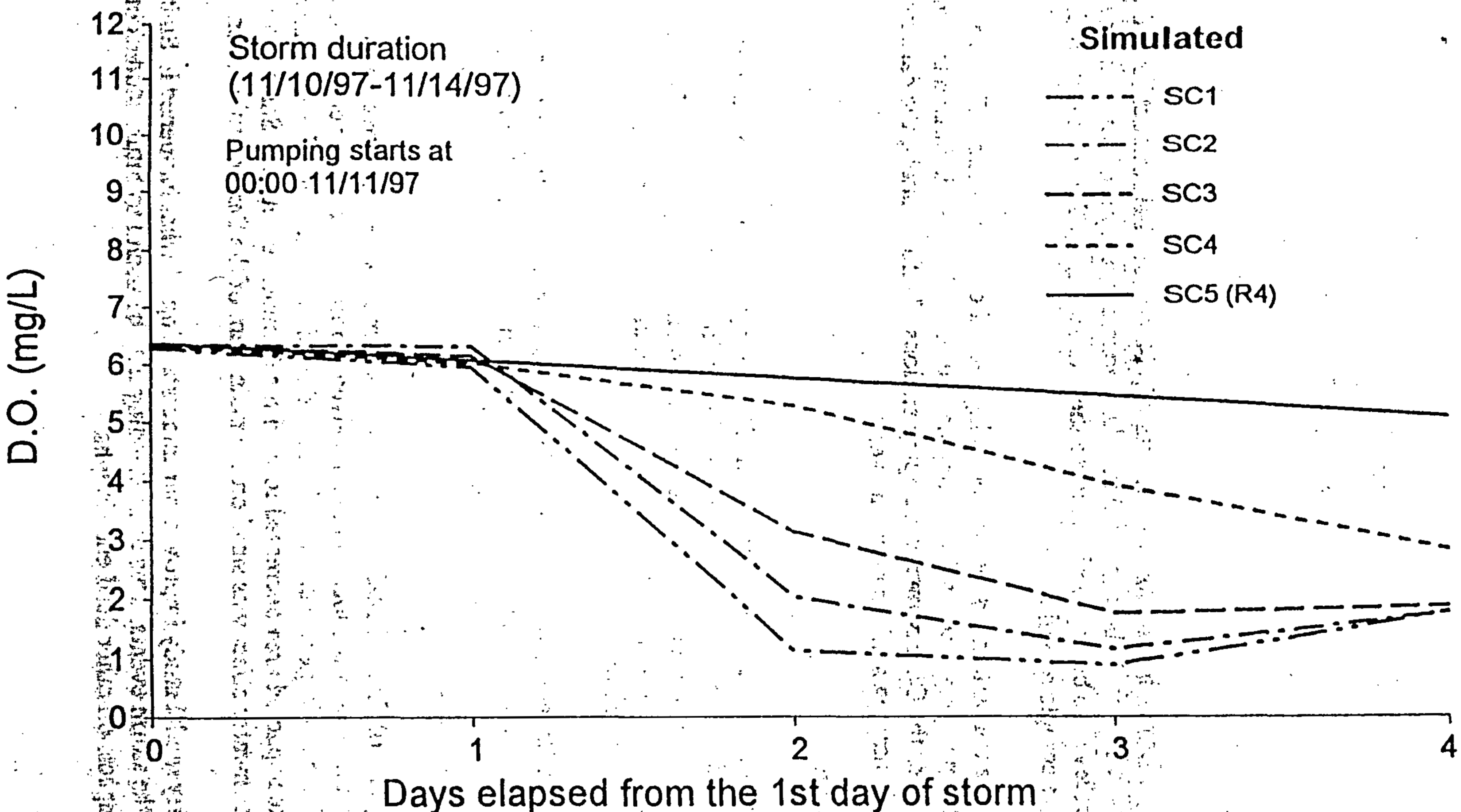


Figure 13. Simulated DO after the Storm of November 10-14, 1997

Chapter 4.

CONCLUSIONS

LIMITATIONS

The investment for this initial model study was 20,000 dollars. This budget limited the amount of effort that could be expended in calibrations and analyses. However, the limited budget was believed to be appropriate due to the uncertainty on the adequacy of data to support a more complete model study.

There was also an uncertainty about the pumping record of stormwater. The City provided us the pumping records for 3 pumping stations. The City indicated that there was more data for the County owned pumping stations. Unfortunately, the data for the County owned pumping stations never arrived.

CONCLUSIONS

The BOD in stormwater runoff ranged from 12 to 19 mg/l. The BOD loading from stormwater could not cause the observed DO depression in Smith Canal. The cause for DO depression in Smith Canal was due to the scouring and resuspension of sediment from the bottom of Smith Canal and also from the scouring and resuspension of sediment from the bottom of storm sewers.

The DO in Smith Canal recovered from the DO depression in more than 5 days after the storm. During this period, the suspended sediment, scoured from channel bottom or storm sewers, was redeposited to the channel bottom. The suspended sediment escapted to the San Joaquin River was small.

The terminal point of Smith Canal at Legion Park was most severely impacted by the stormwater input. This is the location that received stormwater input in terms of flow and pollution load, from a large urban area with mixed residential, commercial and institutional land uses. The impacted area decreased toward the confluence with the San Joaquin River. The stormwater effect was small on the main stem of the San Joaquin River.

This preliminary model study improved our understanding of what happened in Smith Canal during the storm events. This understanding may be useful to future studies of stormwater impacts on other dead end sloughs.

REFERENCES

Beasley, D.B. and L.F. Higgins, 1991. "ANSWERS User's Manual", Publication No. 5, Agricultural Engineering Department, University of Georgia, Coastal Experiment Station, Tifton, GA.

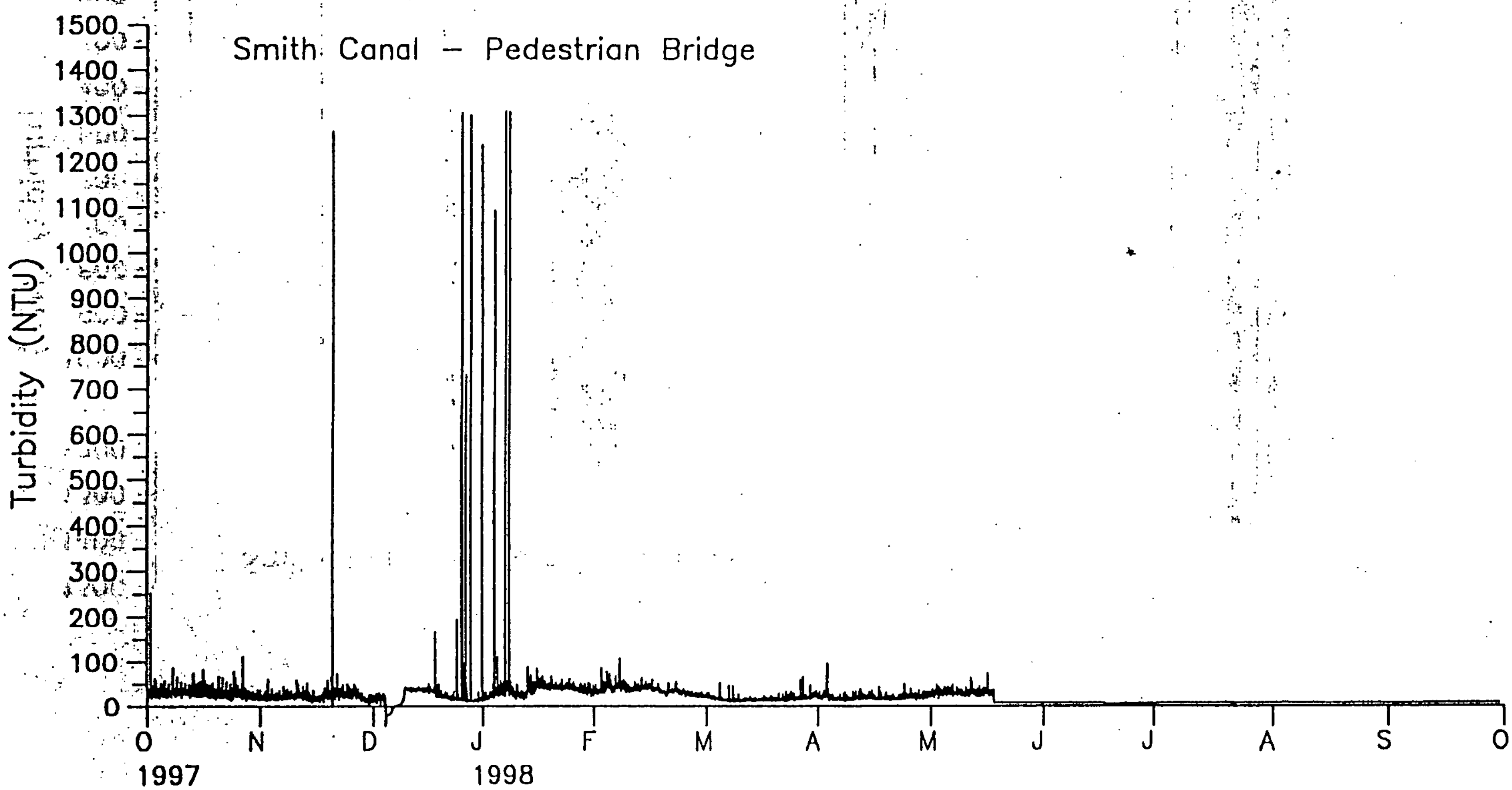
Chen, C.W., D. Leva, and A. Olivieri, 1991. "Modeling the Fate of Copper Discharged to San Francisco Bay", Journal of Environmental Engineering, Vol. 122, No. 10: 924-934.

City of Stockton Stormwater Program, 1996/1997 Stormwater Management and Monitoring Program.

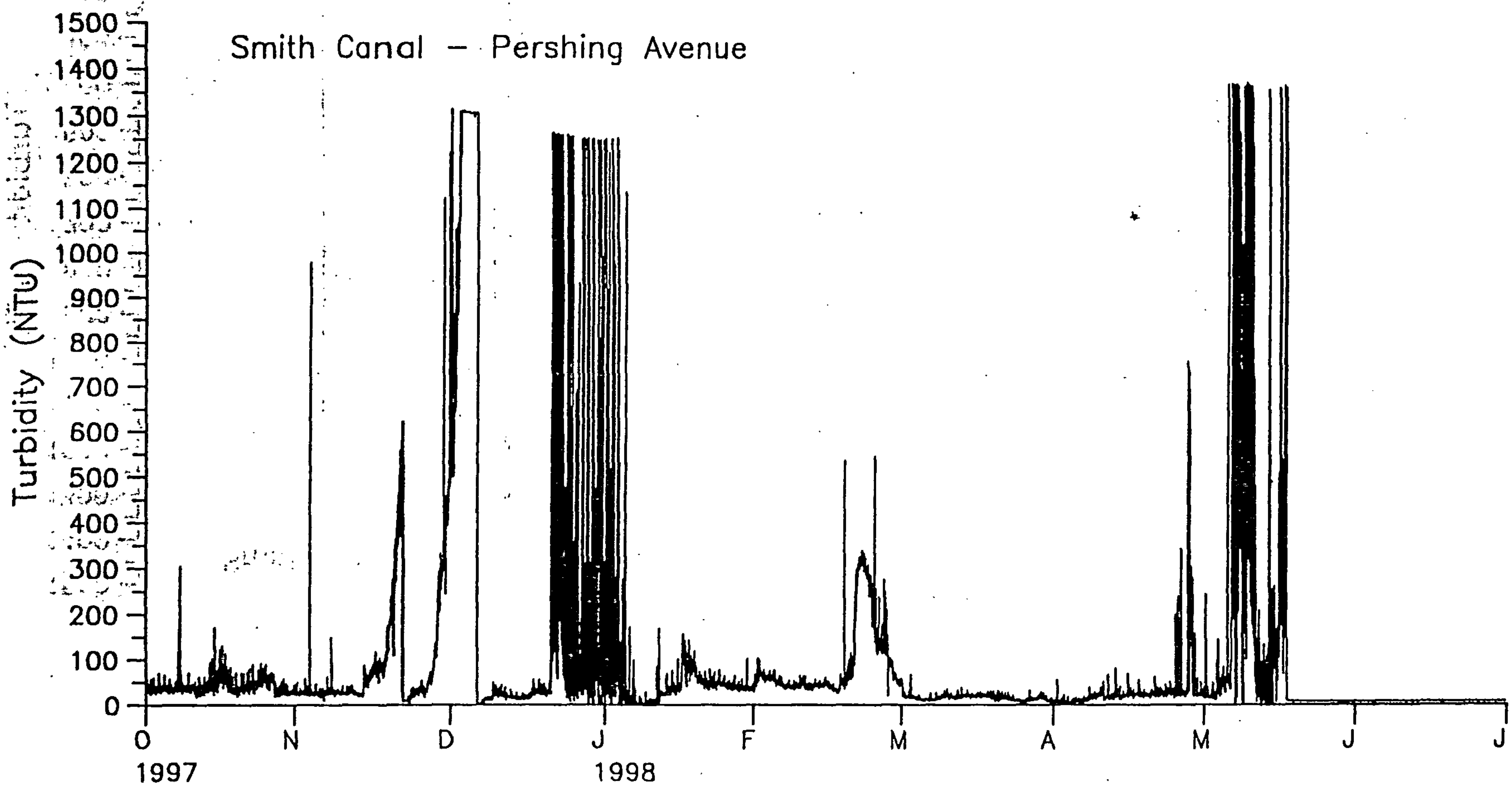
Graf, W. H. 1971. Hydraulics of Sediment Transport. McGraw-Hill Book Company, New York, NY.

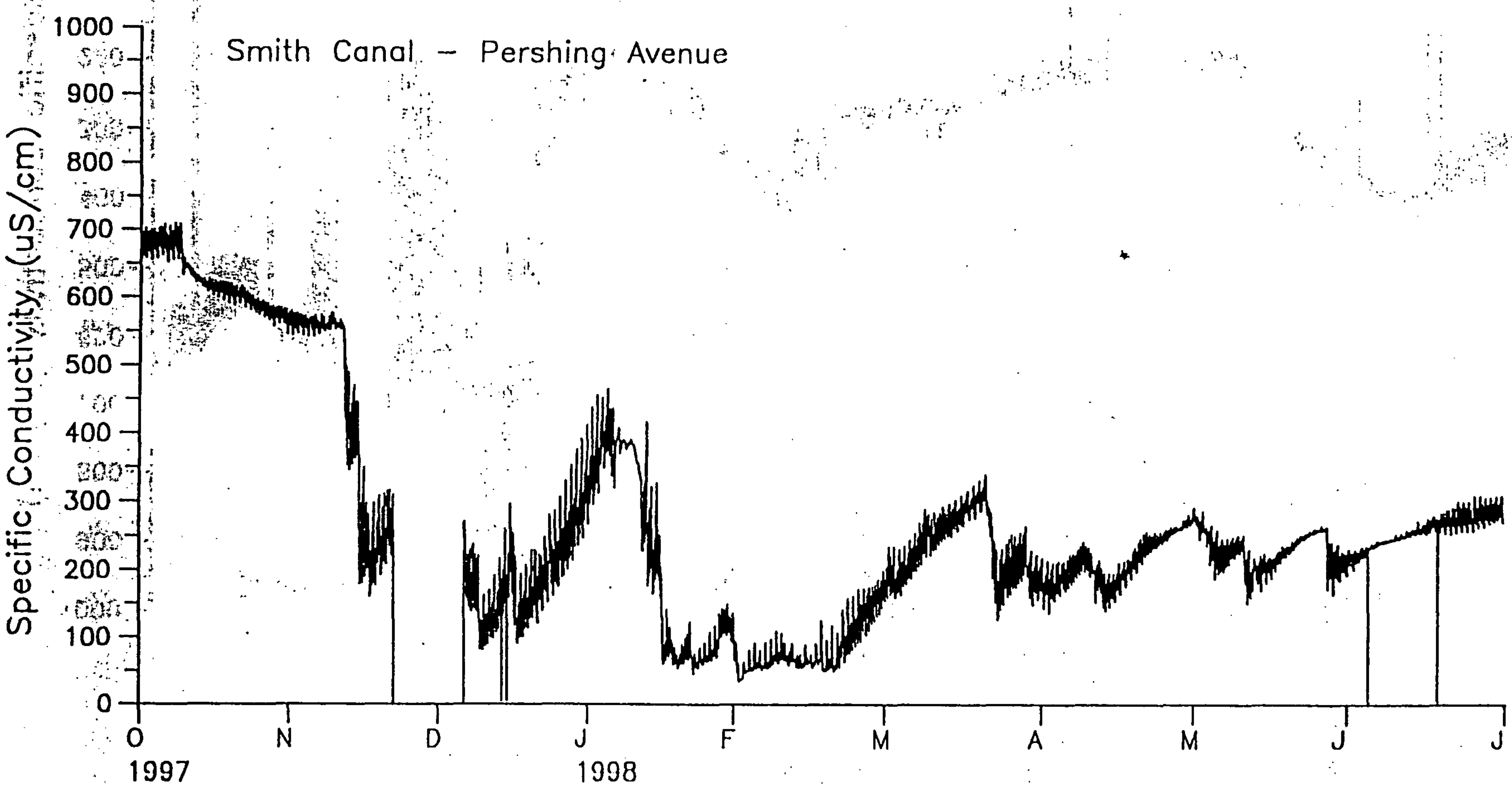
Appendix A

Continuous Recordings of DO, Temperature, Depth, Conductance and Turbidity in Smith Canal

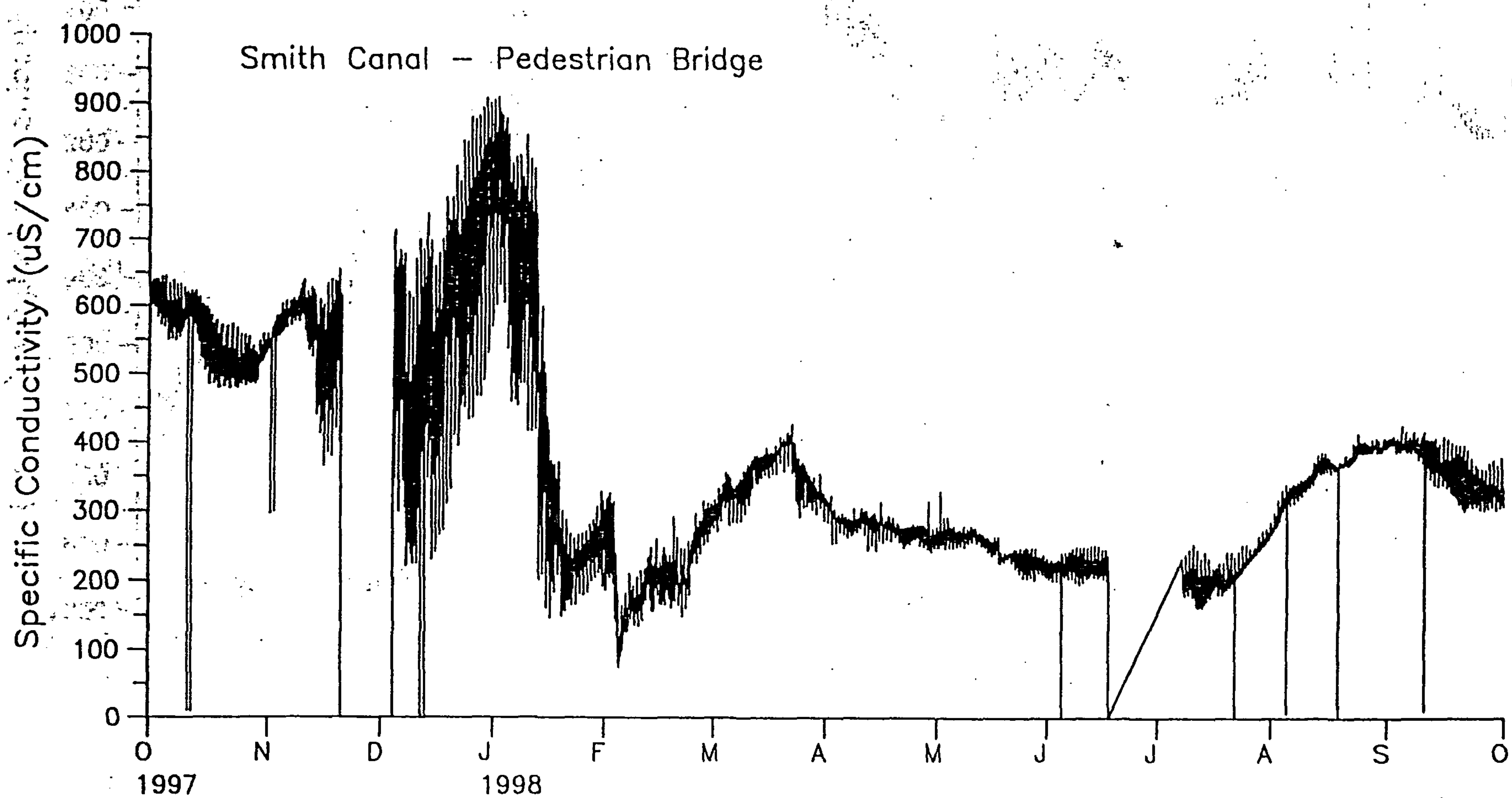


Smith Canal – Pedestrian Bridge
Turbidity (NTU)
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1997
1998

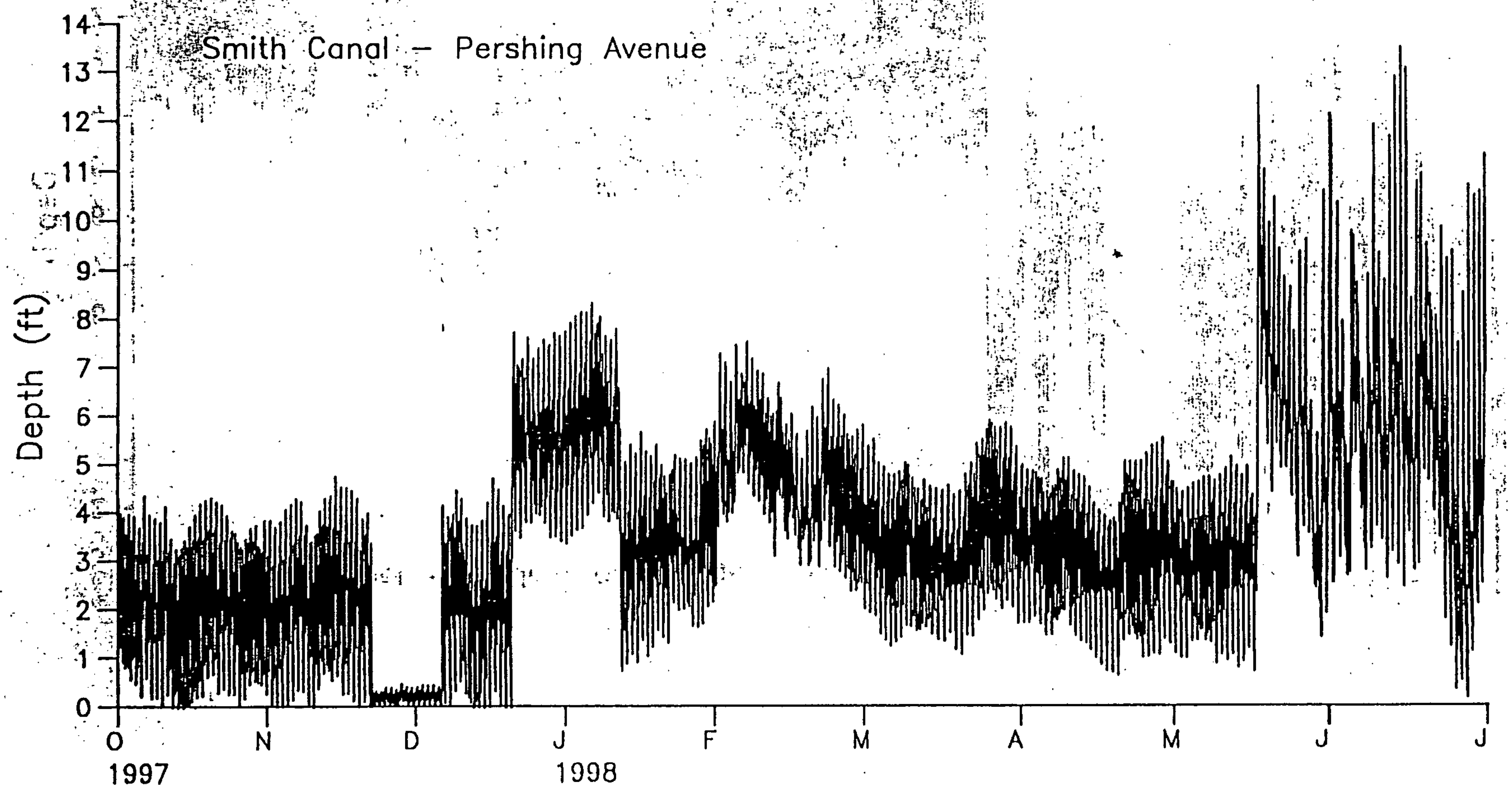

Smith Canal – Pershing Avenue
Turbidity (NTU)
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
O
N
D
J
F
M
A
M
J
J
1997
1998

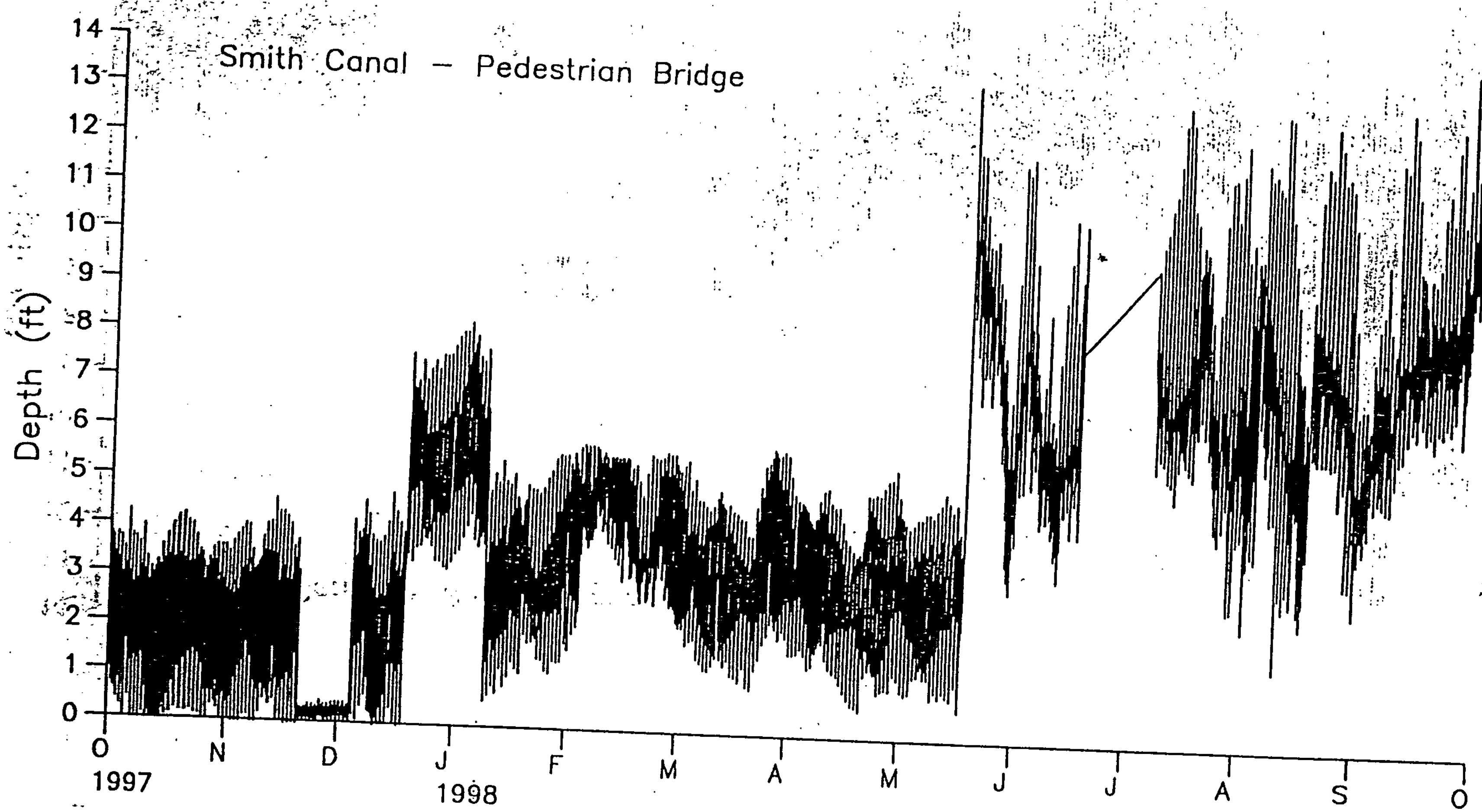


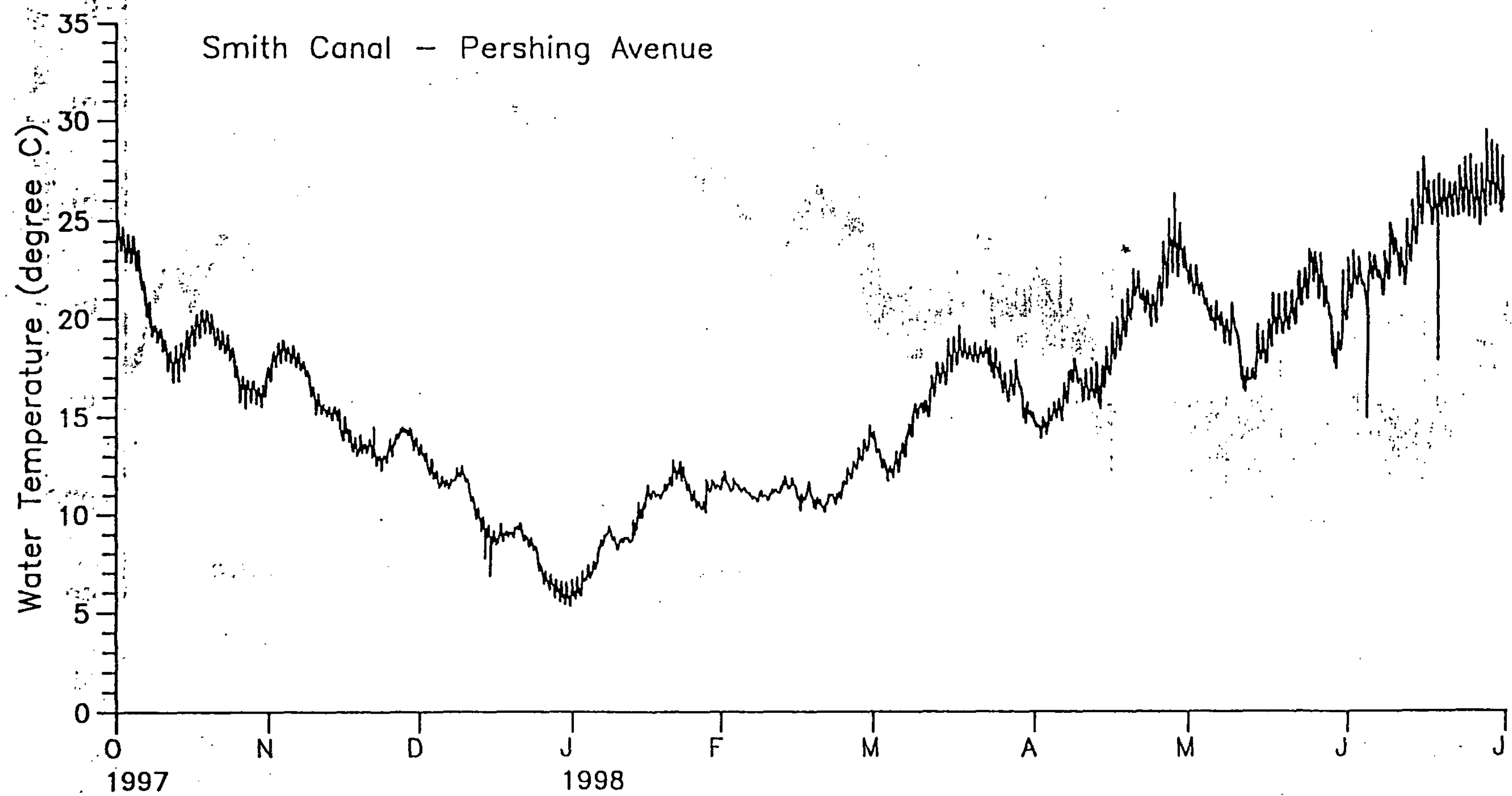
Smith Canal - Pershing Avenue
Specific Conductivity (uS/cm)
1000
900
800
700
600
500
400
300
200
100
0
O
N
D
J
F
M
A
M
J
J
1997
1998



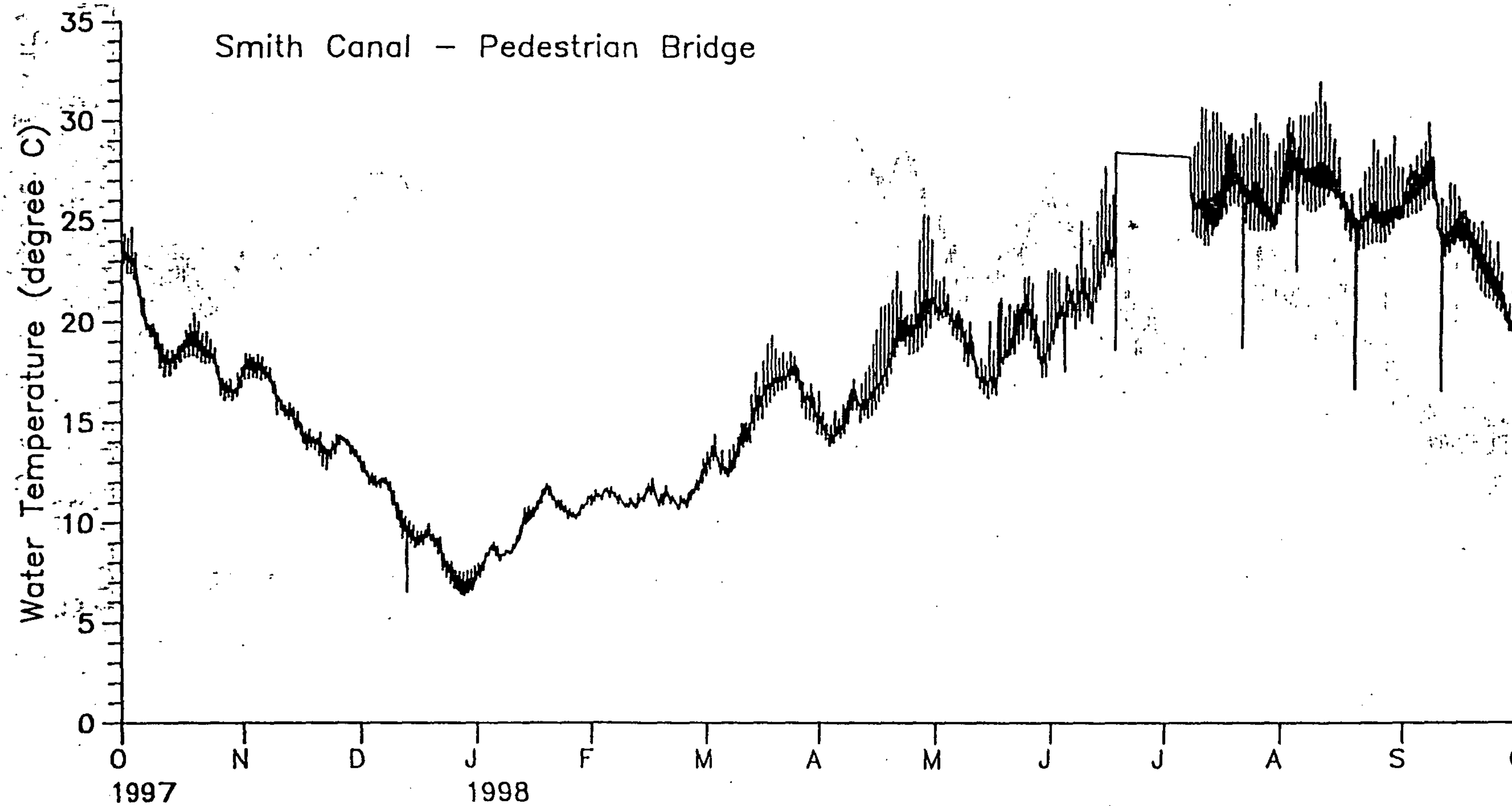
Smith Canal - Pedestrian Bridge
Specific Conductivity (uS/cm)
1000
900
800
700
600
500
400
300
200
100
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1997
1998


Smith Canal – Pershing Avenue
Depth (ft)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
O
N
D
J
F
M
A
M
J
J
1997
1998

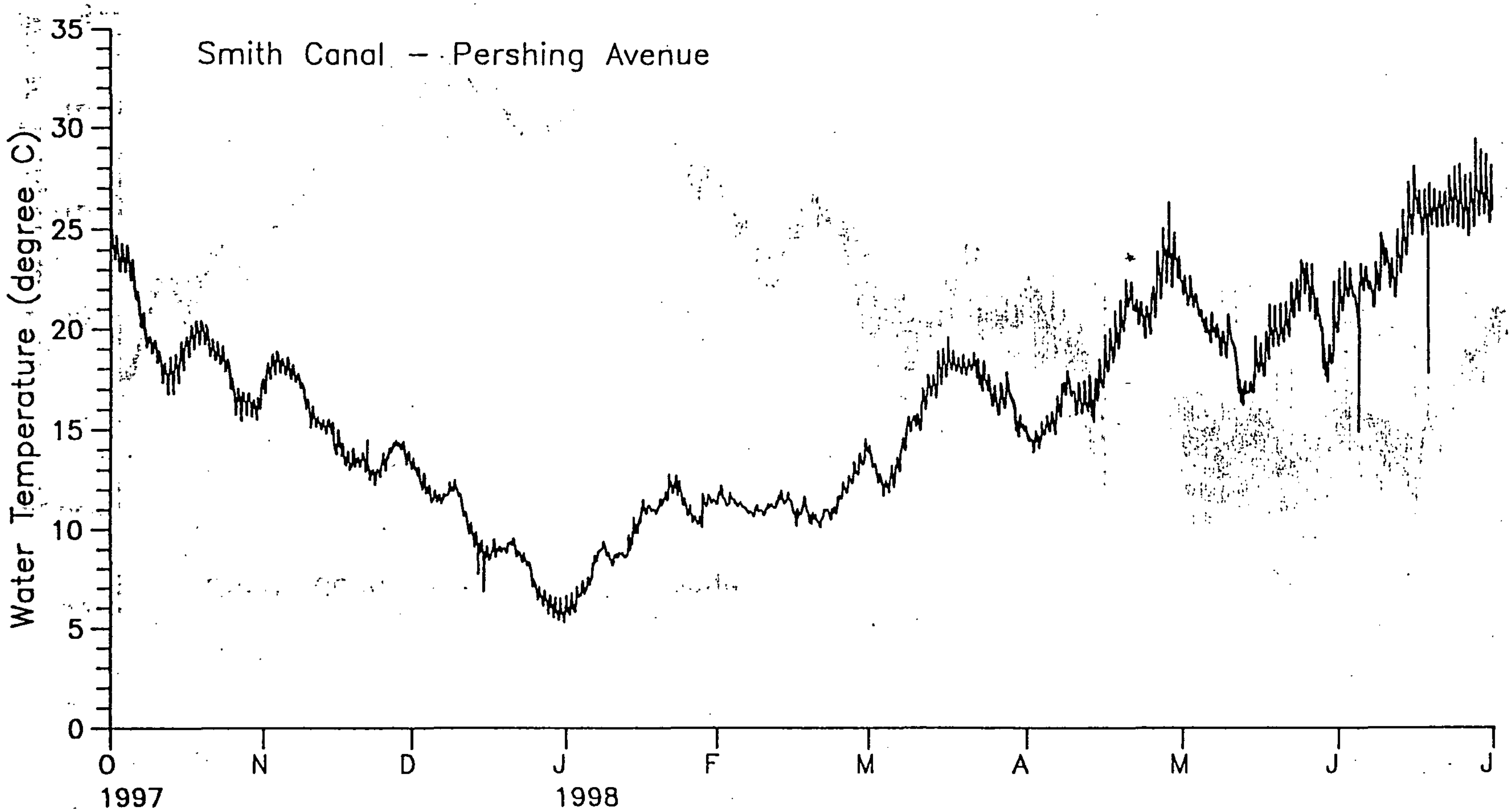

Smith Canal – Pedestrian Bridge
Depth (ft)
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
1997
N
D
J
1998
F
M
A
M
J
J
A
S
O



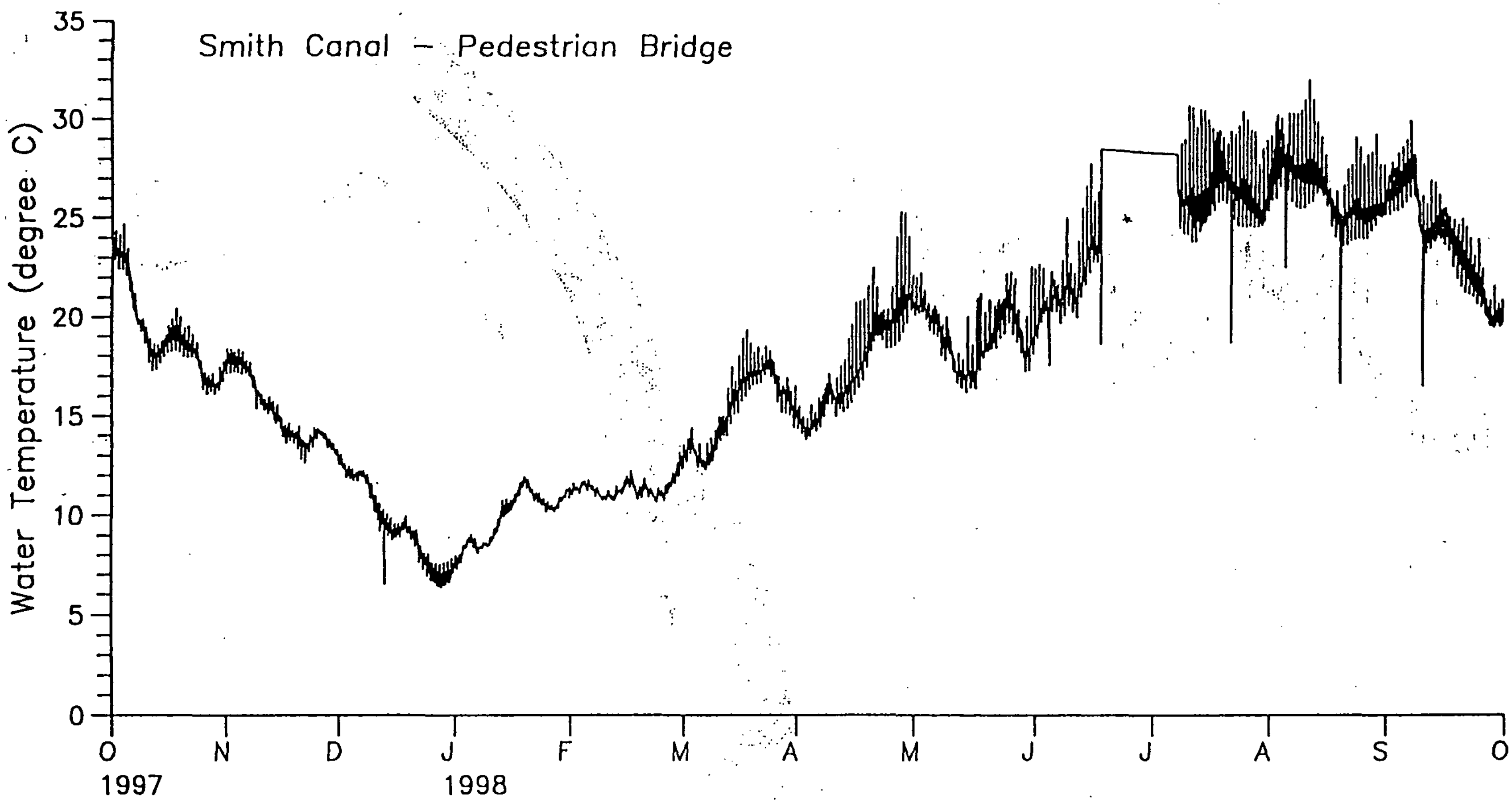
Smith Canal – Pershing Avenue
Water Temperature (degree C)
0
5
10
15
20
25
30
35
O
N
D
J
F
M
A
M
J
J
1997
1998



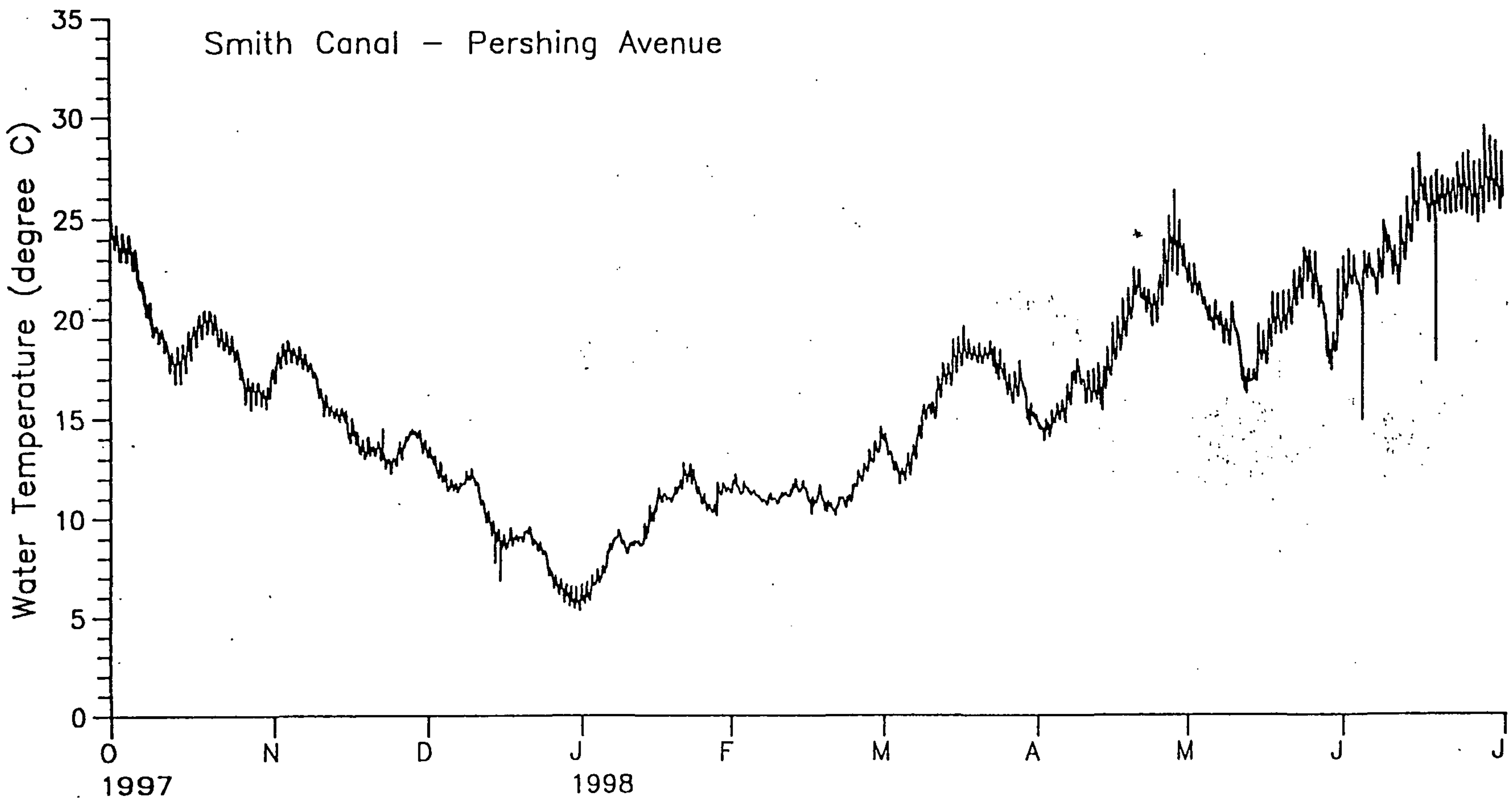
Smith Canal – Pedestrian Bridge
Water Temperature (degree C)
35
30
25
20
15
10
5
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1997
1998

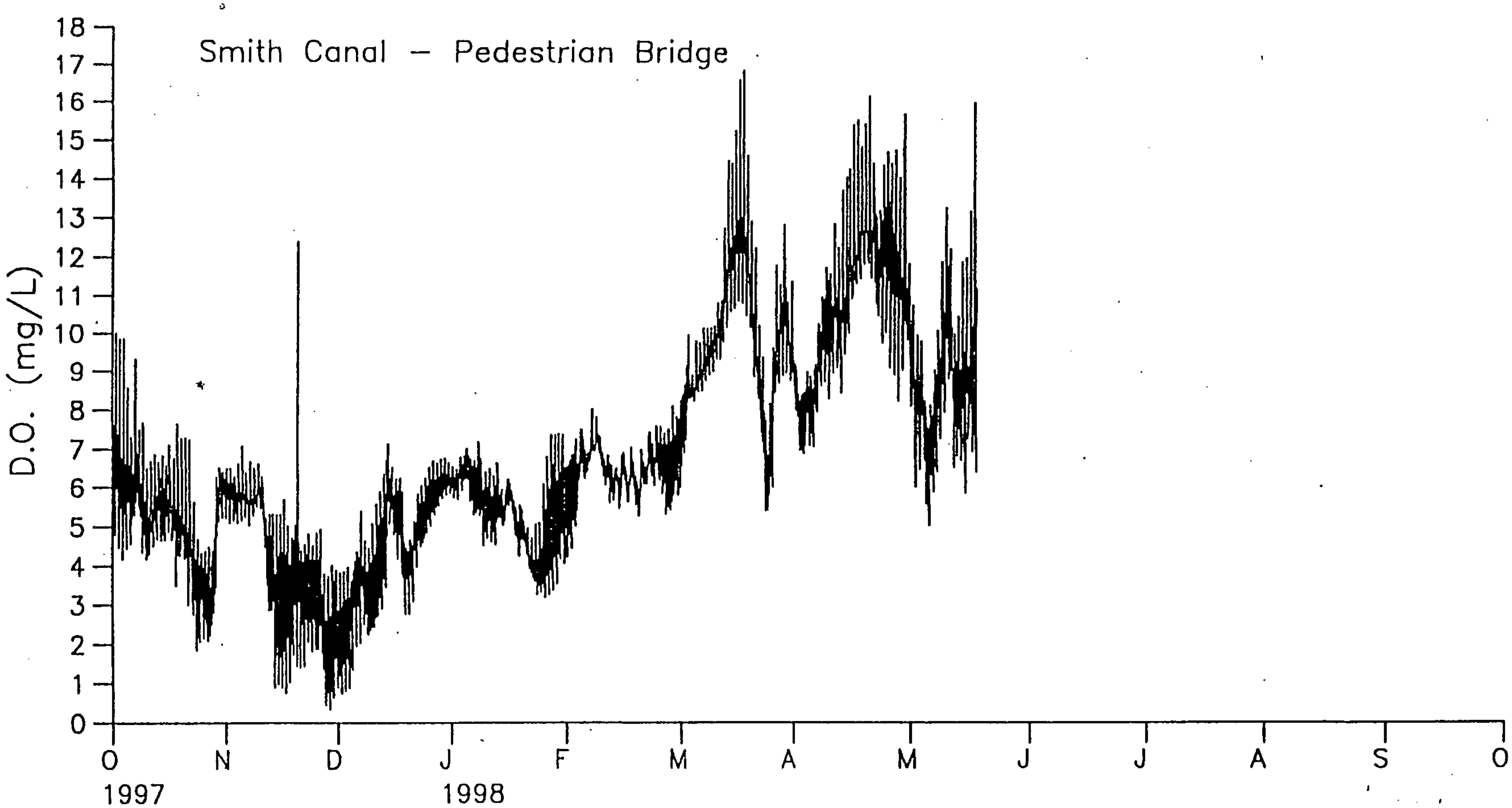


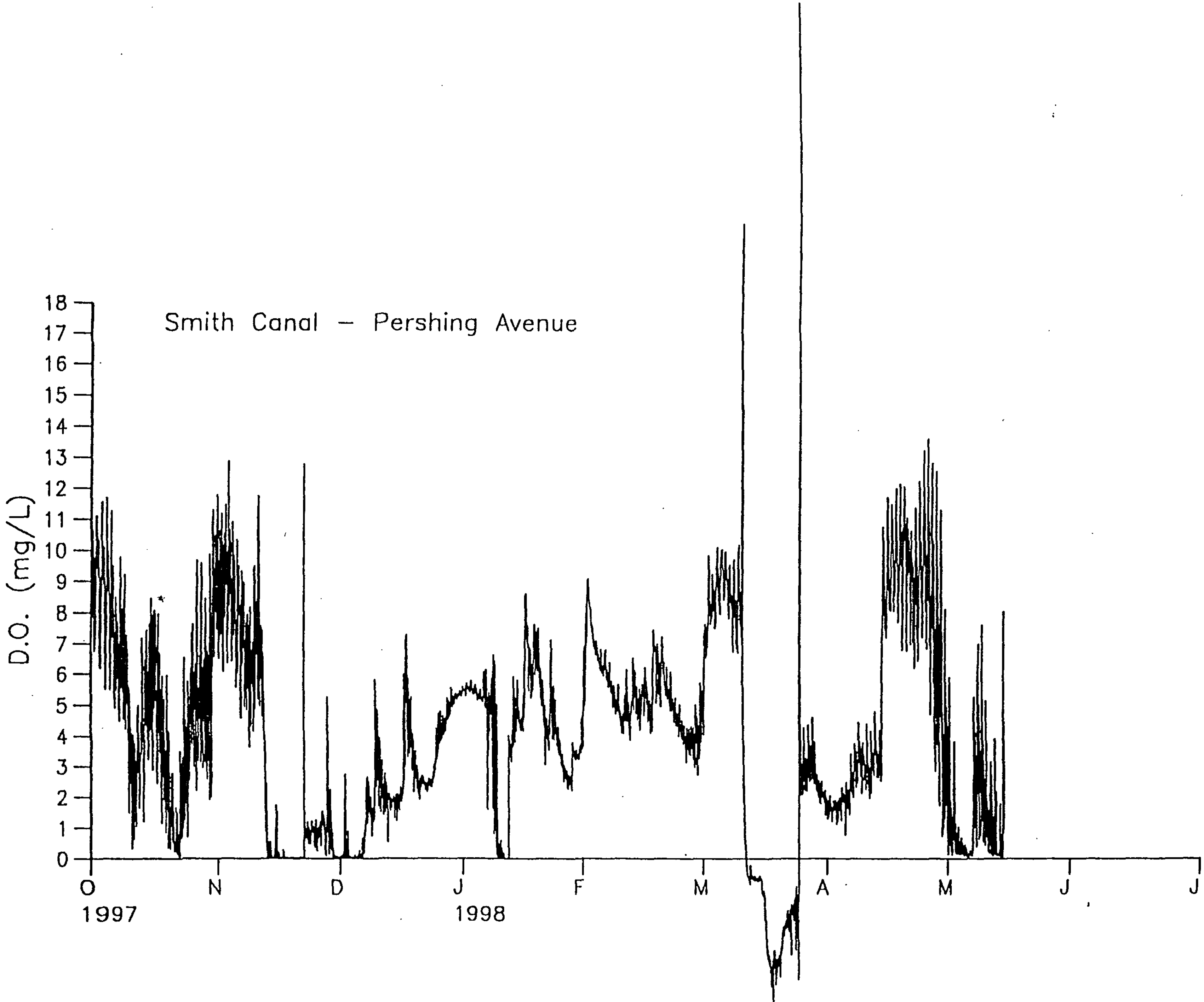
Smith Canal -- Pershing Avenue
Water Temperature (degree C)
35
30
25
20
15
10
5
0
O
N
D
J
F
M
A
M
J
J
1997
1998



Smith Canal – Pedestrian Bridge
Water Temperature (degree C)
0
5
10
15
20
25
30
35
O
N
D
J
F
M
A
M
J
J
A
S
O
1997
1998


Smith Canal – Pershing Avenue
Water Temperature (degree C)
35
30
25
20
15
10
5
0
O
N
D
J
F
M
A
M
J
J
1997
1998


Smith Canal – Pedestrian Bridge
D.O. (mg/L)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
O
N
D
J
F
M
A
M
J
J
A
S
O
1997
1998


Smith Canal – Pershing Avenue
D.O. (mg/L)
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
1997
1998

Appendix B

Sediment Sampling Log Sheet

SMITH CANAL MONITORING PROGRAM
Sediment Sampling for City of Stockton
by: Kinnetic Laboratories, Inc.

SEDIMENT SAMPLING LOG SHEET

SITE ID Smith Canal Pump Stn Ped Bridge

DATE 18 Sept 1997

WEATHER Sunny

WIND/SEAS Calm

TIME 16.28

On Upcurrent side of Pedestrian bridge at Footmarker #140

WATER DEPTH 7'

SAMPLE LENGTH NEEDED 4'

PENETRATION/RECOVERY 4'/ 3.9'

CORE INTERVAL SAMPLED

SAMPLE ID	ANALYSIS	VOLUME
PA-3 TOP	BOD	500 ml
PA-3 BOT	BOD	500 ml

VESSEL Whaler

CREW Jay Wilken,Spencer Johnson, S Trump,

SAMPLING EQUIPT: 4" Hand Core

NAVIGATION TYPE Sight & tape measure.

DESCRIPTION OF MATERIAL

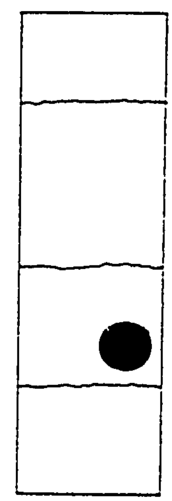
Top 3" loose silt with fine grain sand and organic material dark brown.

Silty clay, trace amounts of fine grain sand. Color same as top. 1'

Medium grained sandy silt no odor, rock color same. 2'

Stiffer consolidated silty clay. No odor. Same color as above. 3'

4'



COMMENTS:

1-5 cm = PS - 3 TOP
6-10 cm = PS - 3 BOT

Loose silt turns to sightly more consolidated silty clay, to a stiffer more consolidated silty clay. 8" med grained sand band at 20" to 28". Uniform color throughout.

* Sample taken approximately 10-15 feet upstream of Ped. Bridge on the 140 foot transect marker.

T:\STORMWAT\FORMS\SMITH-7

SMITH CANAL MONITORING PROGRAM
Sediment Sampling for City of Stockton
by: Kinnetic Laboratories, Inc.

SEDIMENT SAMPLING LOG SHEET

SITE ID	Smith Canal Pump Stn Ped Bridge	VESSEL	Whaler
DATE	18 Sept 1997	CREW	Jay Wilken, Spencer Johnson, S Trump,
WEATHER	Sunny	SAMPLING EQUIPT:	4" Hand Core
WIND/SEAS	Calm	NAVIGATION TYPE	Sight & tape measure.
TIME	15:28		

On Upcurrent side of Ped
bridge at Footmarker #80

WATER DEPTH 6'

SAMPLE LENGTH NEEDED 4'

PENETRATION/RECOVERY 4.2'/ 4.2'

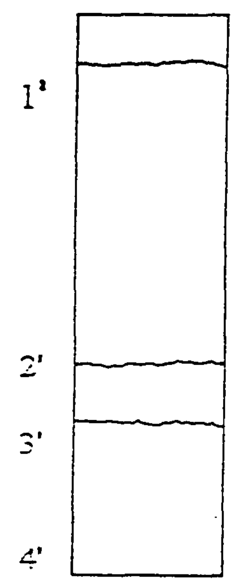
DESCRIPTION OF MATERIAL

Loose silty clay, organic debris, slight H_2S odor, dark brown.

More consolidated silty clay. Slight H_2S odor. No drastic color change from top layer. dark brown, shell hash. Small amounts of fine sand.

Sandy silt, dark brown/grey

Consolidated slightly stiffer silty clay. No color change



CORE INTERVAL SAMPLED

SAMPLE ID	ANALYSIS	VOLUME
PA-3 TOP	BOD	500 ml
PA-3 BOT	BOD	500 ml

COMMENTS:

1-5 cm = PS - 2TOP
6-10 cm = PS - 2 BOT

Trace oil sheen observed at 7" and 17". Color of core very similar throughout. Loose silty clay at the top getting more consolidated and stiffer towards bottom. 3" sandy silt band from 27" to 30"

* Sample taken approximately 5-10 feet upstream of Ped. Bridge on the 80 foot transect marker.

T:\STORMWAT\FORMS\SMITH-6

SMITH CANAL MONITORING PROGRAM
Sediment Sampling for City of Stockton
by: Kinnetic Laboratories, Inc.

SEDIMENT SAMPLING LOG SHEET

SITE ID Smith Canal Pump Stn Ped Bridge

VESSEL Whaler

DATE 18 Sept 1997

CREW Jay Wilken, Spencer Johnson, S Trump,

WEATHER Sunny

SAMPLING EQUIPT: 4" Hand Core

WIND/SEAS Calm

NAVIGATION TYPE Sight & tape measure.

TIME 17.28

On Upcurrent side of Pedestrian bridge at Footmarker #50

WATER DEPTH 8'

SAMPLE LENGTH NEEDED 4'

PENETRATION/RECOVERY 4'/ 3.1'

CORE INTERVAL SAMPLED

SAMPLE ID	ANALYSIS	VOLUME
PA-1 TOP	BOD	500 ml
PA-1 BOT	BOD	500 ml

DESCRIPTION OF MATERIAL

Loose silt, dark brown organic debris slight H_2S odor.

1'

Silt, trace fine grain sand, slight H_2S odor. Color same as above.

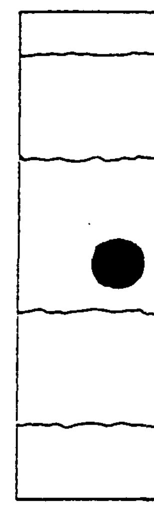
Relatively stiff silt, color same as above, slight H_2S odor. Trace fine grain sand.

2'

Loose silty clay, small amounts of fine grain sand. Color same, no odor.

Silty clay, color same. 1-2 millimeter clay nodules, H_2S odor.

3'



COMMENTS:

1-5 cm = PS - 1TOP
6-10 cm = PS - 1 BOT

Hit rejection with silty clay @ 3.1". Color consistent throughout. Loose silt on top turning more stiff throughout core.

* Sample taken approximately 15-20 feet upstream of Ped. Bridge on the 50 foot transect marker.

T:\STORMWAT\FORMS\SMITH-8

SMITH CANAL MONITORING PROGRAM
Sediment Sampling for City of Stockton
by: Kinnetic Laboratories, Inc.

SEDIMENT SAMPLING LOG SHEET

SITE ID Pershing Ave 1
DATE 18 Sept 1997

WEATHER Sunny

WIND/SEAS Calm

TIME 12:20

Foot Marker #31 on upcurrent side of bridge

WATER DEPTH 3.6'

SAMPLE LENGTH NEEDED 4'
PENETRATION RECOVERY 4'

VESSEL Whaler
CREW Jay Wilken, Spencer Johnson, S Trump,

SAMPLING EQUIPT: Hand Core 4"

NAVIGATION TYPE Sight, tape measure on Bridge

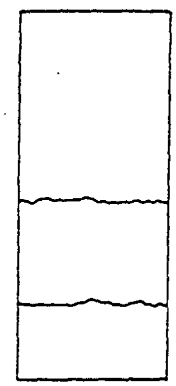
DESCRIPTION OF MATERIAL

Sample: Loose silty clay, small stick (1) fine sand, small stones, broken glass, small amounts of gravel, dark brown. H_2S odor strong

More consolidated silty clay, small amounts of fine sand, slight H_2S odor, dark brown/grey

Stiff silty clay, slight H_2S odor. dark grey, no sand

1'
2'
3'
4'



CORE INTERVAL SAMPLED:

SAMPLE ID	ANALYSIS	VOLUME
PA-1 TOP	BOD	500 ml
PA-1 BOT	BOD	500 ml

COMMENTS:
1-5 cm = PA - 1TOP
6-10 cm = PA - 1 BOT

* Sample taken 1-2 feet upstream of bridge on 31 foot transect mark.

Sample almost entirely silty clay. Loose at top becoming more consolidated towards the bottom. Small amount of gravel and sand in upper portion of core. Some glass two small amounts of organic debris in Upper part of core.

T:\STORMWAT\FORMS\SEDI-P1

Appendix C

Comparison of Simulated and Observed Temperature in San Joaquin River at Stations R1 through R8

SMITH CANAL MONITORING PROGRAM
Sediment Sampling for City of Stockton
by: Kinnetic Laboratories, Inc.

SEDIMENT SAMPLING LOG SHEET

SITE ID Pershing Ave 3
DATE 18 Sept 1997

VESSEL Whaler
CREW Jay Wilken, Spencer Johnson, S Trump,

WEATHER Sunny

SAMPLING EQUIPT: Hand Core 4"

WIND/SEAS Calm

NAVIGATION TYPE Sight & tape measure.

TIME 13:00

Foot Marker #86 on upcurrent side of bridge

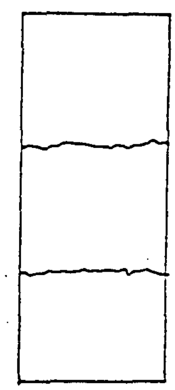
WATER DEPTH 4'

DESCRIPTION OF MATERIAL

Sample dark brown, very loose silty clay with moderate amounts of organic debris, heavy H_2S odor 1'

Silty clay, loosely consolidated. Moderate amounts of sand and gravel. Small rocks, dark brown. Slight H_2S odor. 2'

Hard dry silt layer, light grey in color very stiff, and consolidated uniform silt. 3'



SAMPLE LENGTH NEEDED 4'

PENETRATION/RECOVERY 3'/3'

Silty clay, dark grey in color. Loosely consolidated, no sand or gravel.

CORE INTERVAL SAMPLED

SAMPLE ID	ANALYSIS	VOLUME
PA-3 TOP	BOD	500 ml
PA-3 BOT	BOD	500 ml

COMMENTS:
Rejection of hand core with 8 lb. sledge. Rejection at 3 feet.
1-5 cm = PA - 3TOP
6-10 cm = PA - 3 BOT

Hard dry silt layer formed. Plug in hand core. Silty layer filled end of core from below hard silt layer.

* Samples taken 1-2 feet upstream of bridge on 86 foot transect marker.

T:\STORMWAT\FORMS\SEDI-P3.WPD

SMITH CANAL MONITORING PROGRAM
Sediment Sampling for city of Stockton
by: Kinnetic Laboratories, Inc.

SEDIMENT SAMPLING LOG SHEET

SITE ID	Pershing Ave 2	VESSEL	Whaler
DATE	18 Sept 1997	CREW	Jay Wilken, Spencer Johnson, S Trump.
WEATHER	Sunny	SAMPLING EQUIPT:	Hand Core 4"
WIND/SEAS	Calm	NAVIGATION TYPE	Sight
TIME	10:42 4 MPH N	DESCRIPTION OF MATERIAL	

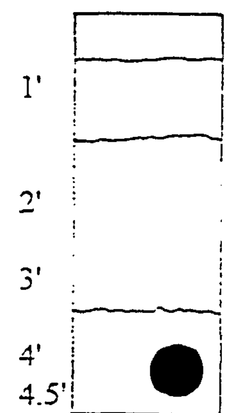
Mid Bridge Span Pershing Ave
Foot Marker 64'

WATER DEPTH 5'

Sample: Loose silty clay, dark brown continuing loose silty clay. dark brown, occasional stones little fine sand.

More consolidated silty clay, dark brown

Consolidated silty clay, dark brown/dark grey



SAMPLE LENGTH NEEDED 4'
PENETRATION/RECOVERY 4'4"

CORE INTERVAL SAMPLED

SAMPLE ID	ANALYSIS	VOLUME
PA-2 TOP	BOD	500 ml
PA-2 BOT	BOD	500 ml

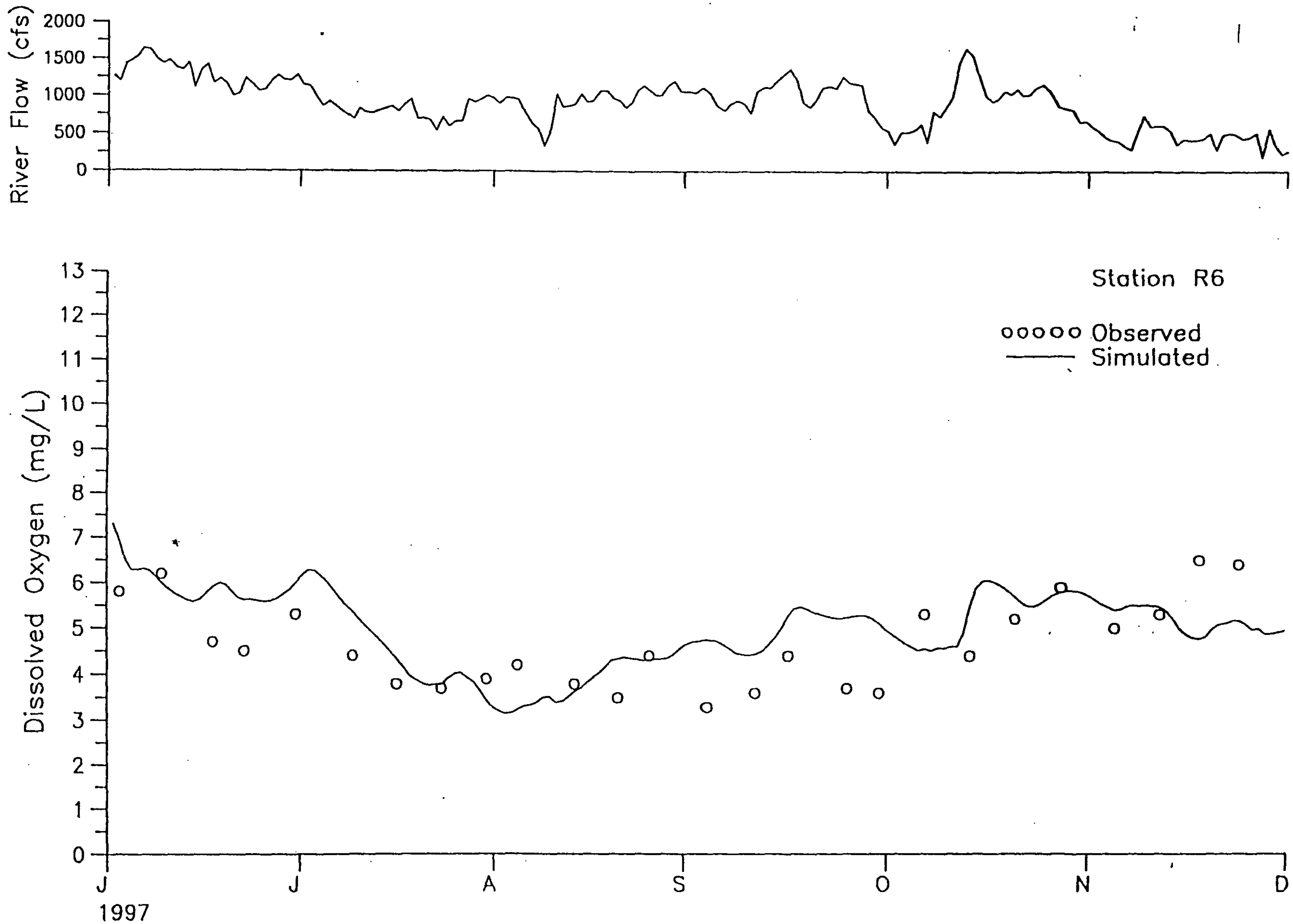
<u>COMMENTS:</u>

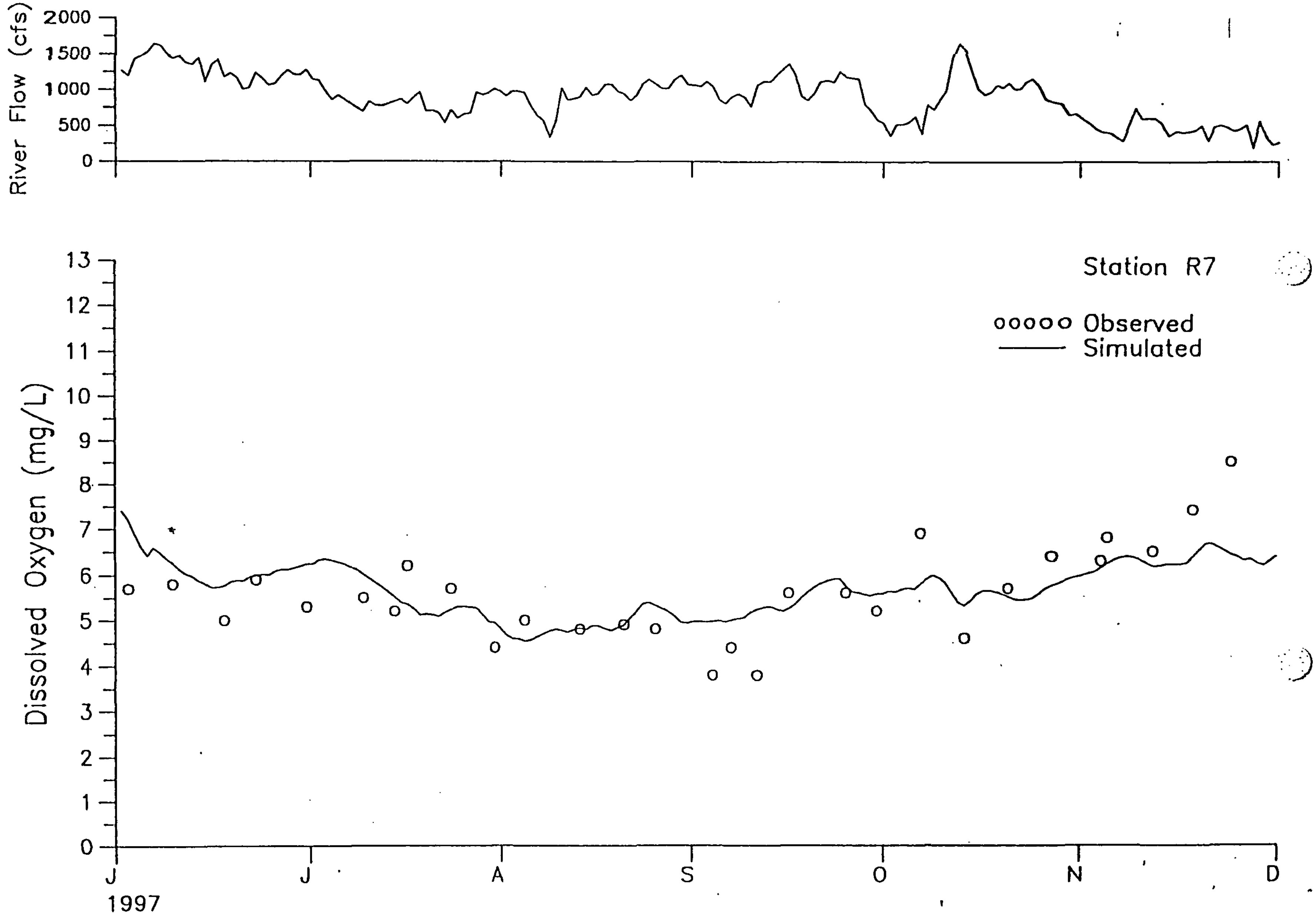
1-5 cm = PA - 2TOP
6-10 cm = PA - 2 BOT

Sample almost entirely silty clay, fine sands and stones in upper sections. Silty clay is loose at the top and becomes more consolidated as it reaches the end of the core. No sharp differentiation in silty clay layers.

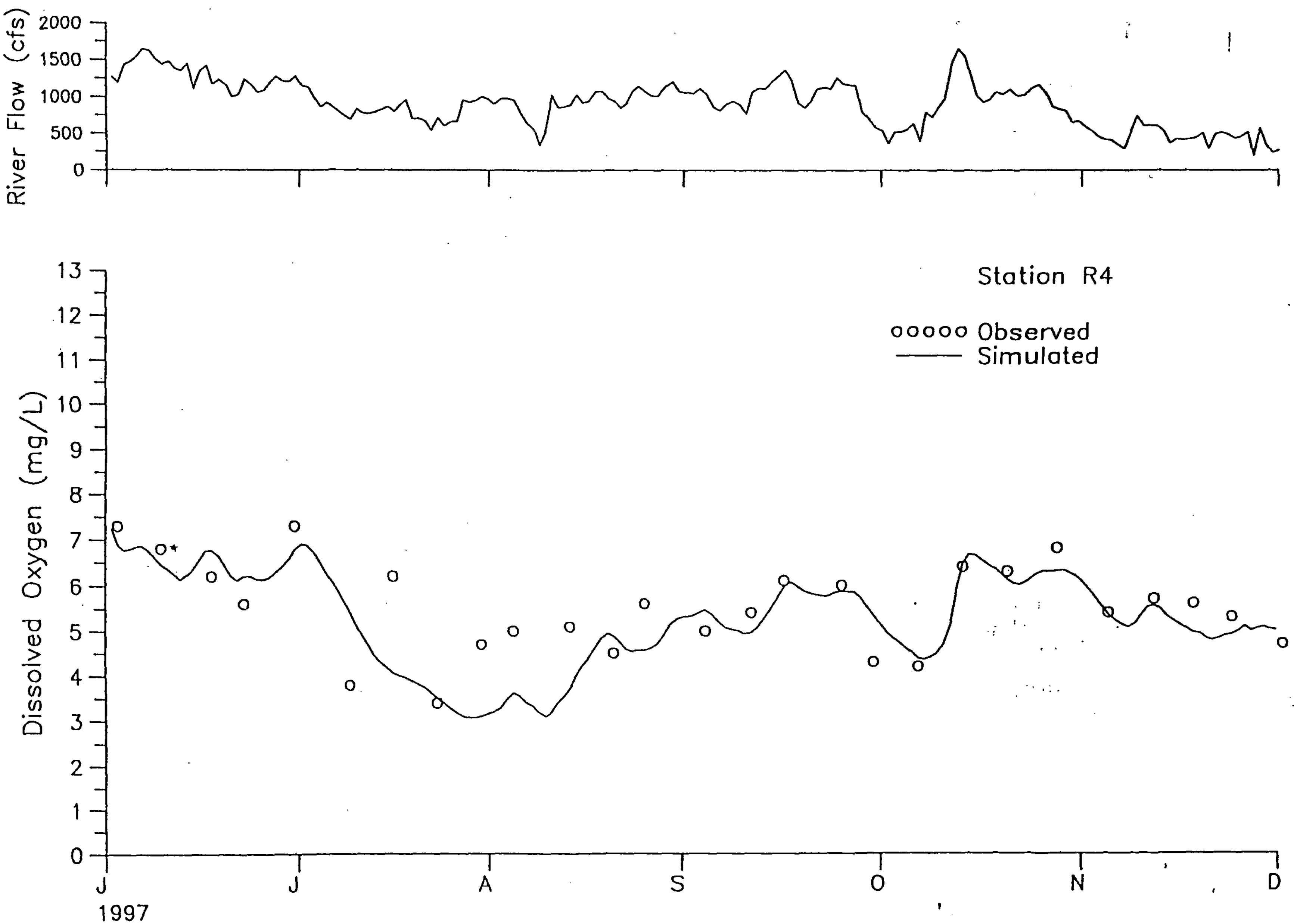
* Sample taken 1-2 feet upstream of bridge on 64' transect mark.

T:\STORMWAT\FORMS\SEDI-P2.WPD

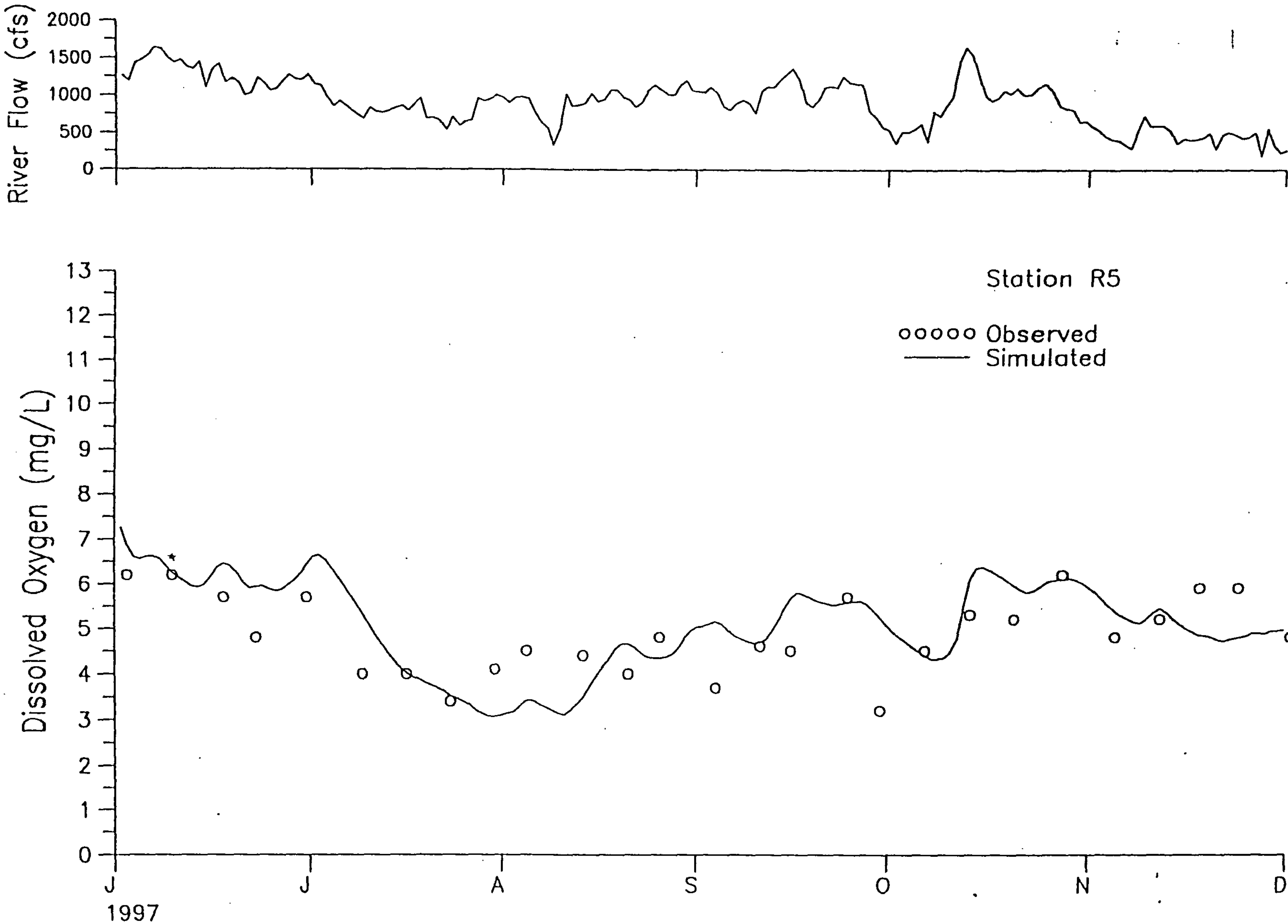

River Flow (cfs)
2000
1500
1000
500
0
Station R6
ooooo Observed
Simulated
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
J
J
A
S
O
N
D
1997



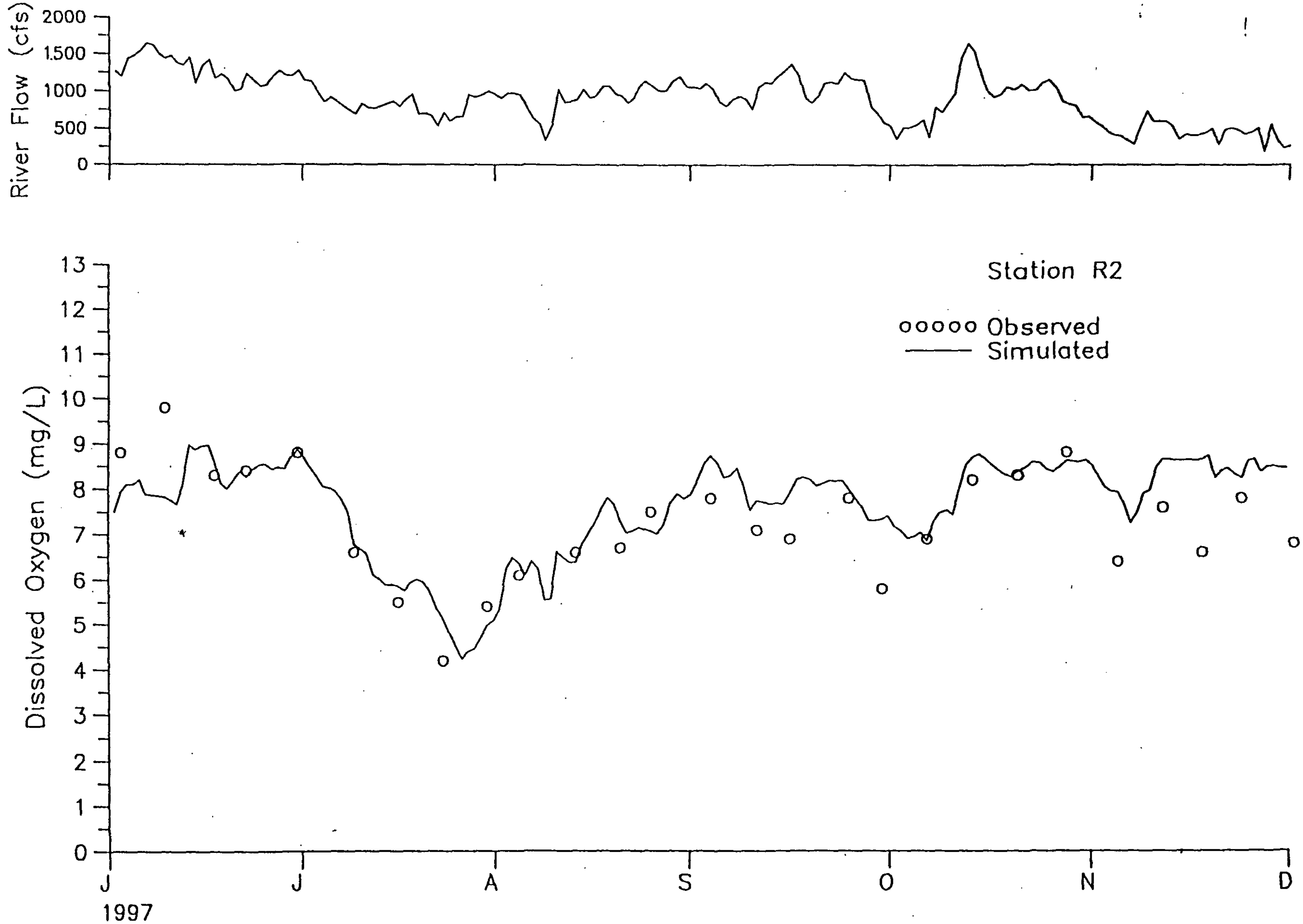
River Flow (cfs)
2000
1500
1000
500
0
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Dissolved Oxygen (mg/L)
Station R7
ooooo Observed
Simulated
J
J
A
S
O
N
D
1997



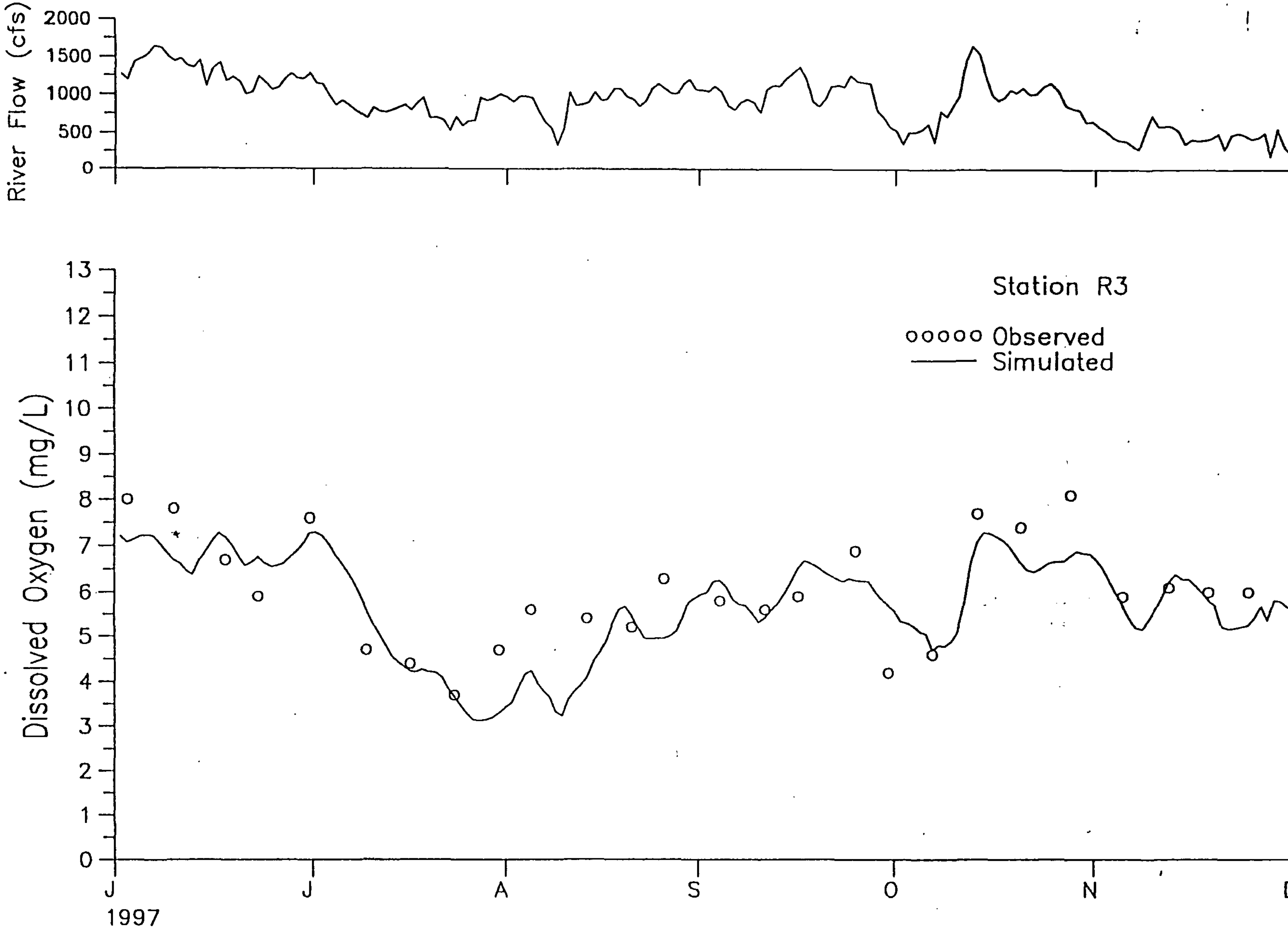
River Flow (cfs)
2000
1500
1000
500
0
Station R4
ooooo Observed
Simulated
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
J
1997
J
A
S
O
N
D



River Flow (cfs)
2000
1500
1000
500
0
Station R5
ooooo Observed
Simulated
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
J
1997
J
A
S
O
N
D



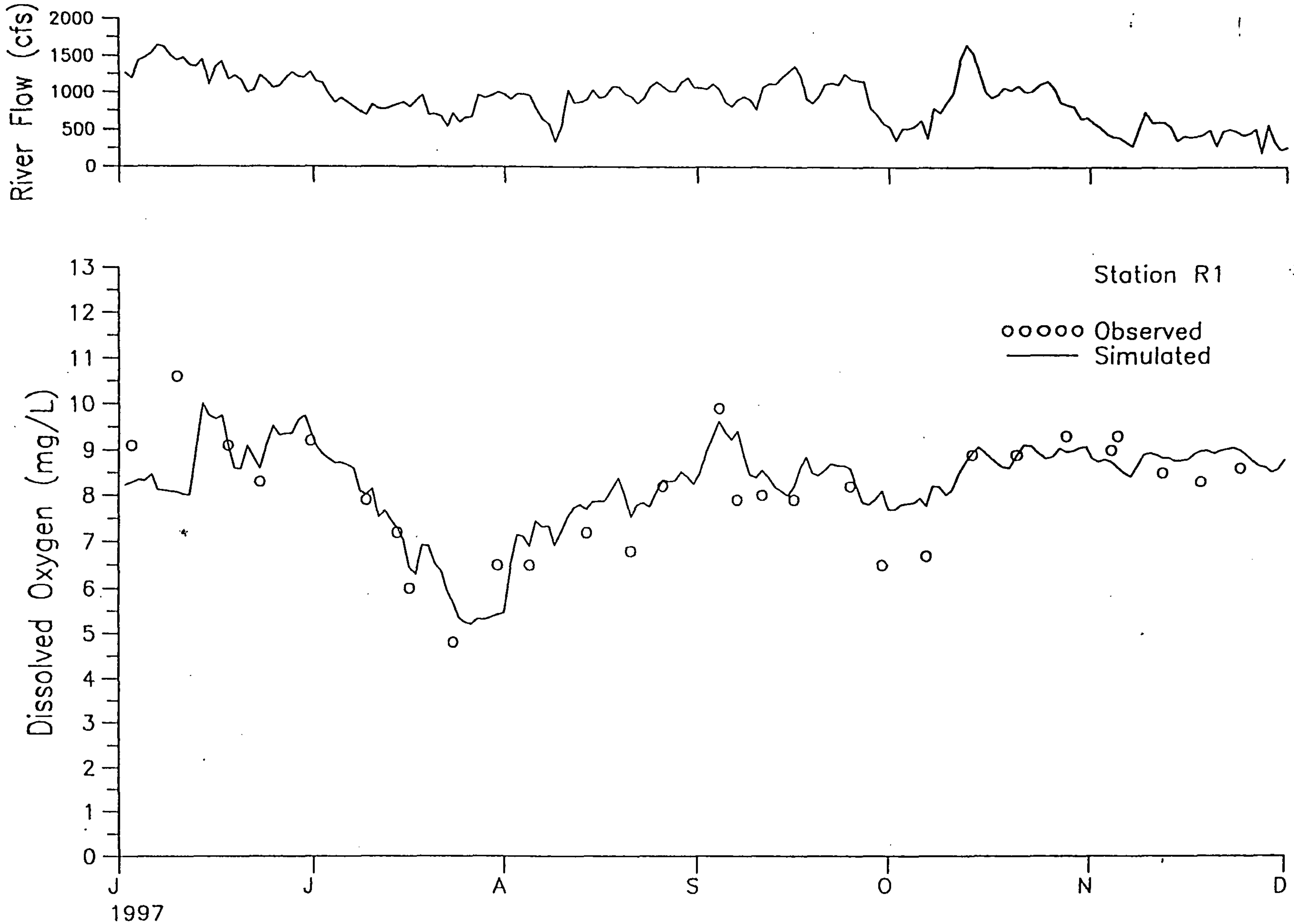
River Flow (cfs)
2000
1500
1000
500
0
Station R2
ooooo Observed
Simulated
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
J
J
A
S
O
N
D
1997

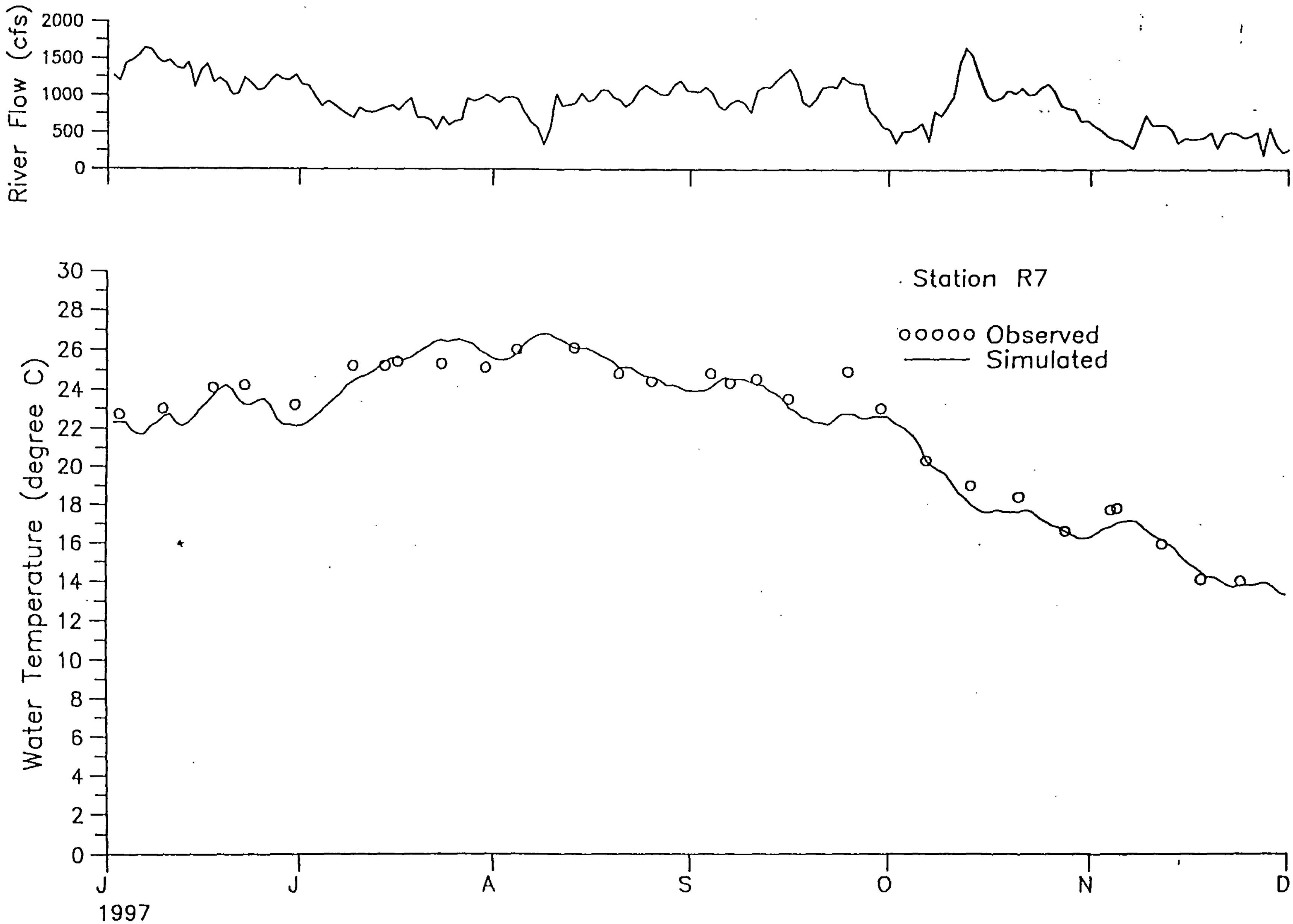


River Flow (cfs)
2000
1500
1000
500
0
Station R3
ooooo Observed
Simulated
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
J
J
A
S
O
N
D
1997

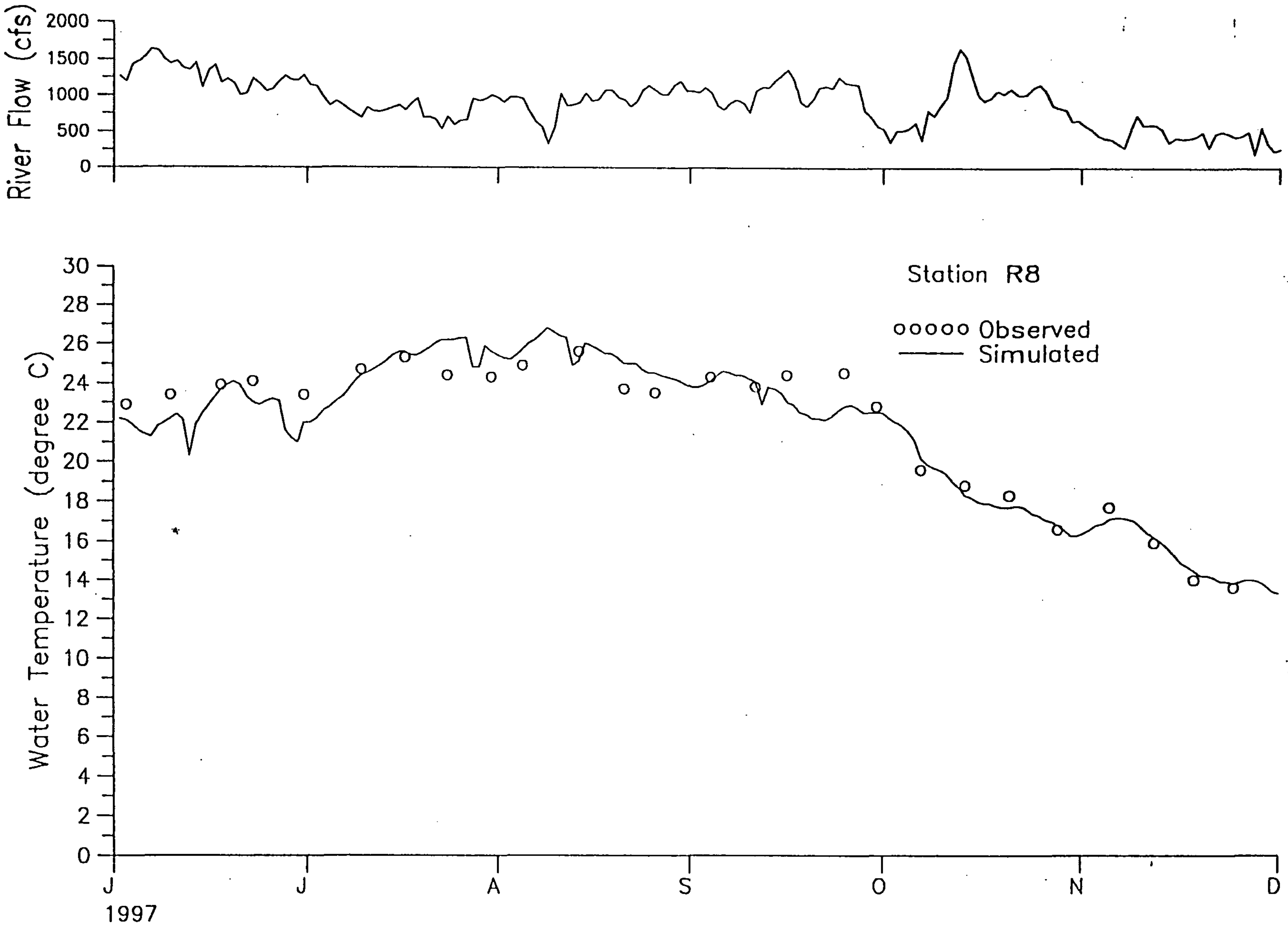
Appendix D

Comparison of Simulated and
Observed Dissoved Oxygen in
San Joaquin River at
Stations R1 through R8

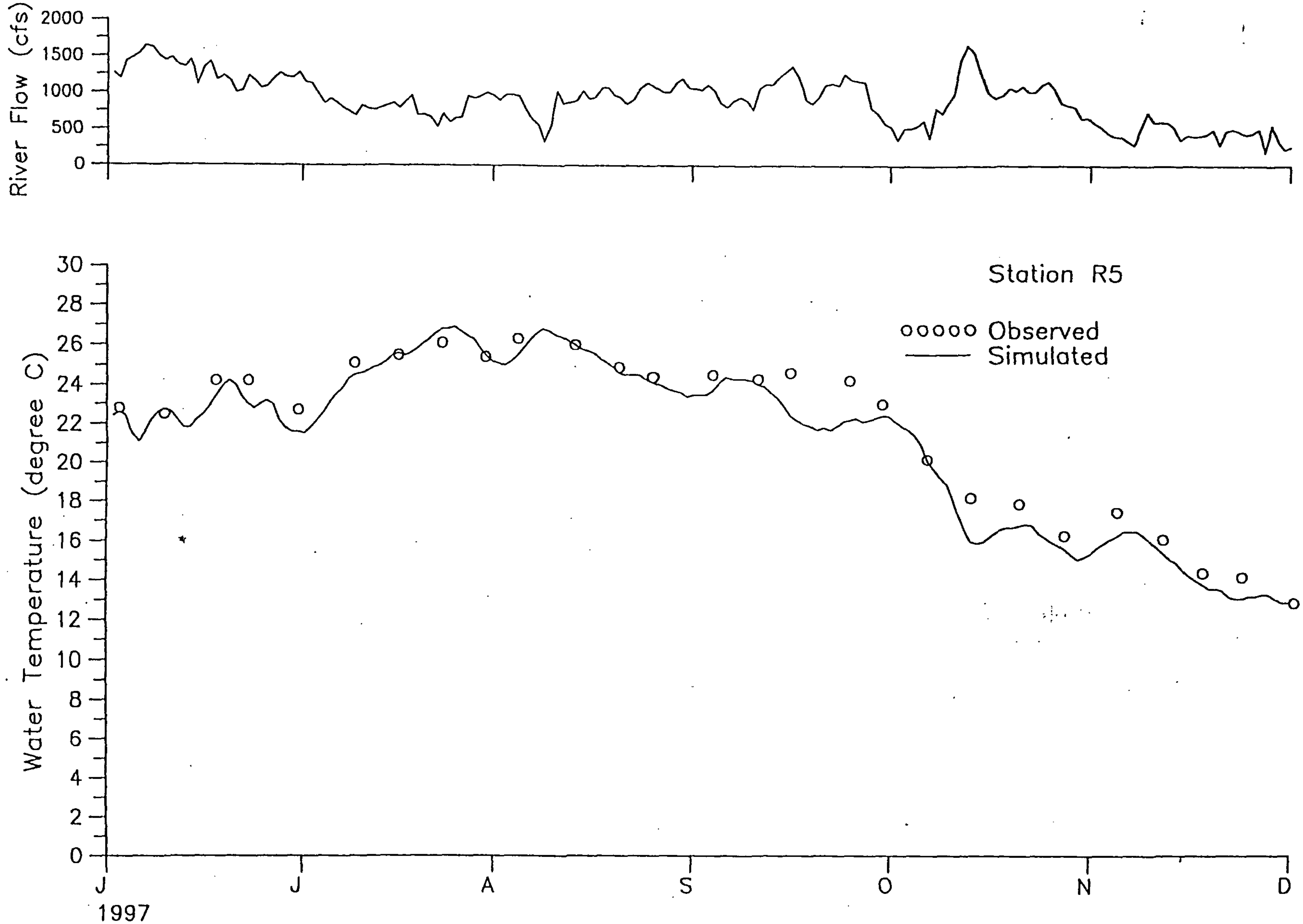

River Flow (cfs)
2000
1500
1000
500
0
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Station R1
ooooo Observed
Simulated
J
J
A
S
O
N
D
1997

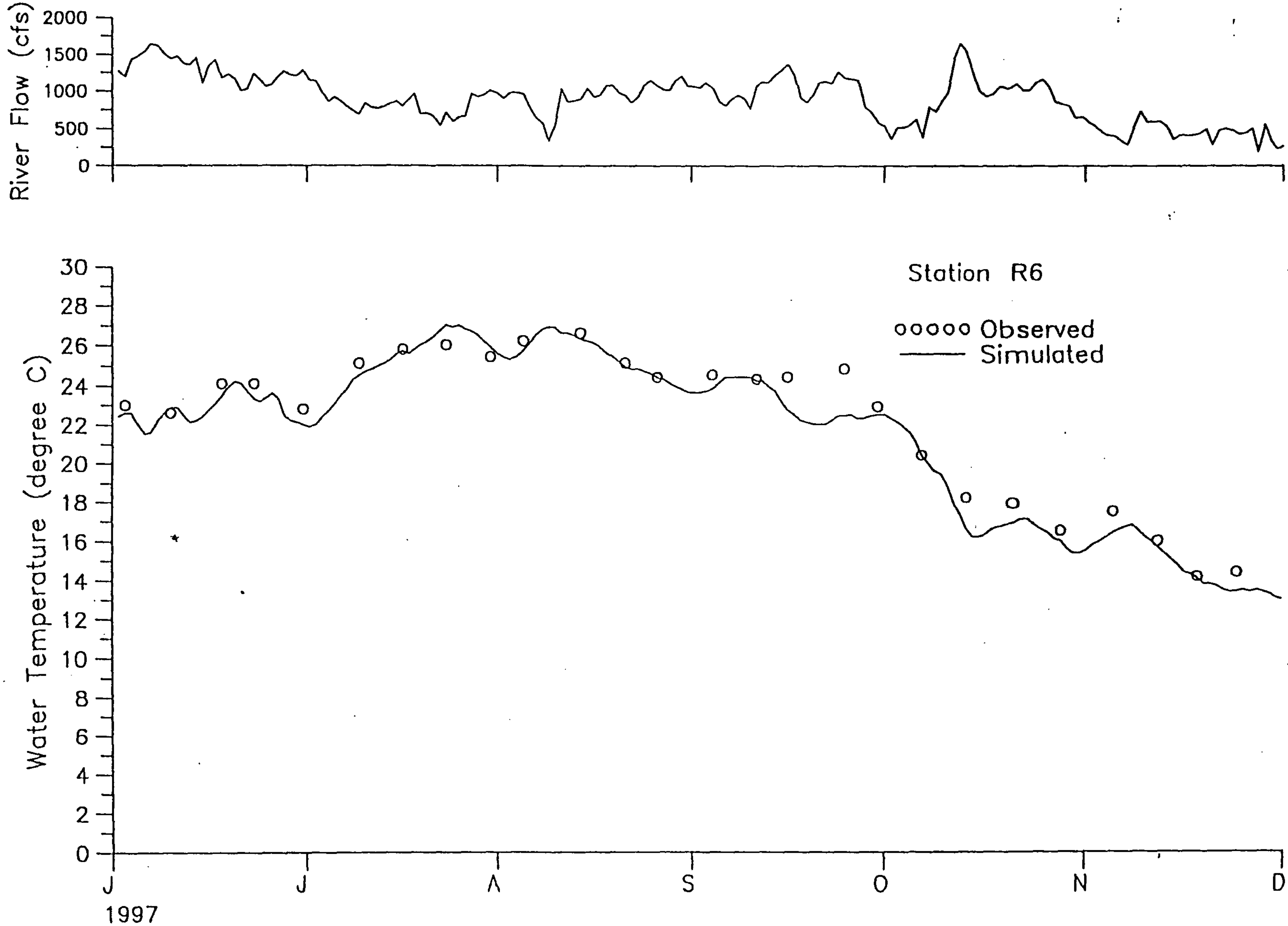


River Flow (cfs)
2000
1500
1000
500
0
Station R7
ooooo Observed
Simulated
Water Temperature (degree C)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
J
J
A
S
O
N
D
1997

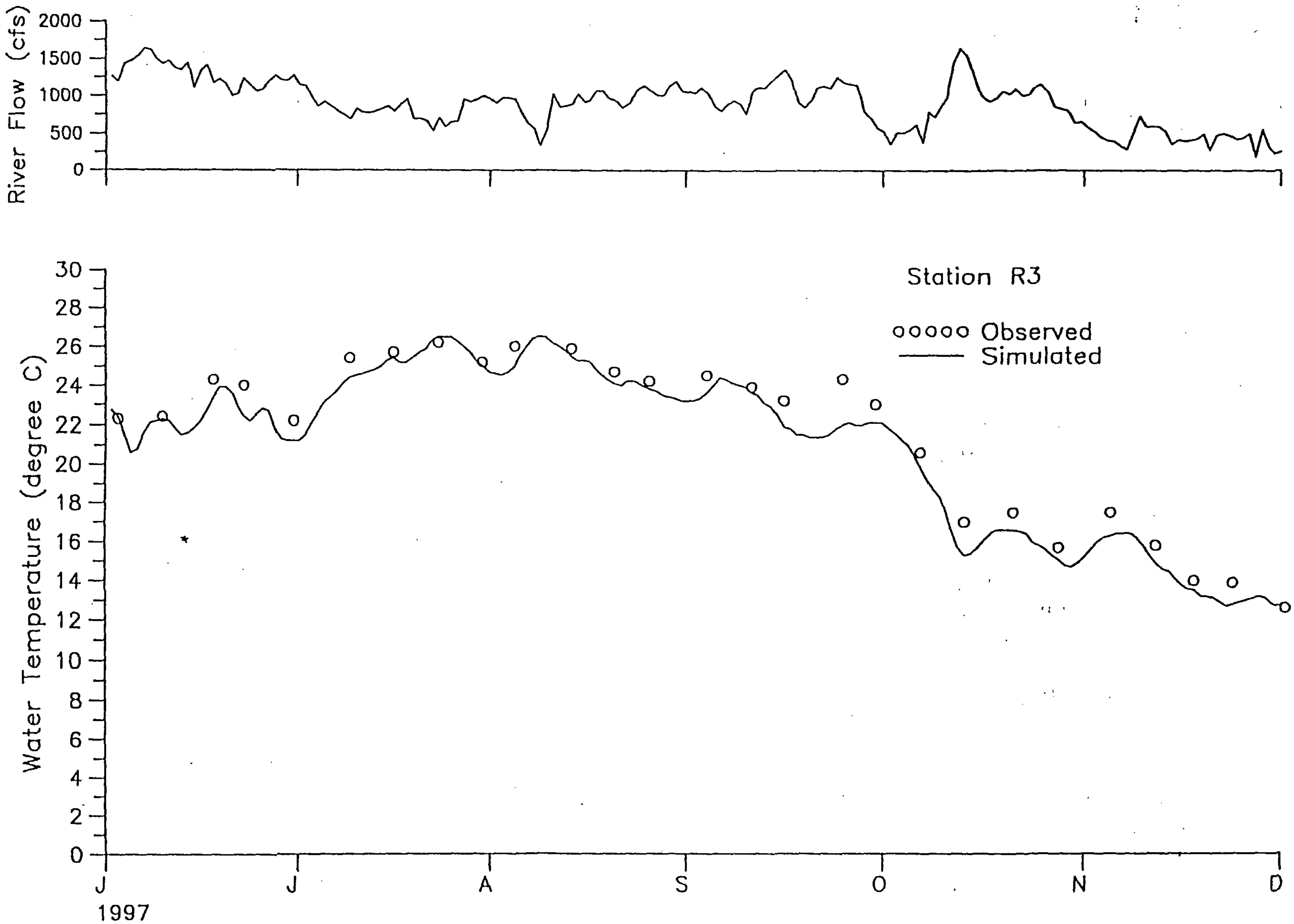


River Flow (cfs)
2000
1500
1000
500
0
Station R8
ooooo Observed
Simulated
Water Temperature (degree C)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
J
J
A
S
O
N
D
1997

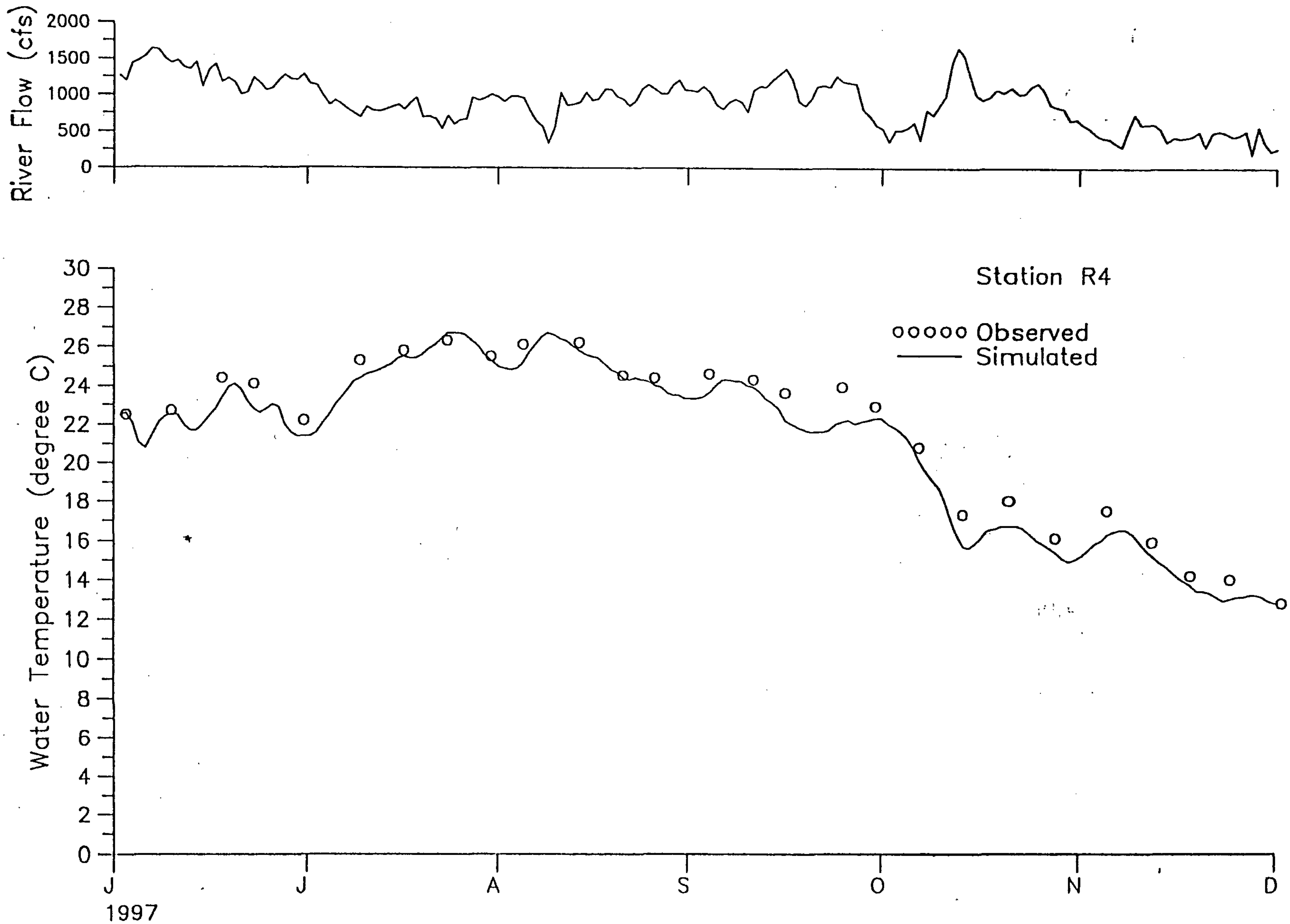

River Flow (cfs)
2000
1500
1000
500
0
Station R5
ooooo Observed
Simulated
Water Temperature (degree C)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
J
J
A
S
O
N
D
1997

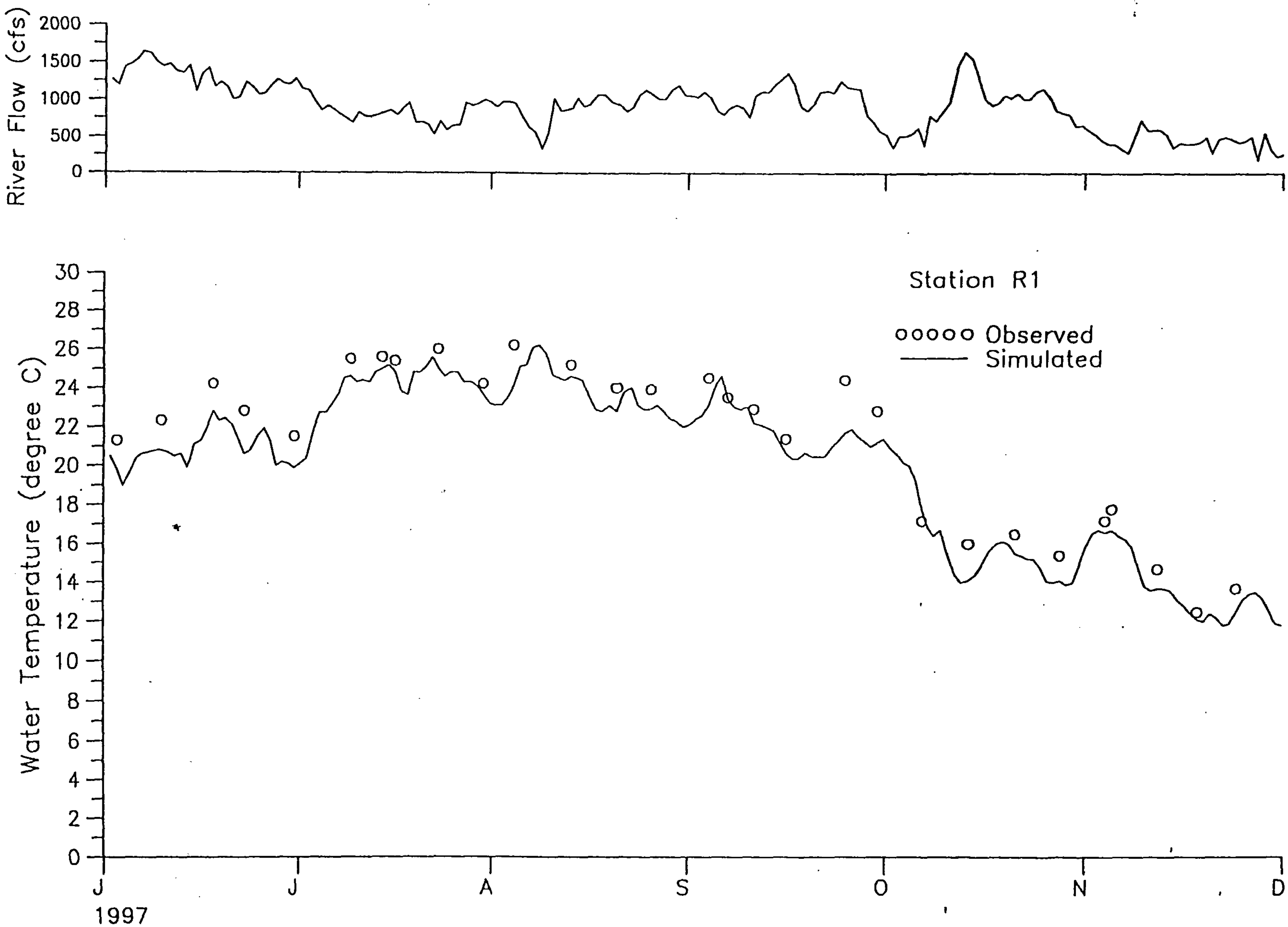


River Flow (cfs)
2000
1500
1000
500
0
Station R6
ooooo Observed
Simulated
Water Temperature (degree C)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
J
J
A
S
O
N
D
1997

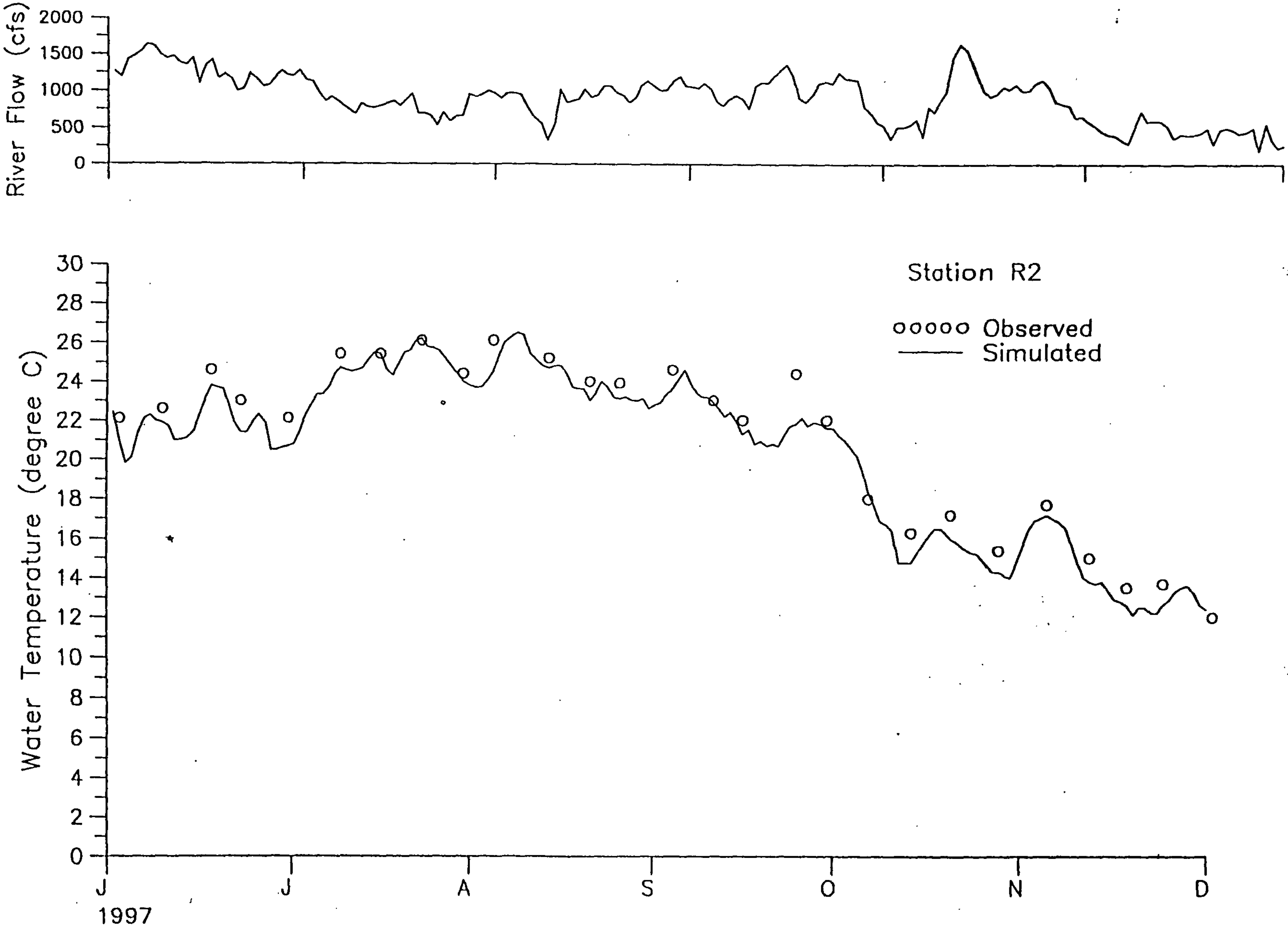


River Flow (cfs)
2000
1500
1000
500
0
Station R3
ooooo Observed
Simulated
Water Temperature (degree C)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
J
J
A
S
O
N
D
1997

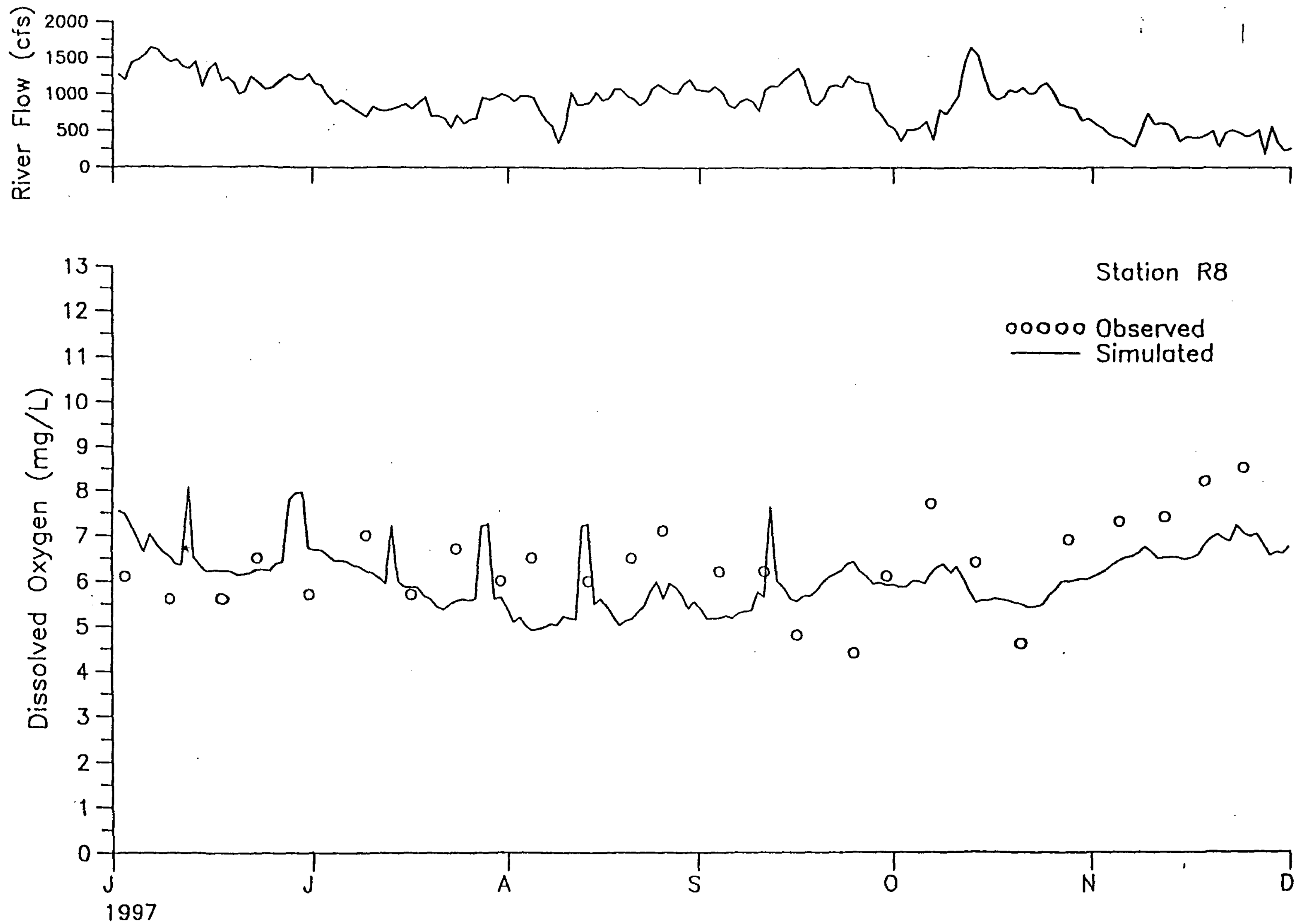

River Flow (cfs)
2000
1500
1000
500
0
Water Temperature (degree C)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
Station R4
ooooo Observed
Simulated
J
J
A
S
O
N
D
1997



River Flow (cfs)
2000
1500
1000
500
0
Station R1
ooooo Observed
Simulated
Water Temperature (degree C)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
J
J
A
S
O
N
D
1997



River Flow (cfs)
2000
1500
1000
500
0
Water Temperature (degree C)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
Station R2
ooooo Observed
Simulated
J
J
A
S
O
N
D
1997



River Flow (cfs)
2000
1500
1000
500
0
Station R8
ooooo Observed
Simulated
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
J
J
A
S
O
N
D
1997

B.1.18 Del Puerto Creek, Chlorpyrifos

Summary of Proposed Action

The California Regional Water Quality Control Board, Central Valley Region, (Regional Board) recommends the addition of the lower portion of Del Puerto Creek to California's Clean Water Act Section 303(d) list due to impairment by chlorpyrifos. Information available to the Regional Board on chlorpyrifos levels indicates that water quality objectives are not being attained. The basis for this recommendation is given below.

Table B-1. 303(d) Listing/TMDL Information

Waterbody Name	Del Puerto Creek	**Pollutants/Stressors**	Chlorpyrifos
Hydrologic Unit	541.10	**Sources**	Agriculture
Total Length	27 miles	**TMDL Priority**	
Size Affected	5 miles	**TMDL Start Date (Mo/Yr)**	
Extent of Impairment	Lower 5 miles, from Rogers Road to the SJR	**TMDL End Date (Mo/Yr)**	
Upstream Extent Latitude	37° 29' 56"	**Upstream Extent Longitude**	121° 10' 37"
Downstream Extent Latitude	37° 32' 29"	**Downstream Extent Longitude**	121° 06' 56"

Watershed Characteristics

Del Puerto Creek originates on the eastern slope of the Coast Range, near the intersection of San Joaquin, Stanislaus, and Alameda Counties. The creek flows northeast approximately 27 miles to its confluence with the San Joaquin River, south of Laird Park. Extensive acreage in the lower part of the watershed is used to grow orchard and field crops, especially southeast of Interstate Highway 5. Several lateral drains that carry tailwater from fields located along the west side of the San Joaquin Valley also drain into Del Puerto Creek.

Water Quality Objectives Not Attained
The narrative objectives for pesticides and toxicity are not being attained for chlorpyrifos in Del Puerto Creek. The narrative objective for pesticides states, "No individual pesticide or combination of pesticides shall be present in concentrations that adversely affect beneficial uses." The narrative toxicity objective in the Basin Plan states, in part, "All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life." The narrative toxicity objective further states that "The Regional Water Board will also consider … numerical criteria and guidelines for toxic substances developed by the State Water Board, the California Office of Environmental Health Hazard Assessment, the California Department of Health Services, the U.S. Food and Drug Administration, the National Academy of Sciences, the U.S. Environmental Protection Agency, and other appropriate organizations to evaluate compliance with this objective" (CRWQCB-CVR, 1998; http://www.swrcb.ca.gov/~rwqcb5/bsnplnab.pdf). The California Department of Fish and Game (CDFG) has established freshwater numeric acute (1-hour average) and chronic (4-day average) criteria for chlorpyrifos of 0.02 µg/L and 0.014 µg/L, respectively, for the protection of aquatic life (Siepmann and Finlayson, 2000).

Evidence of Impairment
Several studies have measured chlorpyrifos levels in Del Puerto Creek (Table B-2). The samples analyzed for these studies were collected between January and June, 1991 to 1993. Five of the 30 samples (17%) analyzed for chlorpyrifos exceeded the CDFG chronic water quality criterion for chlorpyrifos, and three of the samples (10%) exceeded the CDFG acute criterion.

Table B-2. Summary of Chlorpyrifos Concentrations in Del Puerto Creek

Data Source	Sample Years	Number of Sample Dates	Range of Chlorpyrifos Concentrations	Criteria[a]		Number of Sample Dates Equal to or Above Criteria	Percent of Sample Dates Equal to or Above Criteria
Ross 1992 and 1993; Ross *et al*, 1996 and 1999; Fujimura, 1991a,b and 1993a,b,c,d	1991-1993	8	nd	Chronic	0.014 µg/L	0	0%
				Acute	0.02 µg/L	0	0%
Foe, 1995	1991	8	nd – 0.12 µg/L	Chronic	0.014 µg/L	3	38%
				Acute	0.02 µg/L	3	38%
Foe, 1995	1992	14	nd – 0.04 µg/L	Chronic	0.014 µg/L	7	50%
				Acute	0.02 µg/L	7	50%
Summary	1991-1993	30	nd – 0.12 µg/L	Chronic	0.014 µg/L	10	30%
				Acute	0.02 µg/L	10	30%

[a] CDFG water quality criteria for the protection of aquatic life (Siepmann and Finlayson, 2000)
nd = not detected

Extent of Impairment
The lower section of Del Puerto Creek extends for approximately five miles between Interstate 5 and the San Joaquin River. Extensive acreage in the lower part of the watershed is used to grow orchard and field crops, and chlorpyrifos is used as on these crops during the dormant and the growing seasons.

Potential Sources
Applications of chlorpyrifos to orchards and field crops are the most likely source of chlorpyrifos in Del Puerto Creek.

B.1.19 Del Puerto Creek, Diazinon

Summary of Proposed Action

The California Regional Water Quality Control Board, Central Valley Region, (Regional Board) recommends the addition of the lower portion of Del Puerto Creek to California's Clean Water Act Section 303(d) list due to impairment by diazinon. Information available to the Regional Board on diazinon concentrations in Del Puerto Creek indicates that water quality objectives are not being attained. The basis for this recommendation is given below.

Table B-1. 303(d) Listing/TMDL Information

Waterbody Name	Del Puerto Creek	**Pollutants/Stressors**	Diazinon
Hydrologic Unit	541.10	**Sources**	Agriculture
Total Length	27 miles	**TMDL Priority**	
Size Affected	5 miles	**TMDL Start Date (Mo/Yr)**	
Extent of Impairment	Lower 5 miles, from Rogers Road to the SJR	**TMDL End Date (Mo/Yr)**	
Upstream Extent Latitude	37° 29' 56"	**Upstream Extent Longitude**	121° 10' 37"
Downstream Extent Latitude	37° 32' 29"	**Downstream Extent Longitude**	121° 06' 56"

Watershed Characteristics

Del Puerto Creek originates on the eastern slope of the Coast Range, near the intersection of San Joaquin, Stanislaus, and Alameda Counties. The creek flows northeast approximately 27 miles to its confluence with the San Joaquin River, south of Laird Park. Extensive acreage in the lower part of the watershed is used to grow almonds and stone fruits, especially southeast of Interstate Highway 5. Several lateral drains that carry tailwater from orchards located along the west side of the San Joaquin Valley also drain into Del Puerto Creek.

Water Quality Objectives Not Attained

The narrative objectives for pesticides and toxicity are not being attained for diazinon in Del Puerto Creek. The narrative objective for pesticides states, "No individual pesticide or combination of pesticides shall be present in concentrations that adversely affect beneficial uses." The narrative toxicity objective in the Basin Plan states, in part, "All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life." The narrative toxicity objective further states that "The Regional Water Board will also consider ... numerical criteria and guidelines for toxic substances developed by the State Water Board, the California Office of Environmental Health Hazard Assessment, the California Department of Health Services, the U.S. Food and Drug Administration, the National Academy of Sciences, the U.S. Environmental Protection Agency, and other appropriate organizations to evaluate compliance with this objective" (CRWQCB-CVR, 1998; http://www.swrcb.ca.gov/~rwqcb5/bsnplnab.pdf). The California Department of Fish and Game (CDFG) has established freshwater numeric acute (1-hour average) and chronic (4-day average) criteria for diazinon of 0.08 µg/L and 0.05 µg/L, respectively, for the protection of aquatic life (Siepmann and Finlayson, 2000).

Evidence of Impairment

Several studies have measured diazinon concentrations in Del Puerto Creek (Table B-2). The samples analyzed for these studies were collected between January and June 1991 to 1993. Ten of the 30 samples (33%) analyzed for diazinon exceeded the CDFG chronic water quality criterion for diazinon, and six of the 30 samples (20%) exceeded the CDFG acute criterion.

Table B-2. Summary of Diazinon Concentrations in Del Puerto Creek

Data Source	Sample Years	Number of Sample Dates	Range of Diazinon Concentrations	Criteria[a]		Number of Sample Dates Equal to or Above Criteria	Percent Sample Dates Equal to or Above Criteria
Ross 1992 and 1993; Ross *et al*, 1996 and 1999; Fujimura, 1991a,b and 1993a,b,c,d	1991-1993	8	nd	Chronic	0.05 µg/L	0	0%
				Acute	0.08 µg/L	0	0%
Foe, 1995	1991	8	nd – 0.42 µg/L	Chronic	0.05 µg/L	3	38%
				Acute	0.08 µg/L	2	25%
Foe, 1995	1992	14	nd – 2.6 µg/L	Chronic	0.05 µg/L	7	50%
				Acute	0.08 µg/L	7	50%
Summary	1991-1993	30	nd – 2.6 µg/L	Chronic	0.05 µg/L	10	33%
				Acute	0.08 µg/L	9	30%

[a] CDFG water quality criteria for the protection of aquatic life (Siepmann and Finlayson, 2000)
nd = not detected

Extent of Impairment
The lower section of Del Puerto Creek extends for approximately five miles between Interstate 5 and the San Joaquin River. Extensive acreage in the lower part of the watershed is used to grow almonds and stone fruits, and diazinon is applied to many of these orchards during the winter dormant season.

Potential Sources
The application of diazinon to orchards is the most likely source of diazinon in Del Puerto Creek.

B.1.23 Ingram/Hospital Creek, Chlorpyrifos

Summary of Proposed Action

The California Regional Water Quality Control Board, Central Valley Region (Regional Board) recommends the addition of the Ingram/Hospital Creek to California's Clean Water Act Section 303(d) list due to impairment by chlorpyrifos. Information available to the Regional Board on chlorpyrifos concentrations in Ingram/Hospital Creek indicates that water quality objectives are not being attained. The basis for this determination is given below.

Table B-1. 303(d) Listing/TMDL Information

Waterbody Name	Ingram/Hospital Creek	**Pollutants/Stressors**	Chlorpyrifos
Hydrologic Unit	541.10	**Sources**	Agriculture
Total Waterbody Size	2 miles	**TMDL Priority**	
Size Affected	2 miles	**TMDL Start Date (Mo/Yr)**	
Extent of Impairment	2 miles	**TMDL End Date (Mo/Yr)**	
Upstream Extent Latitude	37° 05' 61"	**Upstream Extent Longitude**	121° 12' 08"
Downstream Extent Latitude	37° 38' 10"	**Downstream Extent Longitude**	121° 12' 17"

Watershed Characteristics

Ingram and Hospital Creeks are ephemeral streams that originate in the Coast Range and flow northeast from Ingram Canyon and Hospital Canyon, respectively, to the San Joaquin Valley west of Modesto. The creeks join near Dairy Road and subsequently flow into the San Joaquin River. Upstream of Interstate 5, in Ingram and Hospital Canyons, the creeks are open waterways that transport rainwater runoff during the winter. However, in the agricultural region downstream of Interstate 5 and in the Valley, Ingram and Hospital Creeks are dominated by agricultural return flows. (Westcot *et al*, 1991).

Water Quality Objectives Not Attained

The narrative objectives for pesticides and toxicity are not being attained for chlorpyrifos in the Ingram/Hospital Creek. The narrative objective for pesticides states, "No individual pesticide or combination of pesticides shall be present in concentrations that adversely affect beneficial uses." The narrative toxicity objective in the Basin Plan states, in part, "All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life." The narrative toxicity objective further states that "The Regional Water Board will also consider ... numerical criteria and guidelines for toxic substances developed by the State Water Board, the California Office of Environmental Health Hazard Assessment, the California Department of Health Services, the U.S. Food and Drug Administration, the National Academy of Sciences, the U.S. Environmental Protection Agency, and other appropriate organizations to evaluate compliance with this objective" (CRWQCB-CVR, 1998; http://www.swrcb.ca.gov/~rwqcb5/bsnplnab.pdf). The California Department of Fish and Game (CDFG) has established freshwater numeric acute (1-hour average) and chronic (4-day average) criteria for chlorpyrifos of 0.014 µg/L and 0.02 µg/L, respectively, for the protection of aquatic life (Siepmann and Finlayson, 2000).

Evidence of Impairment

Between 1991 and 1993, multiple studies analyzed a total of 26 ambient water samples collected from Ingram/Hospital Creek for chlorpyrifos. Samples were collected from December through June. The data are summarized in Table B-2.

Table B-2. Summary of Chlorpyrifos Concentrations in Ingram/Hospital Creek

Data Source	Sample Years	Number of Sample Dates	Range of Chlorpyrifos Concentrations	Criteria[a]		Number of Sample Dates Equal to or Above Criteria	Percent of Sample Dates Equal to or Above Criteria
Ross, 1992 and 1993; Ross *et al*, 1996 and 1999; Fujimura, 1991a,b and 1993a,b,c,d	1991 - 1993	9	nd	Chronic	0.014 µg/L	0	0%
				Acute	0.02 µg/L	0	0%
Foe, 1995	1991	5	nd – 0.57 µg/L	Chronic	0.014 µg/L	4	67%
				Acute	0.02 µg/L	4	67%
Foe, 1995	1992	12	nd – 0.06 µg/L	Chronic	0.014 µg/L	3	25%
				Acute	0.02 µg/L	3	25%
Summary	1991 - 1993	26	nd – 0.57	Chronic	0.014 µg/L	7	27%
				Acute	0.02 µg/L	7	27%

[a] CDFG water quality criteria for the protection of aquatic life (Siepmann and Finlayson, 2000)
nd = not detected

Extent of Impairment
Chlorpyrifos impairment exists in Ingram/Hospital Creek from their confluence, east of Dairy Road, to the San Joaquin River, due to chlorpyrifos in agricultural return flows (Foe, 1995). Ingram Creek and Hospital Creek also receive agricultural return flows upstream from their confluence and west toward Interstate 5, however the extent of chlorpyrifos impairment upstream from their confluence is not currently known.

Potential Sources
Agricultural return flows are the most likely source of chlorpyrifos in Ingram/Hospital Creek.

B.1.24 Ingram/Hospital Creek, Diazinon

Summary of Proposed Action
The California Regional Water Quality Control Board, Central Valley Region (Regional Board) recommends the addition of the Ingram/Hospital Creek to California's Clean Water Act Section 303(d) list due to impairment by diazinon. Information available to the Regional Board on diazinon concentrations in Ingram/Hospital Creek indicates that water quality objectives are not being attained. The basis for this recommendation is given below.

Table B-1. 303(d) Listing/TMDL Information

Waterbody Name	Ingram/Hospital Creek	**Pollutants/Stressors**	Diazinon
Hydrologic Unit	541.10	**Sources**	Agriculture
Total Waterbody Size	2 miles	**TMDL Priority**	
Size Affected	2 miles	**TMDL Start Date (Mo/Yr)**	
Extent of Impairment	2 miles	**TMDL End Date (Mo/Yr)**	
Upstream Extent	37° 05' 61"	**Upstream Extent**	121° 12' 08"

Latitude		**Longitude**	
Downstream Extent Latitude	37° 38' 10"	**Downstream Extent Longitude**	121° 12' 17"

Watershed Characteristics

Ingram and Hospital Creeks are ephemeral streams that originate in the Coast Range and flow northeast from Ingram Canyon and Hospital Canyon, respectively, to the San Joaquin Valley west of Modesto. The creeks join near Dairy Road and subsequently flow into the San Joaquin River. Upstream of Interstate 5, in Ingram and Hospital Canyons, the creeks are open waterways that transport rainwater runoff during the winter. However, in the agricultural region downstream of Interstate 5 and in the Valley, Ingram and Hospital Creeks are dominated by agricultural return flows (Westcot *et al*, 1991).

Water Quality Objectives Not Attained

The narrative objectives for pesticides and toxicity are not being attained for diazinon in Ingram/Hospital Creek. The narrative objective for pesticides states, "No individual pesticide or combination of pesticides shall be present in concentrations that adversely affect beneficial uses." The narrative toxicity objective in the Basin Plan states, in part, "All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life." The narrative toxicity objective further states that "The Regional Water Board will also consider ... numerical criteria and guidelines for toxic substances developed by the State Water Board, the California Office of Environmental Health Hazard Assessment, the California Department of Health Services, the U.S. Food and Drug Administration, the National Academy of Sciences, the U.S. Environmental Protection Agency, and other appropriate organizations to evaluate compliance with this objective" (CRWQCB-CVR, 1998; http://www.swrcb.ca.gov/~rwqcb5/bsnplnab.pdf). The California Department of Fish and Game (CDFG) has established acute and chronic water quality criteria for diazinon for the protection of aquatic life of 0.08 and 0.05 µg/L, respectively (Siepmann and Finlayson, 2000).

Evidence of Impairment

Between 1991 and 1993, multiple studies analyzed a total of 28 water samples collected from Ingram/Hospital Creek for diazinon. The data are summarized in Table B-2.

Table B-2. Summary of Diazinon Concentrations in Ingram/Hospital Creek

Data Source	Sample Years	Number of Sample Dates	Range of Diazinon Concentrations	Criteria[a]		Number of Samples Equal to or Above Criteria	Percent Samples Equal to or Above Criteria
Foe, 1995; Ross *et al*, 1992, 1993, 1996, and 1999; Fujimura, 1991a,b, and 1993a,b,c,d	1991	11	nd – 0.31 μg/L	Chronic	0.05 μg/L	3	27%
				Acute	0.08 μg/L	3	27%
Foe, 1995; Ross *et al*, 1992, 1993, 1996, and 1999; Fujimura, 1991a,b, and 1993a,b,c,d	1992	19	nd – 1.8 μg/L	Chronic	0.05 μg/L	11	65%
				Acute	0.08 μg/L	6	35%
Ross, 1992 and 1993; Ross *et al*, 1996 and 1999; Fujimura, 1991a,b and 1993a,b,c,d	1993	2	0.16 - 0.41 μg/L	Chronic	0.05 μg/L	2	100%
				Acute	0.08 μg/L	2	100%
Summary	1991 - 1993	32	nd – 1.8	Chronic	0.05 μg/L	16	50%
				Acute	0.08 μg/L	11	34%

[a] CDFG water quality criteria for the protection of aquatic life (Siepmann and Finlayson, 2000)
nd = not detected

Extent of Impairment

Diazinon impairment exists in Ingram/Hospital Creek from their confluence, east of Dairy Road, to the San Joaquin River, due to diazinon in agricultural return flows. Ingram Creek and Hospital Creek also receive agricultural return flows upstream from their confluence and west toward Interstate 5, however the extent of diazinon impairment upstream from their confluence is not currently known.

Potential Sources

Agricultural return flows are the most likely source of diazinon in Ingram/Hospital Creek.

B.1.34 Newman Wasteway, Chlorpyrifos

Summary of Proposed Actions

The California Regional Water Quality Control Board, Central Valley Region (Regional Board) recommends the addition of the Newman Wasteway to California's Clean Water Act Section 303(d) list due to impairment by chlorpyrifos. Information available to the Regional Board on chlorpyrifos levels in Newman Wasteway indicates that water quality objectives are not being attained. The basis for this recommendation is given below.

Table B-1. 303(d) Listing/TMDL Information

Waterbody Name	Newman Wasteway	**Pollutants/Stressors**	Chlorpyrifos
Hydrologic Unit	541.20	**Sources**	Agriculture
Total Waterbody Size	8.5 miles	**TMDL Priority**	
Size Affected	8.5 miles	**TMDL Start Date (Mo/Yr)**	
Extent of Impairment	The entire Wasteway	**TMDL End Date (Mo/Yr)**	
Upstream Extent Latitude	37° 17' 27"	**Upstream Extent Longitude**	121° 05' 17"
Downstream Extent Latitude	37° 20' 16"	**Downstream Extent Longitude**	120° 58' 20"

Watershed Characteristics

The Newman Wasteway originates at the Delta Mendota Canal in Stanislaus County and flows east into Merced County, past Route 33, to the north of Preston Road and continues northeast to the San Joaquin River, just south of Hills Ferry. The Newman Wasteway, owned by the U.S. Bureau of Reclamation and operated by the San Luis and Delta-Mendota Water Authority, was built to carry emergency releases of water from the Delta-Mendota Canal to the San Joaquin River. Local agricultural drainage is allowed to enter the wasteway.

Water Quality Objectives Not Attained

The narrative objectives for pesticides and toxicity are not being attained for chlorpyrifos in the Newman Wasteway. The narrative objective for pesticides states, "No individual pesticide or combination of pesticides shall be present in concentrations that adversely affect beneficial uses." The narrative toxicity objective in the Basin Plan states, in part, "All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life." The narrative toxicity objective further states that "The Regional Water Board will also consider ... numerical criteria and guidelines for toxic substances developed by the State Water Board, the California Office of Environmental Health Hazard Assessment, the California Department of Health Services, the U.S. Food and Drug Administration, the National Academy of Sciences, the U.S. Environmental Protection Agency, and other appropriate organizations to evaluate compliance with this objective." (CRWQCB-CVR, 1998; www.swrcb.ca.gov/~rwqcb5/bsnplnab.pdf) The California Department of Fish and Game (CDFG) has established freshwater numeric acute (1-hour average) and chronic (4-day average) criteria for chlorpyrifos of 0.02 µg/L and 0.014 µg/L, respectively, for the protection of aquatic life (Siepmann and Finlayson, 2000).

Evidence of Impairment

Between 1991 and 1993, a total of ten ambient water samples collected from the Newman Wasteway were analyzed for chlorpyrifos (Table B-2). Most samples were collected between January and April. Two of the ten (20%) samples contained chlorpyrifos concentrations at or above the CDFG chronic water quality criterion of .014 ug/l, and one of the ten (10%) was above the CDFG acute water quality criterion of .020 ug/l. Overall, chlorpyrifos concentrations in samples collected from Newman Wasteway ranged from less than 1 to 15 times the CDFG chronic water quality criteria (Foe, 1995; Ross, 1992, 1993; Ross *et al*, 1996, 1999; Fujimura, 1991a,b, 1993a,b,c,d).

Table B-2. Summary of Chlorpyrifos Concentrations in Newman Wasteway

Data Source	Sample Years	Number of Sample Dates	Range of Chlorpyrifos Concentrations	Criteria[a]		Number of Sample Dates Equal to or Above Criteria	Percent of Sample Dates Equal to or Above Criteria
Foe, 1995	1991	1	0.01 µg/L	Chronic	0.014 µg/L	0	0%
				Acute	0.02 µg/L	0	0%
Ross, 1992 and 1993; Ross *et al*, 1996 and 1999; Fujimura, 1991a,b and 1993a,b,c,d	1991 - 1993	9	nd – 0.27 µg/L	Chronic	0.014 µg/L	2	22%
				Acute	0.02 µg/L	2	22%
Summary	1991 - 1993	10	nd – 0.27 µg/L	Chronic	0.014 µg/L	2	20%
				Acute	0.02 µg/L	2	20%

[a] CDFG water quality criteria for the protection of aquatic life (Siepmann and Finlayson, 2000)
nd = not detected

Extent of Impairment

Because the Newman Wasteway is surrounded by agricultural land from which it receives runoff, it is likely that the entire Wasteway is impaired by chlorpyrifos.

Potential Sources

Agriculture is the likely source of chlorpyrifos in the Newman Wasteway.

B.1.35 Newman Wasteway, Diazinon

Summary of Proposed Action

The California Regional Water Quality Control Board, Central Valley Region (Regional Board) recommends the addition of the Newman Wasteway to California's Clean Water Act Section 303(d) list due to impairment by diazinon. Information available to the Regional Board on diazinon concentrations in the Newman Wasteway indicates that water quality objectives are not being attained. The basis for this determination is given below.

Table B-1. 303(d) Listing/TMDL Information

Waterbody Name	Newman Wasteway	**Pollutants/Stressors**	Diazinon
Hydrologic Unit	541.20	**Sources**	Agriculture
Total Waterbody Size	8.5 miles	**TMDL Priority**	
Size Affected	8.5 miles	**TMDL Start Date (Mo/Yr)**	
Extent of Impairment	The entire wasteway	**TMDL End Date (Mo/Yr)**	
Upstream Extent Latitude	37° 17' 27"	**Upstream Extent Longitude**	121° 05' 17"
Downstream Extent Latitude	37° 20' 16"	**Downstream Extent Longitude**	120° 58' 20"

Watershed Characteristics

The Newman Wasteway originates at the Delta Mendota Canal in Stanislaus County and flows east into Merced County, past Route 33, to the north of Preston Road and continues northeast to the San Joaquin River, just south of Hills Ferry. The Newman Wasteway, owned by the U.S. Bureau of Reclamation and operated by the San Luis and Delta-Mendota Water Authority, was built to carry emergency releases of water from the Delta-Mendota Canal to the San Joaquin River. Local agricultural drainage is allowed to enter the wasteway.

Water Quality Objectives Not Attained

The narrative objectives for pesticides and toxicity are not being attained for diazinon in the Newman Wasteway. The narrative objective for pesticides states, "No individual pesticide or combination of pesticides shall be present in concentrations that adversely affect beneficial uses." The narrative toxicity objective in the Basin Plan states, in part, "All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life." The narrative toxicity objective further states that "The Regional Water Board will also consider ... numerical criteria and guidelines for toxic substances developed by the State Water Board, the California Office of Environmental Health Hazard Assessment, the California Department of Health Services, the U.S. Food and Drug Administration, the National Academy of Sciences, the U.S. Environmental Protection Agency, and other appropriate organizations to evaluate compliance with this objective." (CRWQCB-CVR, 1998; http://www.swrcb.ca.gov/~rwqcb5/bsnplnab.pdf) The California Department of Fish and Game (CDFG) has established freshwater numeric acute (1-hour average) and chronic (4-day average) criteria for diazinon of 0.08 µg/L and 0.05 µg/L, respectively, for the protection of aquatic life (Siepmann and Finlayson, 2000).

Evidence of Impairment

Between 1991 and 1993, multiple studies analyzed a total of ten water samples collected in Newman Wasteway for diazinon (Table B-2). Four out of ten (40%) exceeded the CDFG chronic criterion of 0.05 µg/L, and three out of ten (30%) exceeded the CDFG acute criterion of 0.08 µg/L. Diazinon concentrations ranged from less than 1 time to more than 700 times the CDFG chronic criterion.

Table B-2. Summary of Diazinon Concentrations in Newman Wasteway

Data Source	Sample Years	Number of Sample Dates	Range of Diazinon Concentrations	Criteria[a]		Number of Sample Dates Equal to or Above Criteria	Percent of Sample Dates Equal to or Above Criteria
Foe, 1995	1991	1	0.01 µg/L	Chronic	0.05 µg/L	0	0%
				Acute	0.08 µg/L	0	0%
Ross, 1992 and 1993; Ross *et al*, 1996 and 1999; Fujimura, 1991a,b and 1993a,b,c,d	1991 - 1993	9	nd – 36.82 µg/L	Chronic	0.05 µg/L	4	44%
				Acute	0.08 µg/L	3	33%
Summary	1991 - 1993	10	nd – 36.82 µg/L	Chronic	0.05 µg/L	4	40%
				Acute	0.08 µg/L	3	30%

[a] CDFG water quality criteria for the protection of aquatic life (Siepmann and Finlayson, 2000)
nd = not detected

Extent of Impairment
Diazinon is used on agricultural crops, especially nut and stone fruit orchards during the dormant season. Because the Newman Wasteway is surrounded by agricultural land, including orchards, and receives agriculture runoff, it is likely that the entire Wasteway is impaired by diazinon.

Potential Sources
Since diazinon is applied to crops in the area surrounding the Newman Wasteway and runoff from agriculture enters surface waters that flow to the Newman Wasteway, the main source of diazinon is likely agriculture.

B.1.37 Orestimba Creek, Azinphos-methyl

Summary of Proposed Action

The California Regional Water Quality Control Board-Central Valley Region (Regional Board) recommends the addition of Orestimba Creek to California's Clean Water Act Section 303(d) list due to impairment by azinphos-methyl. Information available to the Regional Board on azinphos-methyl concentrations in Orestimba Creek indicates that water quality objectives are not being attained. The basis for this determination is given below.

Table B-1. 303(d) Listing/TMDL Information

Waterbody Name	Orestimba Creek	**Pollutants/Stressors**	Azinphos-methyl
Hydrologic Unit	541.10	**Sources**	Agriculture
Total Waterbody Size	30 miles	**TMDL Priority**	
Size Affected	10 miles	**TMDL Start Date (Mo/Yr)**	
Extent of Impairment	The lower 10 miles, from the foothills to the SJR	**TMDL End Date (Mo/Yr)**	
Upstream Extent Latitude	37° 19' 31"	**Upstream Extent Longitude**	121° 06' 58"
Downstream Extent Latitude	37° 25' 17"	**Downstream Extent Longitude**	121° 00' 13"

Watershed Characteristics

Orestimba Creek is an ephemeral stream draining a portion of the west side of the San Joaquin Valley. Orestimba Creek flows result from stormwater runoff in the winter and irrigation return flow in the spring and summer. During the winter the creek can receive flow from Coastal Ranges as well as from the area that drains into the main canal of the Central California Irrigation District, depending on the intensity and duration of storms, thus increasing the drainage area to 125,102 acres.

Water Quality Objectives Not Attained

The narrative objectives for pesticides and toxicity are not being attained for azinphos-methyl in Orestimba Creek. The narrative objective for pesticides states, "No individual pesticide or combination of pesticides shall be present in concentrations that adversely affect beneficial uses." The narrative toxicity objective in the Basin Plan states, in part, "All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life." The narrative toxicity objective further states that "The Regional Water Board will also consider ... numerical criteria and guidelines for toxic substances developed by the State Water Board, the California Office of Environmental Health Hazard Assessment, the California Department of Health Services, the U.S. Food and Drug Administration, the National Academy of Sciences, the U.S. Environmental Protection Agency, and other appropriate organizations to evaluate compliance with this objective" (CRWQCB-CVR, 1998; http://www.swrcb.ca.gov/~rwqcb5/bsnplnab.pdf). The US Environmental Protection Agency (USEPA) has established an ambient water quality criterion for azinphos-methyl for the protection of freshwater aquatic life of 0.01 μg/L (USEPA, 1976).

Evidence of Impairment

Between 1992 and 1993, a total of 46 water samples collected from Orestimba Creek at River Road were analyzed for azinphos-methyl (Table 1). Between February 1992 and November 1993, two of the six samples analyzed (33%) contained azinphos-methyl concentrations at or above the USEPA criterion. The highest concentrations generally occurred between June and November; concentrations were also high in February (Ross, 1992, 1993; Ross *et al*, 1996, 1999; Fujimura, 1991a,b, 1993a,b,c,d). In a second study conducted in 1993, seven of 40 samples collected throughout the year (18%) contained azinphos-methyl concentrations at or above the USEPA criterion (Ross, 1992 and 1993; Ross *et al*, 1996 and 1999; Fujimura, 1991a and b, and 1993a, b, c, and d).

Table B-2. Summary of Azinphos-methyl Concentrations in Orestimba Creek

Data Source	Sample Years	Number of Samples	Range of Azinphos-methyl Concentrations	Criterion[a]	Number of Samples Equal to or Above Criterion	Percent Samples Equal to or Above Criterion
Ross, 1992 and 1993; Ross *et al*, 1996 and 1999; Fujimura, 1991a,b and 1993a,b,c,d	1992-1993	6	nd - 0.1 µg/L	0.01 µg/L	2	33%
Panshin *et al*, 1998	1993	40	nd - 0.39 µg/L		7	18%
Summary	1992 - 1993	46	nd - 0.39 µg/L		9	20%

a) USEPA instantaneous maximum ambient water quality criterion (USEPA, 1976)
nd = not detected

Extent of Impairment
Orestimba Creek is already on the 303(d) list because of impairment by chlorpyrifos and diazinon. Because the source (agriculture) is the same for these pesticides, it is likely that agricultural runoff containing azinphos-methyl also impairs the lower 10 miles of Orestimba Creek.

Potential Sources
Azinphos-methyl is used to control insects on many agricultural crops, including almonds and field crops. Therefore the likely source of azinphos-methyl is agriculture.

B.1.38 Orestimba Creek, DDE

Summary of Proposed Action

The California Regional Water Quality Control Board-Central Valley Region (Regional Board), recommends the addition of Orestimba Creek to California's Clean Water Act Section 303(d) list due to impairment by DDE. Information available to the Regional Board on DDE levels in Orestimba Creek indicates that water quality objectives are not being attained. The basis for this recommendation is given below.

Table B-1. 303(d) Listing/TMDL Information

Waterbody Name	Orestimba Creek	**Pollutants/Stressors**	DDE
Hydrologic Unit	541.10	**Sources**	Historical Agriculture
Total Waterbody Size	30 miles	**TMDL Priority**	
Size Affected	10 miles	**TMDL Start Date (Mo/Yr)**	
Extent of Impairment	The lower 10 miles, from the foothills to the SJR	**TMDL End Date (Mo/Yr)**	
Upstream Extent Latitude	37° 19' 31"	**Upstream Extent Longitude**	121° 06' 58"
Downstream Extent Latitude	37° 25' 17"	**Downstream Extent Longitude**	121° 00' 12"

Watershed Characteristics

Orestimba Creek is an ephemeral stream draining a portion of the west side of the San Joaquin Valley. Stream flow in Orestimba Creek results from storm runoff in the winter and irrigation return flows in the spring and summer. During the winter, the creek can receive flow from the Coast Range as well as from the area that drains into the main canal of the Central California Irrigation District, depending on the intensity and duration of storms, thus increasing the drainage area to 125,102 acres.

Water Quality Objectives Not Attained

The United States Environmental Protection Agency (USEPA) California Toxic Rule (CTR) criterion for DDE for the protection of human health is not being attained. The USEPA criterion for DDE for the protection of human health through consumption of drinking water and aquatic organisms is 0.00059 µg/L. DDE is a breakdown product of DDT, which was used as an insecticide on agricultural crops and insects that carry diseases. DDT was banned for use as a pesticide in the United States in 1972 because of its harmful effects on humans and wildlife. DDT is relatively insoluble in water, binds strongly to soil, and breaks down into DDD and DDE (US Department of Health and Human Services-Agency for Toxic Substances and Disease Registry [USDHHS-ATSDR], 1995). DDT, DDD, and DDE are known to have detrimental health effects on humans and other animals (USDHHS-ATSDR, 1994).

Evidence of Impairment

During a 1993 monitoring study conducted by the US Geological Survey (USGS), 40 water samples were collected in Orestimba Creek at River Road (Table B-2). Fifteen of these samples (38%) exceeded the USEPA Criterion. DDE concentrations ranged from less than 1 to more than 100 times the USEPA Criterion. Samples were collected primarily January thru March, with additional sampling in May and June, and minimal sampling throughout the rest of the year. Concentrations exceeding the USEPA Criterion occurred primarily in January and February.

Table B-2. Summary of DDE Concentrations in Orestimba Creek

Data Source	Sample Years	Number of Samples	Range of DDE Concentrations	Criterion[a]	Number of Samples Equal to or Above Criterion	Percent Samples Equal to or Above Criterion
Panshin *et al*, 1998	1993	40	nd - 0.062 µg/L	0.00059 µg/L	15	38%

a) USEPA California Toxics Rule criterion for Sources of Drinking Water (USEPA, 2000a)
nd = not detected

Extent of Impairment
Orestimba Creek is already listed on the 303(d) list for diazinon and chlorpyrifos (SWRCB, 1999), and is proposed for listing for azinphos-methyl. Because the source (agriculture) is the same for all of these pesticides, it is likely that agricultural runoff containing DDE also impairs the lower ten miles of Orestimba Creek.

Potential Sources
DDT was widely used to control insects on agricultural crops before it was banned nationwide in 1972. The most likely source of DDE, a breakdown product of DDT, is from historical agricultural use of DDT.

B.1.51 Sutter Bypass, Diazinon

Summary of Proposed Action

The California Regional Water Quality Control Board, Central Valley Region (Regional Board) recommends the addition of the Sutter Bypass to California's Clean Water Act Section 303(d) list due to impairment by diazinon. Information available to the Regional Board on diazinon concentrations in the Sutter Bypass indicates that water quality objectives are not being attained. The basis for this recommendation is given below.

Table B-1. 303(d) Listing/TMDL Information

Water Body Name	Sutter Bypass	**Pollutants/Stressors**	Diazinon
Hydrologic Unit	520.10	**Sources**	Agriculture
Total Water Body Size	25 miles	**TMDL Priority**	
Size Affected	25 miles	**TMDL Start Date**	
Extent of Impairment	Entire length	**TMDL End Date**	
Upstream Extent Latitude	39° 08' 53"	**Upstream Extent Longitude**	121° 50' 18"
Downstream Extent Latitude	38° 46' 50"	**Downstream Extent Longitude**	121° 38' 31"

Watershed Characteristics

The Sutter Bypass is located in Butte and Sutter Counties. It flows south for approximately 25 miles, from the Sacramento River to the Feather River. The water flowing through the bypass is primarily from the Sacramento River. However, water quality in the bypass is impacted by agricultural runoff, including storm water and irrigation runoff from extensive orchard areas. A number of other waterbodies also flow into the Sutter Bypass, and many of these tributaries also drain orchards.

Water Quality Objectives Exceeded

The narrative objectives for pesticides and toxicity are not being attained for diazinon in the Sutter Bypass. The narrative objective for pesticides states, "No individual pesticide or combination of pesticides shall be present in concentrations that adversely affect beneficial uses." The narrative toxicity objective in the Basin Plan states, in part, "All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life." The narrative toxicity objective further states that "The Regional Water Board will also consider ... numerical criteria and guidelines for toxic substances developed by the State Water Board, the California Office of Environmental Health Hazard Assessment, the California Department of Health Services, the U.S. Food and Drug Administration, the National Academy of Sciences, the U.S. Environmental Protection Agency, and other appropriate organizations to evaluate compliance with this objective" (CRWQCB-CVR, 1998; http://www.swrcb.ca.gov/~rwqcb5/bsnplnab.pdf). The California Department of Fish and Game (CDFG) has established freshwater numeric acute (1-hour average) and chronic (4-day average) criteria for diazinon of 0.08 μg/L and 0.05 μg/L, respectively, for the protection of aquatic life (Siepmann and Finlayson, 2000).

Evidence of Impairment

Several studies have measured diazinon concentrations in water samples collected from the Sutter Bypass (Table B-2). These studies were conducted between December and March, the winter orchard dormant season. A total of 78 samples were analyzed for diazinon; of these 78 samples 27 (35%) exceeded the CDFG chronic water quality criterion for diazinon, and ten (13%) exceeded the acute criterion (Nordmark, 1998, 1999, and 2000).

Table B-2. Summary of Diazinon Concentrations in the Sutter Bypass

Data Source	Sample Years	Number of Samples	Range of Diazinon Concentration	Criteria[a]		Number of Samples Equal to or Above Criteria	Percent Samples Equal to or Above Criteria
Nordmark *et al*, 1998	Dec. 1996 – Mar. 1997	16	nd - 0.086 µg/L	Chronic	0.05 µg/L	0	0%
				Acute	0.08 µg/L	1	6%
Nordmark, 1998	Dec. 1997 – Mar. 1998	20	nd - 0.104 µg/L	Chronic	0.05 µg/L	0	0%
				Acute	0.08 µg/L	3	15%
Nordmark, 1999	Dec. 1998 – Mar. 1999	20	nd - 0.11 µg/L	Chronic	0.05 µg/L	2	10%
				Acute	0.08 µg/L	3	15%
Nordmark, 2000	Dec. 1999 – Mar. 2000	22	nd - 0.093 µg/L	Chronic	0.05 µg/L	0	0%
				Acute	0.08 µg/L	1	4%
Summary	1996 - 2000	78	nd - 0.11 µg/L	Chronic	0.05 µg/L	2	2%
				Acute	0.08 µg/L	8	10%

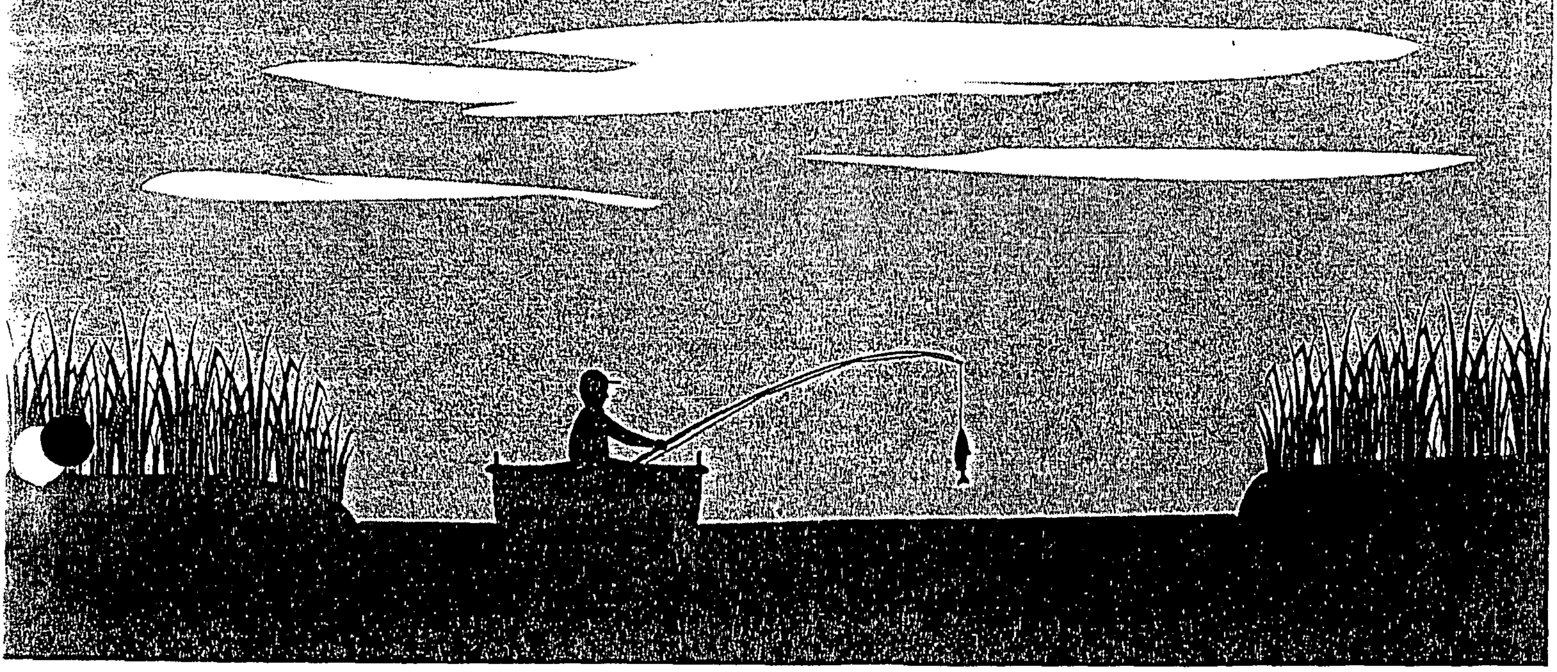
[a] CDFG water quality criteria for the protection of aquatic life (Siepmann and Finlayson, 2000)
nd = not detected

Extent of Impairment
Because of the extensive acreage of orchards drained by the Sutter Bypass and its tributaries, the entire Sutter Bypass is likely to be impaired by diazinon.

Potential Sources
Diazinon is used as a dormant spray on almonds and stonefruits, and these applications are the most likely sources of diazinon runoff to the Sutter Bypass.

Contaminant Concentrations in Fish from the Sacramento–San Joaquin Delta and Lower San Joaquin River 1998

SFEI



Contaminant Concentrations in Fish from the Sacramento–San Joaquin Delta and Lower San Joaquin River 1998

Jay A. Davis and Michael D. May
San Francisco Estuary Institute, Richmond, California

Gary Ichikawa
Moss Landing Marine Laboratory, Moss Landing, California

David Crane
Water Pollution Control Laboratory, California Department of Fish and Game, Rancho Cordova, California

September 2000

Table of Contents

Acknowledgments

Funding for this study was arranged by Bill Jennings (Deltakeeper) and Chris Foe (Central Valley Regional Water Quality Control Board). Chris Foe, Bob Brodberg (Office of Environmental Health Hazard Assessment), and Bill Jennings were actively engaged in all phases of the study, from sampling design to review of a draft of this report.

Staff of the Moss Landing Marine Laboratory, including Mark Pranger, Alex Cully, Autumn Bonnema, and Jon Goetzl, collected the fish samples. Jack Linn (California Department of Fish and Game) provided guidance and assistance in fish collections. Moss Landing Marine Lab staff (Jon Goetzl and Lisa Berrios) also performed trace element measurements. Kathleen Regalado, Laurie Smith, Abdou Mekebri, Gary Munoz, and Jim McCall of the California Department of Fish and Game Water Pollution Control Laboratory performed the trace organic analyses. Ray Schaffter (California Department of Fish and Game) arranged for age determination of largemouth bass.

Henry Lee (U.S. EPA) reviewed a draft of this report.

Liz Hartman and Frank Leung (SFEI) assisted with contract management.

Largemouth bass and white catfish graphics from Freshwater Fishes of California by Samuel M. McGuinis. Illustrations by Doris Alcorn. Copyright ©1984 by The Regents of the University of California. Published by University Press of California. All rights reserved.

Cover created by Michael May.

This report should be cited as:

Davis, J.A., M.D. May, G. Ichikawa, and D. Crane. 2000. Contaminant Concentrations in Fish from the Sacramento–San Joaquin Delta and Lower San Joaquin River, 1998. San Francisco Estuary Institute, Richmond, CA.

San Francisco Estuary Institute
1325 South 46th Street
Richmond, CA 94804
(510) 231-9539

Executive Summary

In spite of the popularity of the Delta as a fishing location, human health concerns raised beginning in 1971, the existence of a consumption advisory for the Bay, and recent concern over fish tissue contamination in the Sacramento River watershed, very little systematic sampling has been conducted in the Delta to evaluate human health risks associated with chemical contamination of fish tissue. *This report documents the most systematic, comprehensive survey of chemical contamination of fish in the Delta yet performed.*

The objectives of this study were, in order of priority:

1. To conduct a pilot study to determine whether mercury, organochlorine pesticides, and PCBs occur in fish that are being used as human food in the Delta at concentrations of potential human health concern.
2. To measure contaminant levels in fish to begin to track long-term trends and evaluate the effectiveness of management efforts.
3. To determine spatial patterns in contamination in the Delta.
4. To provide data that are useful in assessing the ecological hazards of mercury and organochlorines in organisms at high trophic levels.

Sampling was performed in late summer 1998, and focused on largemouth bass and white catfish, two abundant and popular sport fish species. Measured concentrations were compared to screening values, which are defined as concentrations of target analytes in fish or shellfish tissue that are of potential public health concern. Exceedance of screening values should be interpreted as an indication that more intensive site-specific monitoring and/or evaluation of human health risk should be conducted.

Mercury concentrations were frequently above the screening value. One half of the largemouth bass and white catfish samples analyzed exceeded the mercury screening value (11 of 19 largemouth bass and 4 of 11 white catfish). Consistent regional variation hdw been observed iu™both species/$with the higher concentrations and more screening value exceedances in the lower San Joaquin River watershed, and generally low concentrations in the central Delta. Concentrations of PCBs were above the screening value in 30% of the samples (3 of 19 largemouth bass and 6 of 11 white catfish). Available data suggest that PCBs are elevated in localized hotspots rather than on a regional basis. Concentrations of DDT exceeded the screening value in 23% of the samples (1 of 19 largemouth bass and 6 of 11 white catfish). All of the samples above the DDT screening value were obtained from the south Delta or lower San Joaquin River watershed. Other chemicals which are possible concerns in the Delta include dieldrin, toxaphene, arsenic, PAHs, and dioxins.

The following recommendations are based on these findings: 1) Long term monitoring should be conducted to track trends in contaminants of concern in sport fish relative to screening values; 2) Further fish sampling should be conducted in the San Joaquin River watershed to characterize human health concerns related to chemical contamination; and 3) A fishery resource use study should be conducted in the Delta and Central Valley.

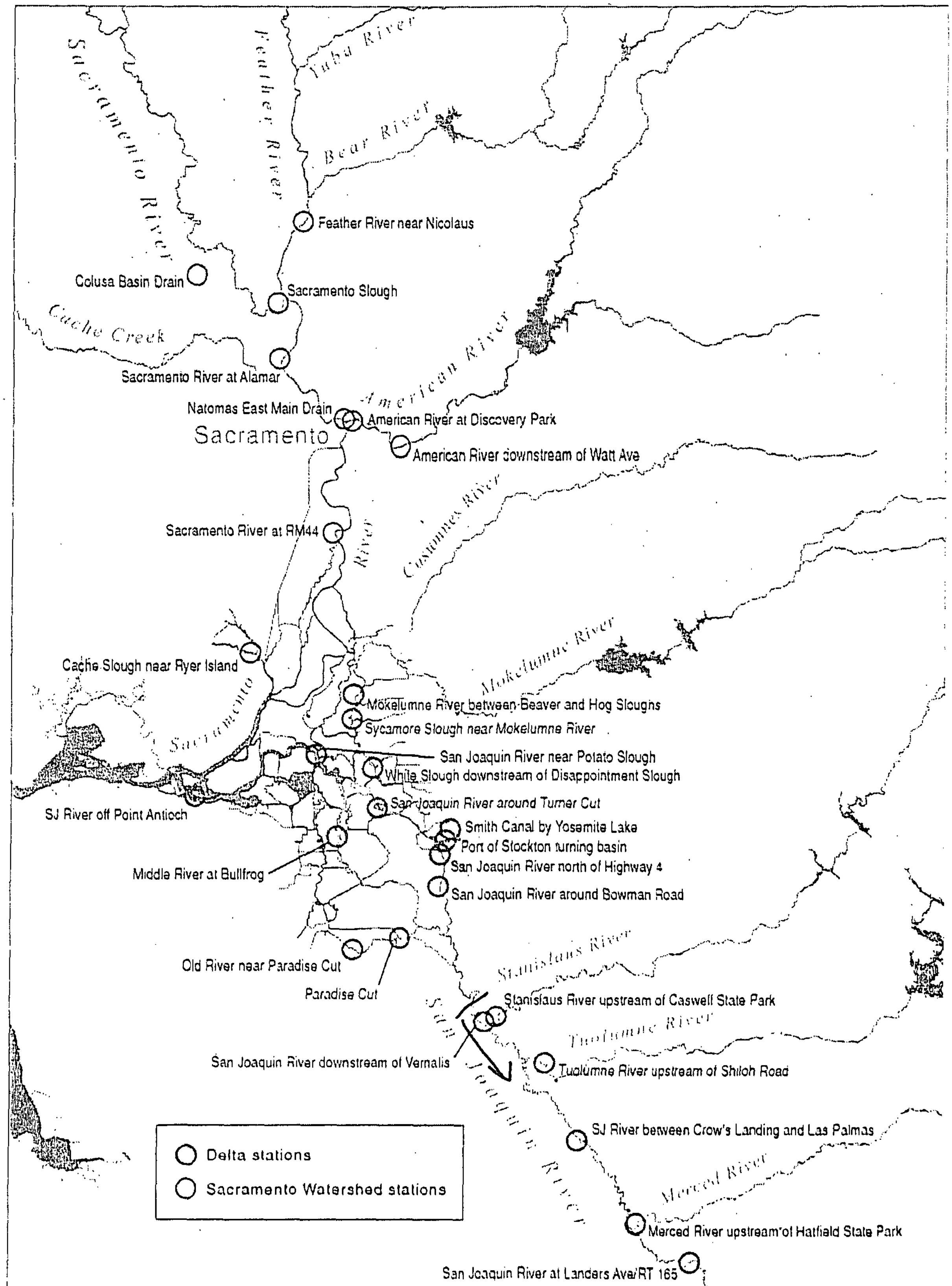


Figure 1. Sampling locations for this study. SRWP sampling locations are also shown.

Introduction

In 1969, as the scope of worldwide environmental contamination due to mercury was first being discovered, two striped bass from the Delta were found to have 700 ng/g mercury in their muscle tissue. In 1970, as a result of this finding, an Interagency Committee was created to evaluate mercury contamination in California (California State Department of Public Health 1971). The Committee assembled existing data and initiated further studies of mercury in sport fish, commercial fish, game birds, water, and sediments. In samples collected between April and July 1970, 55 of 102 fish collected in the Delta region were higher than 500 ng/g. This included 42 striped bass weighing over 4 pounds that were all higher than 500 ng/g. In 1971, based on these studies, a human health advisory was issued for the Delta advising pregnant women and children not to consume striped bass.

In 1993 the advisory for the Delta was revised by the California Environmental Protection Agency's Office of Environmental Health Hazard Assessment (OEHHA) upon review of more mercury data for striped bass. The revised advisory included size-specific consumption advice for adults, children 6–15 years, and pregnant women and children under age 6.

Recent studies in the Bay–Delta watershed have also found concentrations of mercury and other chemicals that are of potential human health concern in striped bass and other popular sport fish species. Extensive sampling was conducted in San Francisco Bay in 1994 and 1997 (SFBRWQCB 1995, Fairey et al. 1997, SFEI 1999). In response to the 1994 results, an interim fish consumption advisory was issued for the Bay–Delta, due to concern over human exposure to methylmercury, PCBs, organochlorine pesticides, and dioxins (OEHHA 1994). This advisory is still in place. The current version of the advisory states that:

- Adults should limit consumption of Bay sport fish, and striped bass and sturgeon from the Delta to, at most, two meals per month.
- Adults should not eat any striped bass over 35 inches (89 cm).
- Pregnant women or women that may become pregnant or are breast-feeding, and children under 6 should not eat more than one meal per month, and should not eat any meals of shark over 24 inches (61 cm) or striped bass over 27 inches (69 cm).

Sport fish have also been sampled in the Sacramento River under the Sacramento River Watershed Program (SRWP) since 1997 (Larry Walker Associates 2000). This annual sampling program includes two locations in the northern Delta and several others just upstream of the Delta in the lower Sacramento River watershed. Concentrations of mercury in white catfish and largemouth bass in this program have frequently been above screening values and have been comparable to concentrations that led to the interim advisory for the Bay. Concentrations of PCBs, dieldrin, DDT, and toxaphene above screening values have also been found in this Program.

In spite of the popularity of the Delta as a fishing location, the concerns raised in the 1971 report (California State Department of Public Health 1971), the existence of the consumption advisory for the Bay, and recent concern over fish tissue contamination in the Sacramento River watershed, very little sampling has been conducted in the Delta since 1971 to evaluate human health risks associated with chemical contamination of fish tissue. This report documents the most systematic, comprehensive survey of chemical contamination of fish in the Delta yet performed.

The objectives of this study were, in order of priority:

- To conduct a pilot study to determine whether mercury, organochlorine pesticides, and PCBs occur in fish that are being used as human food in the Delta at concentrations of potential human health concern.
- To measure contaminant levels in fish to begin to track long-term trends and evaluate the effectiveness of management efforts.
- To determine spatial patterns in contamination in the Delta.
- To provide data that are useful in assessing the ecological hazards of mercury and organochlorines in organisms at high trophic levels.

Sampling in 1998 for the SRWP and the Delta Study had similar objectives, employed identical methods, and focused on the same species. The data from these two efforts are therefore directly comparable and can be combined to provide a picture of chemical contamination in sport fish that covers a large portion of the Central Valley. SRWP data from 1997 and 1998 are incorporated into the analysis presented in this report to provide this broad context. The State Water Resources Control Board's Toxic Substances Monitoring Program (TSMP) is another primary source of data on sport fish contamination in the Central Valley. The TSMP began measurement of toxic chemicals in freshwater fish and shellfish throughout California in 1978 and has continued to the present (Rasmussen 1997). Although the species and locations sampled by the TSMP have fluctuated, the data generated by this program collectively provide a fragmented yet informative overview of fish tissue contamination in California's freshwater habitats, including the Delta. TSMP data are also incorporated into the discussion of spatial and temporal trends in this report.

The primary source of funds for this study was an environmental mitigation fund contributed by the Port of Stockton as part of a federal court settlement agreement. The Deltakeeper had filed a lawsuit alleging Clean Water Act violations by the Port, and the mitigation fund was one component of the out-of-court settlement agreement. Additional funds were provided by the Central Valley Regional Water Quality Control Board.

Methods

Largemouth bass (*Micropterus salmoides*) and white catfish (*Ictalurus catus*) were selected as the primary target species for this study. These popular sport fish species are resident and relatively abundant in the Delta (CDFG 1999). These species are also at a high trophic level, a characteristic which favors accumulation of mercury and organochlorines. Furthermore, since largemouth bass feed in the water column and white catfish are more bottom-oriented foragers, these two species capture different routes of exposure and accumulation as recommended in U.S. EPA guidance on surveys of fish tissue contamination (U.S. EPA 1995).

Largemouth bass are primarily piscivores; occasionally populations prefer crayfish, tadpoles, or frogs (Moyle 1976). The target size range for largemouth bass was 305–438 mm (12–17.25 in). This range was selected based on the lower legal limit and U.S. EPA (1995) guidance that the smallest fish in a composite be no less than 75% of the largest. Largemouth bass in this size range were from 2 to 6 years old. A literature search did not yield any information on the mobility of largemouth bass in the Delta. A recent report (Lee 2000) described the growing popularity of largemouth bass fishing tournaments in the Delta, which results in the capture and relocation of thousands of largemouth annually. These relocations may introduce additional variance in contaminant concentrations at sampling locations in the Delta.

White catfish are opportunistic, carnivorous bottom feeders. In the Delta they feed primarily on amphipods and shrimp, but also eat fish and large invertebrates (Moyle 1976). The target size range for white catfish was 229–330 mm (9–13 in). This range was selected based on the size of fish caught in TSMP sampling and U.S. EPA guidance on compositing. This range brackets the mean length of white catfish (258 mm) measured in August of 1997 by the Resident Fishes Monitoring Program (CDFG 1999). The white catfish population in the Delta is one of the slowest growing populations of this species known. Based on information presented in Moyle (1976), fish in the target range would be between 4 and 7 years old. The slow growth rate of white catfish in the Delta (Moyle 1976) might lead to relatively high mercury concentrations relative to length in this region compared to white catfish populations in other regions, as observed in a study comparing sympatric populations of dwarf and normal lake whitefish (Doyon et al. 1998). A literature search did not yield any information on the mobility of white catfish in the Delta.

Fish samples were collected between August 10 and September 11, 1998. Fish were collected with an electrofisher boat and with fyke nets. Total length (longest length from tip of tail fin to tip of nose/mouth) was measured in the field. Information on bycatch, including species and approximate numbers, was recorded. A detailed sampling report is available from SFEI.

Sampling locations were selected to include known fishing areas and to provide broad geographic coverage (Figure 1). Published information on fish catch and consumption for the Delta were not available, so location selection had to be based on anecdotal information on fishing locations. The sampling design called for collection of both largemouth bass and white catfish at each of the 19 locations. White catfish could not be collected at 8 locations. At three of these locations brown bullhead (*Ictalurus nebulosus*) was collected as an alternate, following the same protocol for size as used for white catfish.

The target number of fish for each composite was five. Target species that were larger than the specified size ranges were kept if they were caught. At sites where large largemouth bass were caught, fish were analyzed individually in order to investigate relationships between length, age, and mercury and lipid and organics. Individual largemouth bass were also analyzed at one location (San Joaquin River at Vernalis) where 10 fish were caught (with the original intent of forming two composites of five fish). In calculating summary statistics, the individual results from these three locations were averaged to provide values that could be compared to the composites from the other locations. White catfish and brown bullhead were analyzed as composites of five fish. Duplicate composites of white catfish were analyzed at one location: San Joaquin River at Vernalis.

The clam *Corbicula fluminea* was collected at three locations (Port of Stockton near New Mormon Slough, Middle River at Bullfrog, and Sacramento River at Rio Vista) for evaluation of human health concerns from clam consumption. One composite sample was prepared for each location. The number included in each composite ranged from 24 to 68 individuals; the average length in each composite ranged from 25 to 33 mm. Mercury was analyzed in each of these samples. Organics were analyzed in two of the three samples.

Sampling and chemical analysis was performed in accordance with the QAPP for the Regional Monitoring Program for San Francisco Bay (Lowe et al. 1999). After capture, fish were wrapped in chemically cleaned Teflon sheeting, placed in Ziploc bags, and frozen on dry ice for transportation to the laboratory. Dissection and tissue sample preparation were performed following U.S. EPA (1995) guidance using non-contaminating techniques in a clean room environment. Fish were thawed and weighed prior to dissection. Scales were removed from largemouth bass prior to filleting. Skin was removed from white catfish and black bullhead. Approximately 40 g of fillet were taken from each fish, yielding a total of approximately 200 g for each composite sample. Approximately 180 g were placed in a clean jar for organic analysis, and 20 g were stored in a clean jar for mercury analysis.

Trace elements were analyzed by the Moss Landing Marine Laboratory. Samples for trace element analysis were digested in a nitric:perchloric acid mixture. Mercury was analyzed using a Perkin Elmer Flow Injection Mercury System (FIMS). Continuing calibration checks were run after every 10 samples. Blanks, standard reference materials (DORM-1: dogfish muscle and liver), and matrix spikes were run with each set of samples for fish. Arsenic and selenium were analyzed with a Perkin Elmer ELAN 6000 ICP-MS. NRC SRM 2976 was used for arsenic and selenium measurements. QA/QC results all met the data quality objectives of the QAPP. A full QA and data report on the trace element analysis is available from SFEI.

Trace organics were analyzed by the California Department of Fish and Game Water Pollution Control Laboratory. A 10 g sample of homogenate for trace organic analysis was extracted with a 50/50 mixture of acetone/dichloromethane in a Dionex Accelerated Solvent Extractor (ASE 200). Extract cleanup was then performed using gel permeation chromatography. Twenty percent of each extract was removed and weighed for percent lipid determination. For organochlorine analysis, cleaned up extract was then fractionated into four fractions using Florisil. Each fraction was then analyzed using dual column high resolution gas chromatography with a Hewlett-Packard 6890 *plus* GC with electron capture detection, with two 60 m, 0.25 mm i.d., 0.25 um film thickness columns (DB-5 and DB-17: J&W Scientic). Extracts for PAH analysis were cleaned up using activated silica gel/alumina and analyzed on a Varian 4D Ion Trap GCMS using a 60 m, 0.25 mm i.d., 25 um film thickness DB5-MS capillary column. Reference materials from the International Atomic Energy Agency (IAEA) (fish homogenate MA-B-3/OC and mussel MA-M-2/OC) and the National Institute of Standards and Technology (SRM 1588a: organics in cod liver oil) were used in QA evaluation. Overall, the reported data were of excellent quality. Minor exceedance of data quality objectives occurred for particular analytes, but had minimal impact on the data presented in this report. A full QA and data report for the trace organics is available from SFEI.

Scales were removed from largemouth bass prior to dissection to allow estimation of age. Scale aging was performed for the largemouth bass analyzed as individuals by Ray Schaffter of the DFG Bay–Delta unit in Stockton. Consensus from three readers was obtained on 20 of 24 samples.

U.S. EPA (1995) defines screening values as concentrations of target analytes in fish or shellfish tissue that are of potential public health concern. Exceedance of screening values should be taken as an indication that more intensive site-specific monitoring and/or evaluation of human health risk should be conducted. Screening values were taken from OEHHA (1999) or calculated following U.S. EPA (1995) guidance and using the consumption rate (21 g/day) employed by OEHHA (1999).

Statistical analyses were performed using SAS (SAS Institute, 1990). All data are presented in wet weight unless otherwise noted. Summary statistics are presented as medians, which provide an indication of central tendency regardless of the distribution of the data. Appendix A contains tables with the complete dataset.

Results and Discussion

Mercury

Introduction

Mercury is the primary concern behind the past and present advisories for consumption of fish from the Delta. In humans, mercury is a neurotoxicant, and is particularly hazardous for fetuses and children as their nervous systems develop (OEHHA, 1994b). Mercury can cause many types of problems in children, including mental impairment, impaired coordination, and other developmental abnormalities. In adults, mercury has neurotoxic effects that include decrements in motor skills and sensory ability at comparatively low doses, to tremors, inability to walk, convulsions and death at extremely high exposures. Similarly, in wildlife species mercury can cause damage to nervous, excretory, and reproductive systems, and early life stages are most sensitive (Wolfe et al. 1998).

Mercury exists in the environment in a variety of chemical forms. The most important form of mercury in the aquatic environment is methylmercury, which is readily accumulated by biota and transferred through the food web. Most of the mercury that accumulates in fish tissue is methylmercury (U.S. EPA, 1995). Methylmercury is also the form of mercury of greatest toxicological concern at concentrations typically found in the environment. The principal sources of mercury to aquatic ecosystems in northern California are historic mercury and gold mining sites, fossil fuel combustion, trace impurities in products such as bleach, and direct use of the metal in applications such as thermometers and dental amalgam (SFRWQCB, 1998). Fish, especially long-lived predators at the top of the food web, accumulate high concentrations of mercury and are fundamental indicators of the human and wildlife health risks associated with mercury in aquatic ecosystems.

Analytical considerations

The screening value for mercury, 0.3 μg/g wet weight, applies to methylmercury. Because of the higher cost of methylmercury analysis and data indicating that most mercury in fish tissue is present as methylmercury, U.S. EPA (1995) recommends that total mercury be measured in fish contaminant monitoring programs and the conservative assumption made that all mercury is present as methylmercury in order to be most protective of human health. Total mercury was measured in these samples.

The mercury concentrations in fish were easily measured with the analytical methods employed. The minimum concentration in field samples was 12 ng/g wet, 12 times higher than the method detection limit (1 ng/g wet).

Data distribution and summary statistics

Largemouth bass had the highest median mercury concentration (350 ng/g) (Table 1, Figure 2). In composite samples, concentrations ranged from a low of 84 ng/g in Smith Canal to a high of 670 ng/g at Stanislaus River upstream of Caswell State Park. Eleven of nineteen locations had concentrations above the 300 ng/g screening value (Table 2, Figure 3). Eight locations in the central and southern Delta had concentrations below the screening value. Locations further upstream on both the Sacramento and San Joaquin rivers were all above the screening value (Figure 3). Concentrations in the fish analyzed individually (from three locations) ranged from a low of 240 ng/g (Sycamore Slough) to a high of 700 ng/g in a large fish (also Sycamore Slough).

Other species were analyzed solely as composites. White catfish had slightly lower concentrations than largemouth bass, with a median of 290 ng/g (Table 1, Figure 2). Concentrations in white catfish composites ranged from a low of 85 ng/g at Smith

Table 1. Summary statistics by species for trace elements and selected organic contaminants. *Data are medians. All units ng/g wet weight unless indicated. For median calculation, ND was set equal to zero. ND = not detected.*

Species	Number of composites analyzed	individuals per composite	length (mm)	% lipid	mercury	arsenic	selenium	sum of PCBs	sum of DDTs	sum of chlor danes	dieldrin	diazinon	chlorpyrifos
Largemouth Bass	19	5	361	0.6	350	79	450	6.1	39	1.0	ND	ND	ND
White Catfish	11	5	258	0.8	280	15	180	20	130	5	ND	ND	ND
Black Bullhead	3	4–5	288	0.6	140	49	140	3.2	15	ND	ND	ND	ND
Corbicula spp.	2–3	24–68	31	1.4	12	1000	310	64	48	7.5	2.7	ND	2.9

Canal to a high of 470 ng/g at San Joaquin River at Bowman Road. Four of eleven locations had concentrations in white catfish that exceeded the screening value (Table 2, Figure 4). Similar to the largemouth bass, many locations in the central and southern Delta were below the screening value. White catfish were only found at one location upstream on the San Joaquin River (at Landers Avenue) where a concentration of 250 ng/g was observed. Mercury concentrations in white catfish at seven SRWP locations in 1997 were all above the screening value (Figure 4).

The median concentration for three black bullhead samples was much lower (141

Figure 2. Mercury concentrations in Delta fish and Corbicula, and Sacramento River watershed fish, 1998.

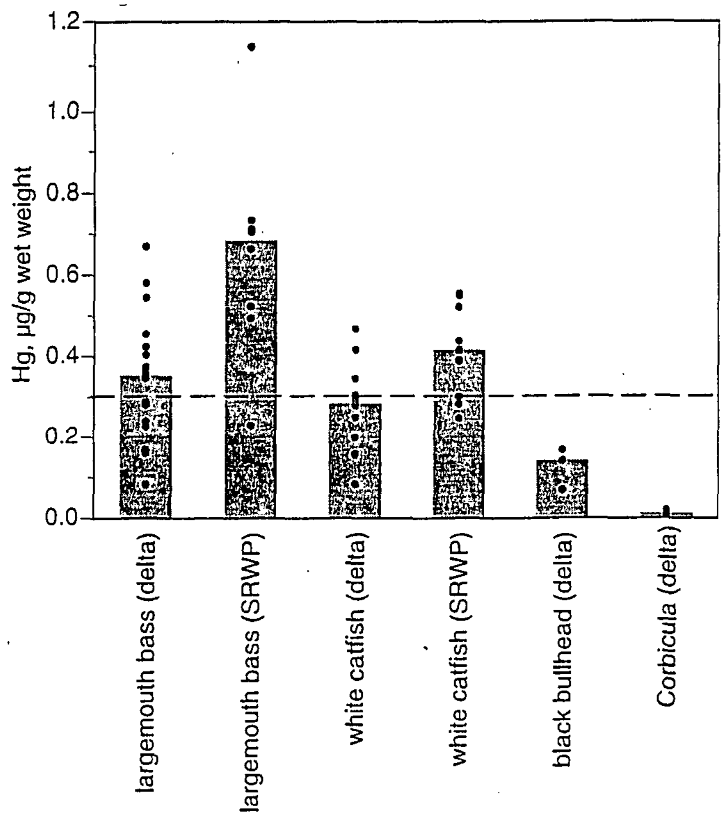


Table 2. Summary of concentrations above screening values for each species. Numerator indicates the number above the screening value, denominator indicates the number of samples analyzed. Composite samples only. All units ng/g wet weight.

Species	mercury	arsenic	selenium	sum of PCBs	sum of DDTs	sum of chlordanes	dieldrin	diazinon	chlorpyrifos
screening value	*300*	*1000*	*20000*	*20**	*100*	*30*	*2*	*300*	*10000*
Largemouth Bass	11/19	0/19	0/19	3/19	1/19	0/19	0/19	0/19	0/19
White Catfish	4/11	0/11	0/11	6/11	6/11	0/11	1/11	0/11	0/11
Black Bullhead	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3
Corbicula	0/3	2/3	0/3	1/2	0/2	0/2	1/2	0/2	0/2
All species	15/36	2/36	0/36	10/35	7/35	0/35	2/35	0/35	0/35

* *screening value is for sum of Aroclors; data are sum of congeners*

ng/g) (Table 1). All of these were below the screening value (Table 2). Mercury concentrations in *Corbicula* were much lower than in the fish, with a median of 12 ng/g in three samples (Table 1).

Controlling Factors

Within a given species, the older and larger fish tend to have higher mercury concentrations. At two locations, Port of Stockton and Sycamore Slough, largemouth

Figure 3. ***Mercury concentrations in largemouth bass at each sampling location.*** *Data from this study and the SRWP (see figure 1).*

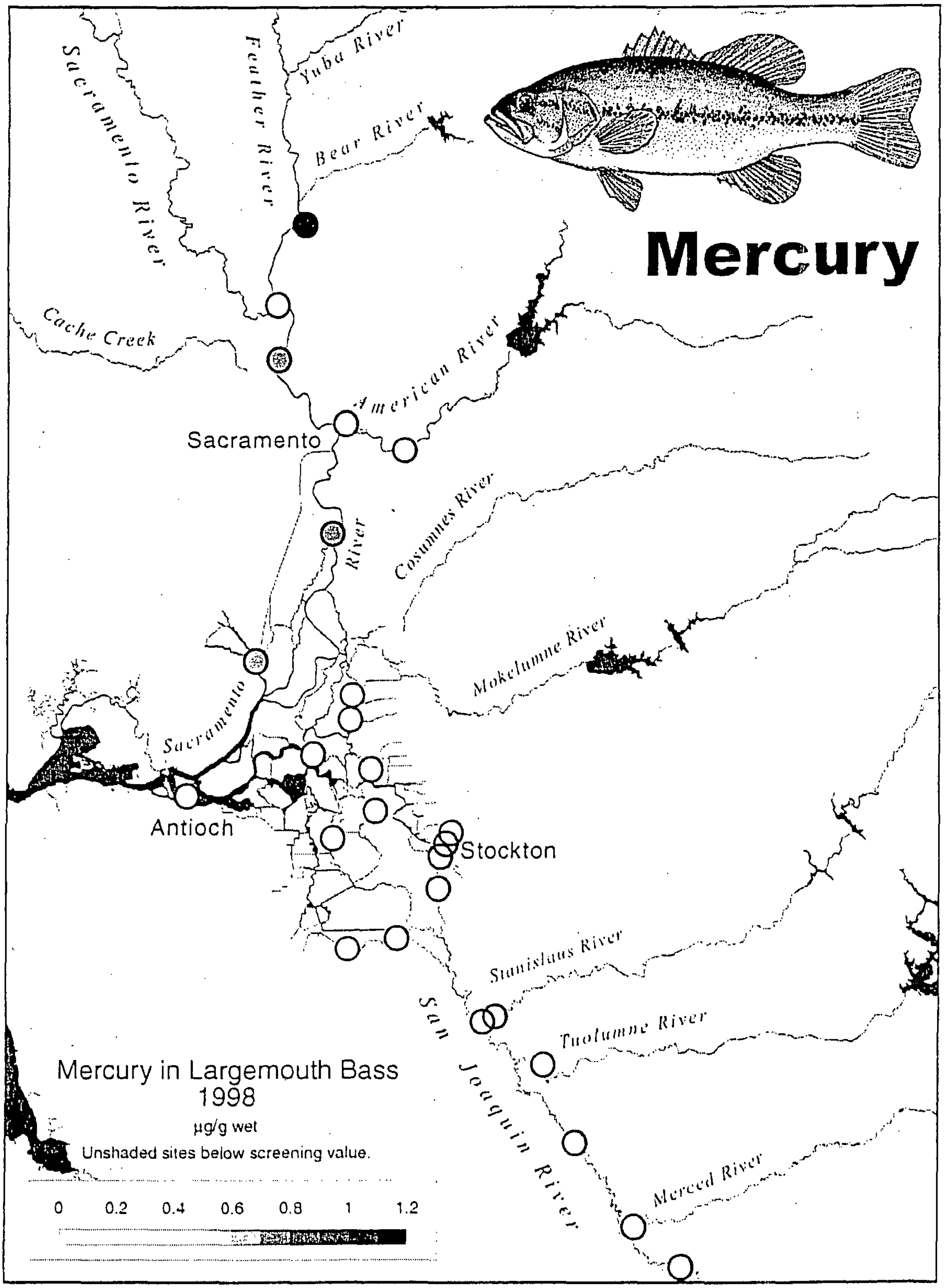
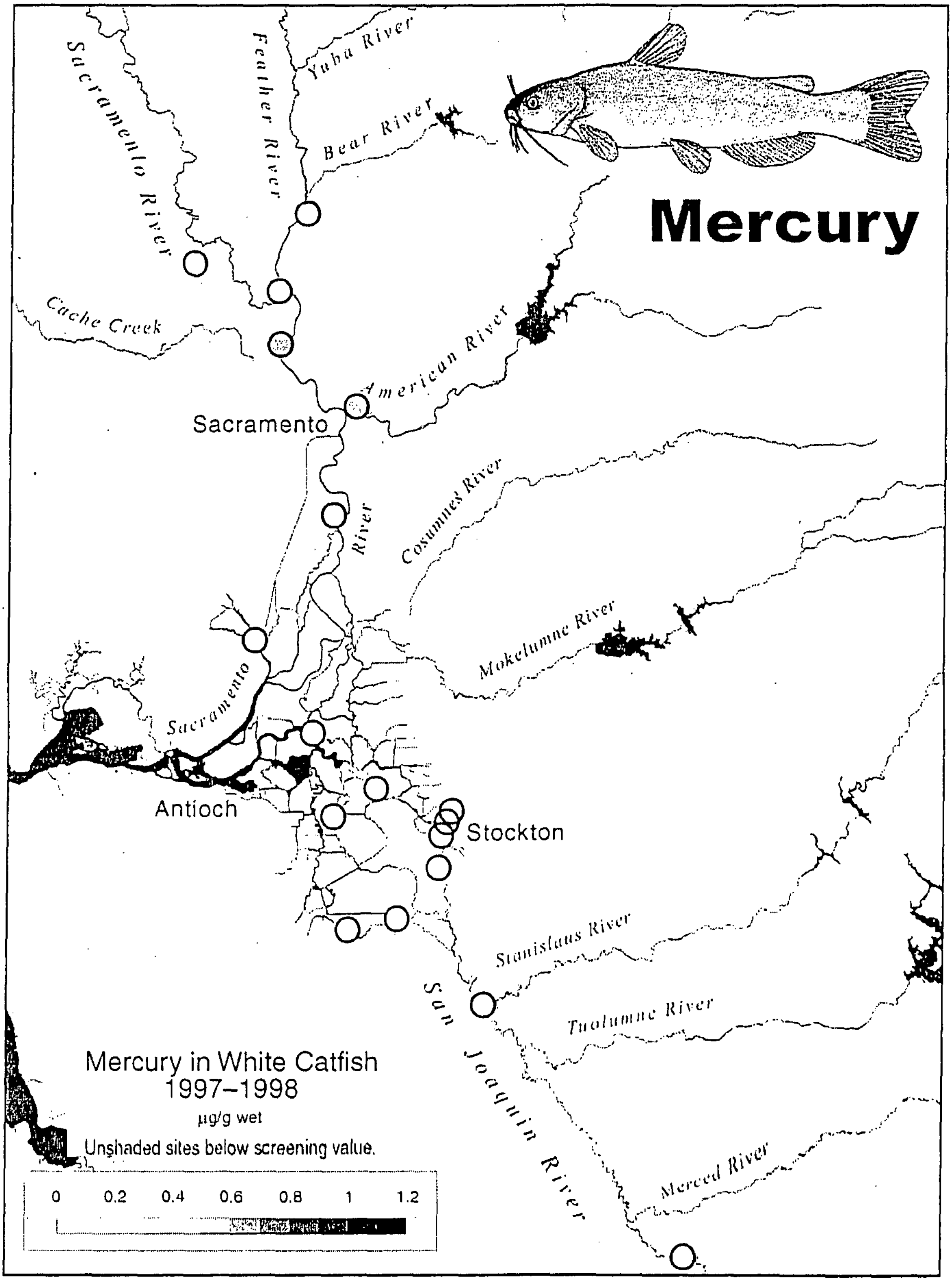


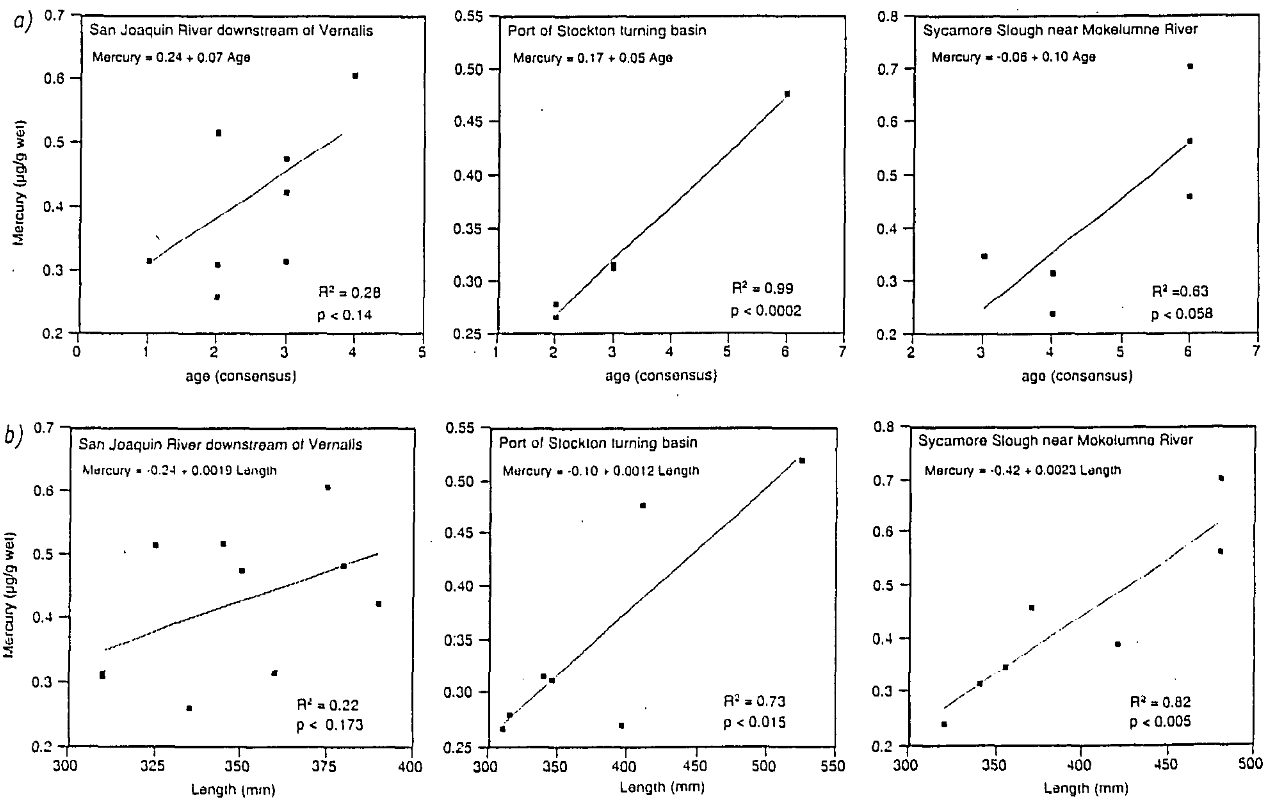
Figure 4. Mercury concentrations in white catfish at each sampling location. Data from this study and the SRWP (see figure 1).



bass were caught that exceeded the size range set for composite samples. Largemouth bass were analyzed individually at these locations to take advantage of the wider size range available for inclusion in regressions of mercury with size or age. Individual largemouth bass were also analyzed at the San Joaquin River at Vernalis, where enough fish were collected to prepare duplicate composite samples (i.e., 10 largemouth bass).

In spite of small samples sizes and the limited size range sampled, some significant regressions (three of six) were obtained for both age and length versus mercury concentration (Figures 5 a,b). The fit of the linear regressions were similar for both length and age, although perhaps slightly better overall for length. The inclusion of the large fish (> 438 mm) caught at Port of Stockton and Sycamore Slough helped reveal the relationships with age and length. Regressions for length versus mercury at these two locations were both significant. At San Joaquin River at Vernalis a larger number of fish were available for analysis, but the fish were all in the target size range (305–438 mm) for composite samples. These individual data indicate confirm that length and age are important variables influencing mercury concentrations in Delta largemouth bass. The limited size ranges selected in this study facilitate comparability of the composite samples, but constrain the ability to assess relationships between size and mercury concentration. Evaluation of broader size ranges in the future would yield information that would be valuable in assessment of human health risks.

Figure 5. a) Mercury concentration versus age in individual largemouth bass: 1) San Joaquin River at Vernalis; 2) Port of Stockton; 3) Sycamore Slough. b) Mercury concentration versus length in individual largemouth bass: 1) San Joaquin River at Vernalis; 2) Port of Stockton; 3) Sycamore Slough.



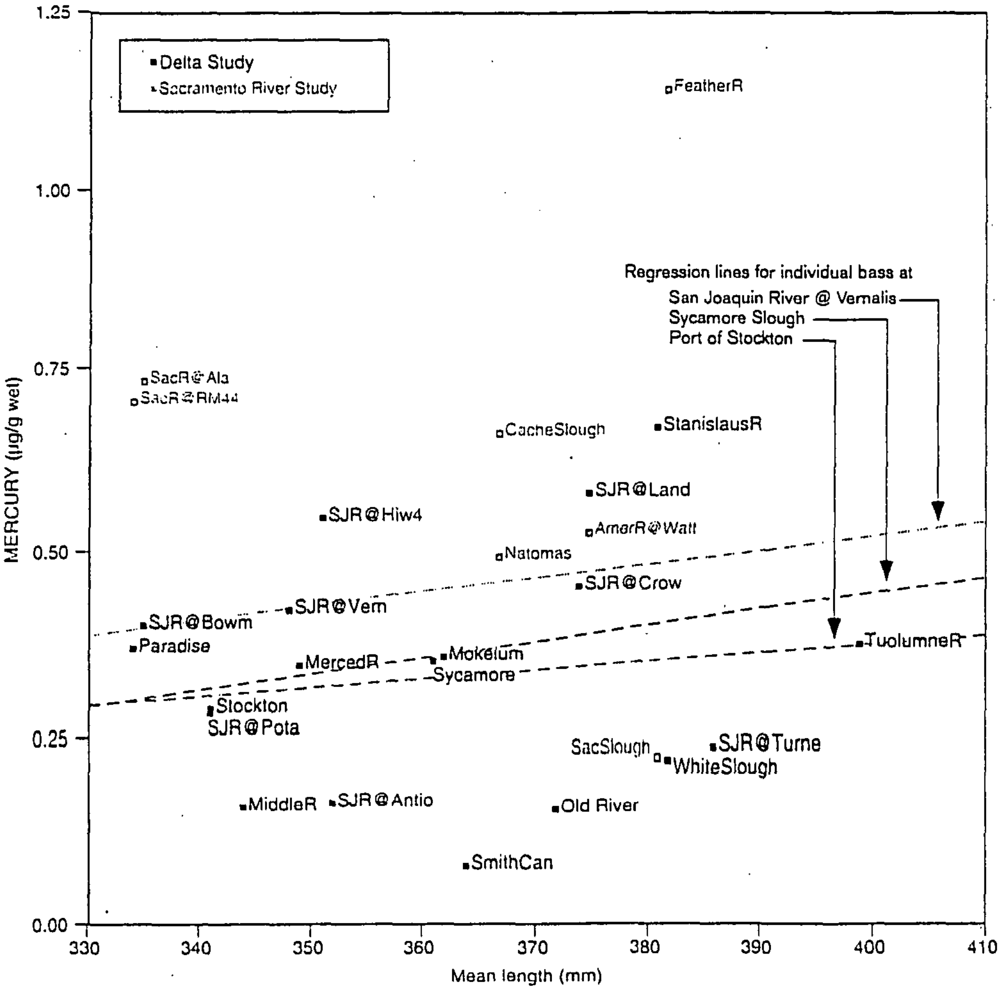
Spatial Patterns

Substantial regional variation was observed in mercury concentrations in largemouth bass. Largemouth bass from the Delta (from Vernalis downstream in the south and downstream of SRWP sites in the north) had an average mercury concentration in composite samples of 290 ng/g. The average mercury concentration measured in the SRWP for largemouth bass in the lower Sacramento River and northern Delta was 650 ng/g, more than twice as high as the Delta average. The average concentration in San Joaquin River (upstream of Vernalis) largemouth bass (490 ng/g) was also elevated relative to the Delta. Many of the samples analyzed in the Delta had concentrations below the 300 ng/g screening value, while all but one sample from the SRWP region and all samples from the San Joaquin region were above the screening value (Figure 3).

Given the clear relationship with length observed at the locations where individual largemouth bass were analyzed, accounting for variation in age or length when comparing locations yields a clearer picture of spatial variation. Plots of mercury concentration versus length allow visual comparisons that incorporate size differences (Figures 6 and 7).

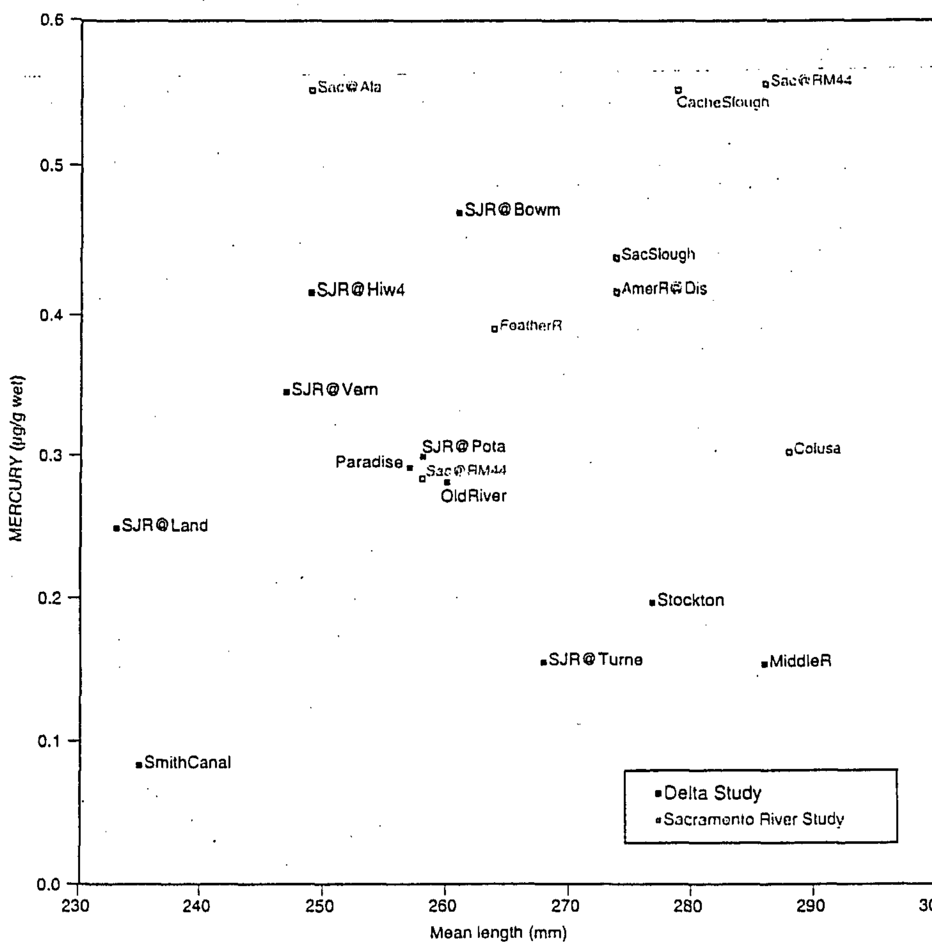
On the largemouth bass plot (Figure 6), the regression lines obtained from

Figure 6. Mercury concentrations versus average fish length in composite samples of largemouth bass. *Data from this study and the SRWP (see figure 1).*



individual fish at the three locations are provided for reference. Several SRWP locations (Feather River at Nicolaus, Sacramento River at Alamar, Sacramento River at River Mile 44, and Cache Slough near Ryer Island Ferry) had high concentrations relative to length. Several stations from the central and southern Delta (Port of Stockton, Smith Canal, San Joaquin River at Turner Cut, White Slough, San Joaqun River near Potato Slough, San Joaquin River at Point Antioch, Middle River at

Figure 7. Mercury concentrations versus average fish length in composite samples of white catfish. Data from this study and the SRWP (see figure 1).

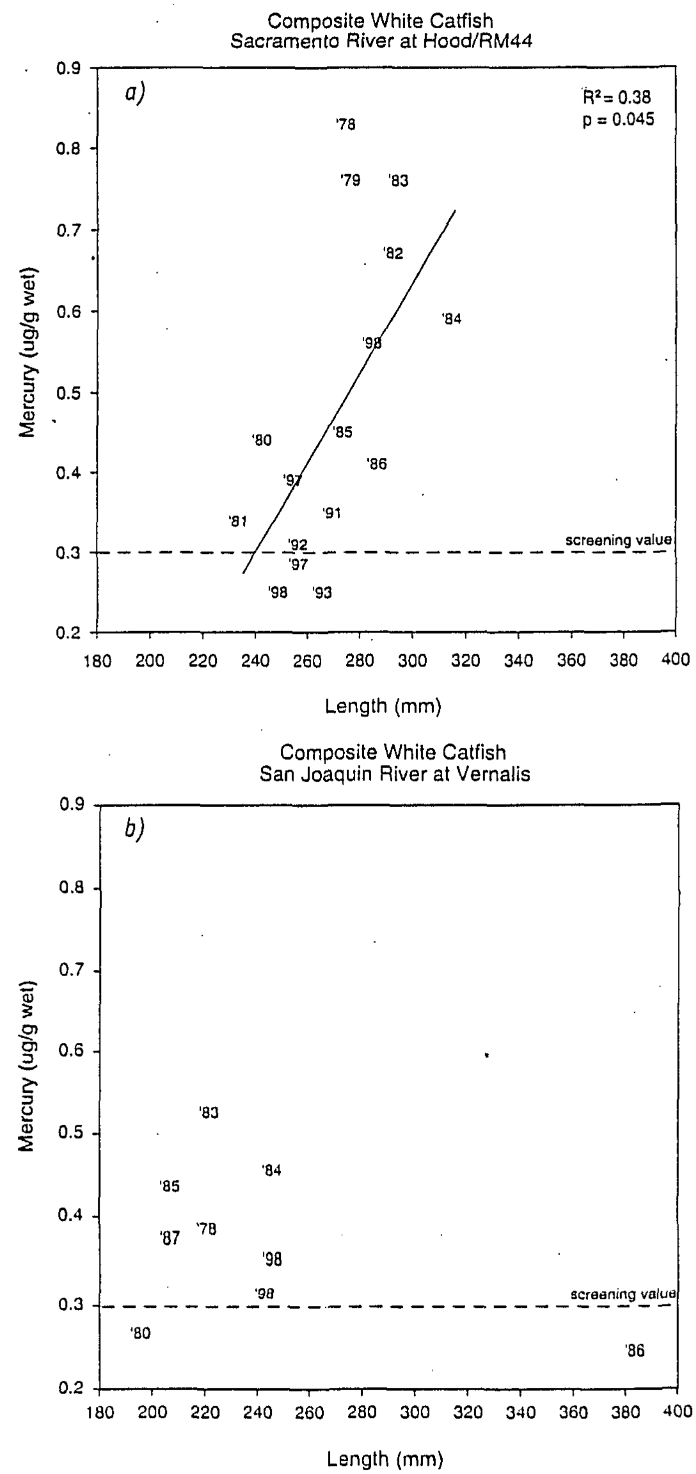


Bullfrog, and Old River near Paradise Cut) had relatively low concentrations relative to length. The central and southern Delta appears to have some peculiar characteristics that result in low mercury bioaccumulation at higher trophic levels.

The white catfish plot shows similar regional variation (Figure 7). Several central and southern Delta locations (Smith Canal, San Joaquin River at Turner Cut, Port of Stockton, and Middle River at Bullfrog) had low concentrations relative to length. As in largemouth bass, the SRWP site at Sacramento River at Alamar had a high concentration. The lack of information on the typical slope of the length-mercury regression line makes it difficult to evaluate the magnitude of concentrations relative to length for the other locations.

Even taking into account size differences, concentrations in largemouth bass composites still exhibited substantial spatial variation, with up to an 8-fold difference between locations in equal-sized fish (Smith Canal - 84 ng/g vs. Cache Slough - 660 ng/g). Factors other than length must be responsible for this remaining variation. These factors are influential enough to cause observed concentrations to vary from well below the screening value to well above the screening value. Mercury concentrations in white catfish were also influenced by factors other than length or age that resulted in samples being either well below or well above the screening value. Possible explanations for the spatial variation observed in these species include spatial variation in total mercury concentrations, mercury methylation and bioavailability, or trophic position. Research funded by CalFED on mercury cycling in the Delta will help determine the relative importance of these other factors.

Figure 8. Mercury concentration versus length in white catfish: a) Sacramento River at Hood/RM44; b) San Joaquin River at Vernalis. *Data from this study, TSMP, and SRWP.*



Temporal Trends

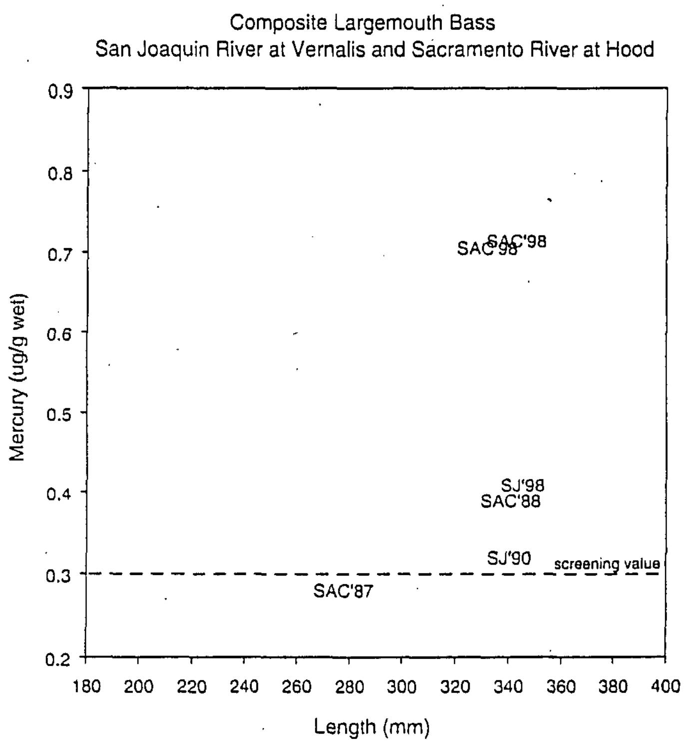
Mercury data from TSMP sampling in the Delta can be compared to the results of this study and the SRWP to provide a limited indication of trends over the last two decades. This is only a limited indication because TSMP sampling in the Delta was generally limited and sporadic.

The best historical time series were generated by the TSMP for white catfish at the Sacramento River at Hood and the San Joaquin River at Vernalis, and sampling at these locations has been continued by the SRWP and the Delta Study to further extend the series (Figures 8a and b). Data for white catfish suggest that concentrations have declined from the late 1970s to the mid-1980s and remained relatively constant from the mid-1980s to 1998. At the Sacramento

River at Hood/RM 44 the time series suggests that concentrations have declined since the late 1970s (Figure 8a). The mercury-length plot shows that concentrations in 1978–1983 were high relative to length (i.e., they have relatively large positive residuals from the regression line). The most recent results from 1997 and 1998 (duplicate samples were collected in both years) fall near or below the regression line; two of the four 1997 and 1998 samples were below the screening value.

The mercury-length plot for the San Joaquin River at Vernalis shows that concentrations in white catfish in 1998 were low relative to previous measurements (Figure 8b). The time series for this location is not as complete as for the Sacramento River at Hood. One point (from 1986) representing two very large fish appears to be an outlier and is not included in the graph. Both of the 1998 samples were above the screening value.

Figure 9. Mercury concentration versus length in largemouth bass at Sacramento River at Hood/RM44 and San Joaquin River at Vernalis. *Data from this study, TSMP, and SRWP.*



The data for largemouth bass are less complete and only go back to the late 1980s (Figure 9). Two composite samples collected in 1998 at Sacramento River at Hood/RM44 of similar size had very similar mercury concentrations (both were 710 ng/g). A 1988 composite sample of similar size had only 390 ng/g mercury. Although the recent data are higher than historic data for fish of similar size, the small number of samples provide an insufficient basis for discussion of long term trends.

PCBs

Introduction

The term "polychlorinated biphenyl" refers to a group of 209 individual chemicals ("congeners") based on substitution of the biphenyl molecule with varying numbers of chlorine atoms. Due to their resistance to electrical, thermal, and chemical processes, PCBs were used in a wide variety of applications (e.g., in electrical transformers and capacitors, vacuum pumps, hydraulic fluids, lubricants, inks, and as a plasticizer) from the time of their initial commercial production in 1929 (Brinkmann and de Kok, 1980). In the U.S., PCBs were sold as mixtures of congeners known as "Aroclors" with varying degrees of chlorine content. By the 1970s a growing appreciation of the toxicity of PCBs led to restrictions on their production and use. In 1979, a final PCB ban was implemented by the U.S. Environmental Protection Agency, prohibiting the manufacture, processing, commercial distribution, and use of PCBs except in totally enclosed applications. A significant amount of PCBs remains in use in these applications: a recent voluntary survey in the Bay Area found that approximately 200,000 kg of PCBs are currently in use in transformers. Leakage from or improper handling of such equipment has led to PCB contamination of runoff from industrial areas. Other sources of PCBs to the Estuary are atmospheric deposition, effluents, and remobilization from sediment (Davis et al. 2000).

In spite of the fact that their use has been restricted for almost two decades, PCBs remain among the environmental contaminants of greatest concern because many of the PCB congeners are potent toxicants that are resistant to degradation and have a strong tendency to accumulate in biota. In general, PCBs are not very toxic in acute exposures, but certain congeners are extremely toxic in chronic exposures. The most toxic PCB congeners are those that closely mimic the potency and mechanism of toxicity of 2,3,7,8-tetrachlorodibenzo-p-dioxin ("dioxin," one of the most toxic compounds known). These PCB congeners can cause toxic symptoms similar to those caused by dioxin exposure, including developmental abnormalities and growth suppression, disruption of the endocrine system, impairment of immune function, and cancer promotion (Ahlborg et al., 1994). Other toxicologically active PCB congeners and their metabolites exert toxicities through different mechanisms than the dioxin-like congeners (McFarland and Clarke, 1989). U.S. EPA classifies PCBs as a probable human carcinogen (U.S. EPA, 1995).

The toxicity of PCBs has historically been evaluated for Aroclor mixtures. In recent years toxicological data have begun to accumulate for specific PCB congeners, but overall the toxicological database is more complete for Aroclor mixtures than for PCB congeners (U.S. EPA 1995). U.S. EPA (1995) consequently recommends using an Aroclor screening value to evaluate fish tissue contamination. In this study PCBs were measured on a congener-specific basis. Advantages of congener-specific data are described in Davis et al. (1997) and U.S. EPA (1995). The congener-specific results were used to estimate Aroclor concentrations.

Due to their general resistance to metabolism and high affinity for lipids, PCBs and other similar organochlorines reach higher concentrations with increasing trophic level in aquatic environments; this process is known as "biomagnification" (Gobas et al., 1993, Suedel et al., 1994). The dioxin-like PCB congeners are also relatively resistant to metabolism (Davis 1997). Consequently, predatory fish, birds, and mammals (including humans that consume fish) at the top of the food web are particularly vulnerable to the effects of PCB contamination.

Analytical considerations

PCBs were measured on a congener-specific basis. A list of 48 congeners was selected for analysis, based on abundance in fish and other media in the Estuary (SFEI 2000) and including specific congeners that are useful indicators of distinct Aroclor mixtures (Newman et al. 1998). Some PCBs have dioxin-like potency, including several congeners measured in this study. Most of the dioxin equivalents due to PCBs in fish are attributable to congeners not measured in this study, especially PCB 126 (SFEI 1999). PCB dioxin-equivalents are therefore not presented in this report.

Screening values for PCBs are expressed as Aroclors. Previous work in the Bay (SFBRWQCB 1995, SFEI 1999) has shown that PCB concentrations expressed as the sum of PCB congeners are slightly lower than those expressed as sums of

Aroclors. In this report sums of congeners are compared to the Aroclor-based screening value. It should be noted that if the data were expressed as sums of Aroclors it is possible that more samples would exceed the screening value.

A sum of PCB congeners could be quantified in each sample. The reporting limit for each congener was 0.20 ng/g wet. In the lowest sample, only one congener was quantified and the sum of congeners was only 0.23 ng/g. Concentrations near reporting limits have relatively high uncertainty associated with them and should be considered as only semi-quantitative.

Data distribution and summary statistics

Of the three fish species sampled, white catfish had the highest median PCB concentration (20 ng/g) (Table 1, Figure 10). PCB concentrations in white catfish ranged from a low of 8 ng/g at Middle River at Bullfrog to a high of 102 ng/g at Smith Canal. Six of eleven locations had concentrations above the 20 ng/g screening value (Table 2, Figure 11). Locations above the screening value were scattered around the Delta. In the SRWP, PCB concentrations in white catfish at two of four locations in 1997 were above the screening value (Figure 11).

The median PCB concentration in largemouth bass was 6 ng/g (Table 1), with a range from 2 ng/g at Mokelumne River to a high of 112 ng/g at Smith Canal. Three of 19 locations where largemouth bass were collected had concentrations above the screening value (Table 2). Two of these were in the Stockton area (Smith Canal and

Figure 10. PCB concentrations in Delta fish and* Corbicula, *and Sacramento River watershed fish, 1998.

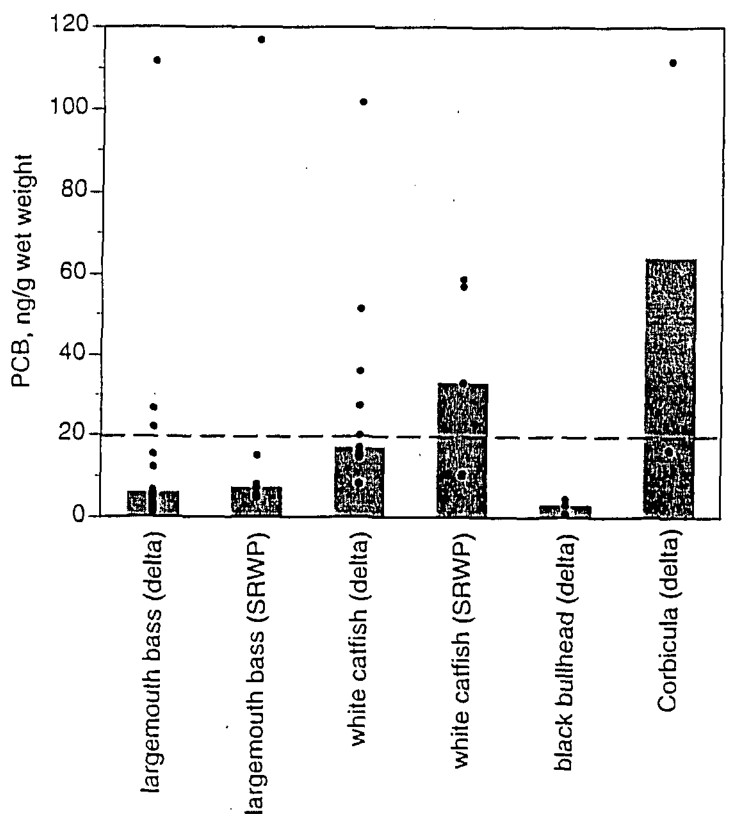


Figure 11. PCB concentrations in white catfish at each sampling location. Data from this study and the SRWP (see figure 1).

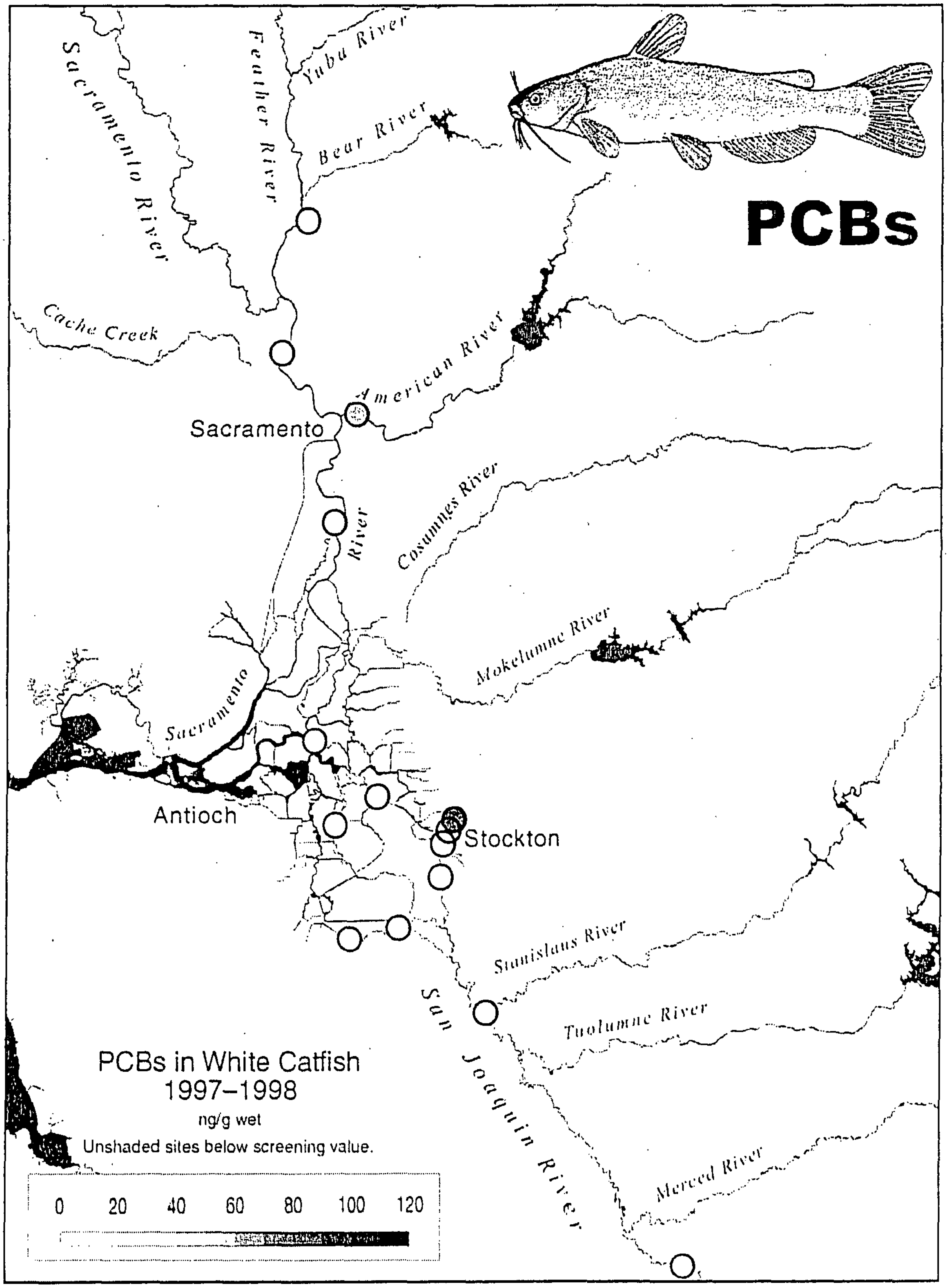
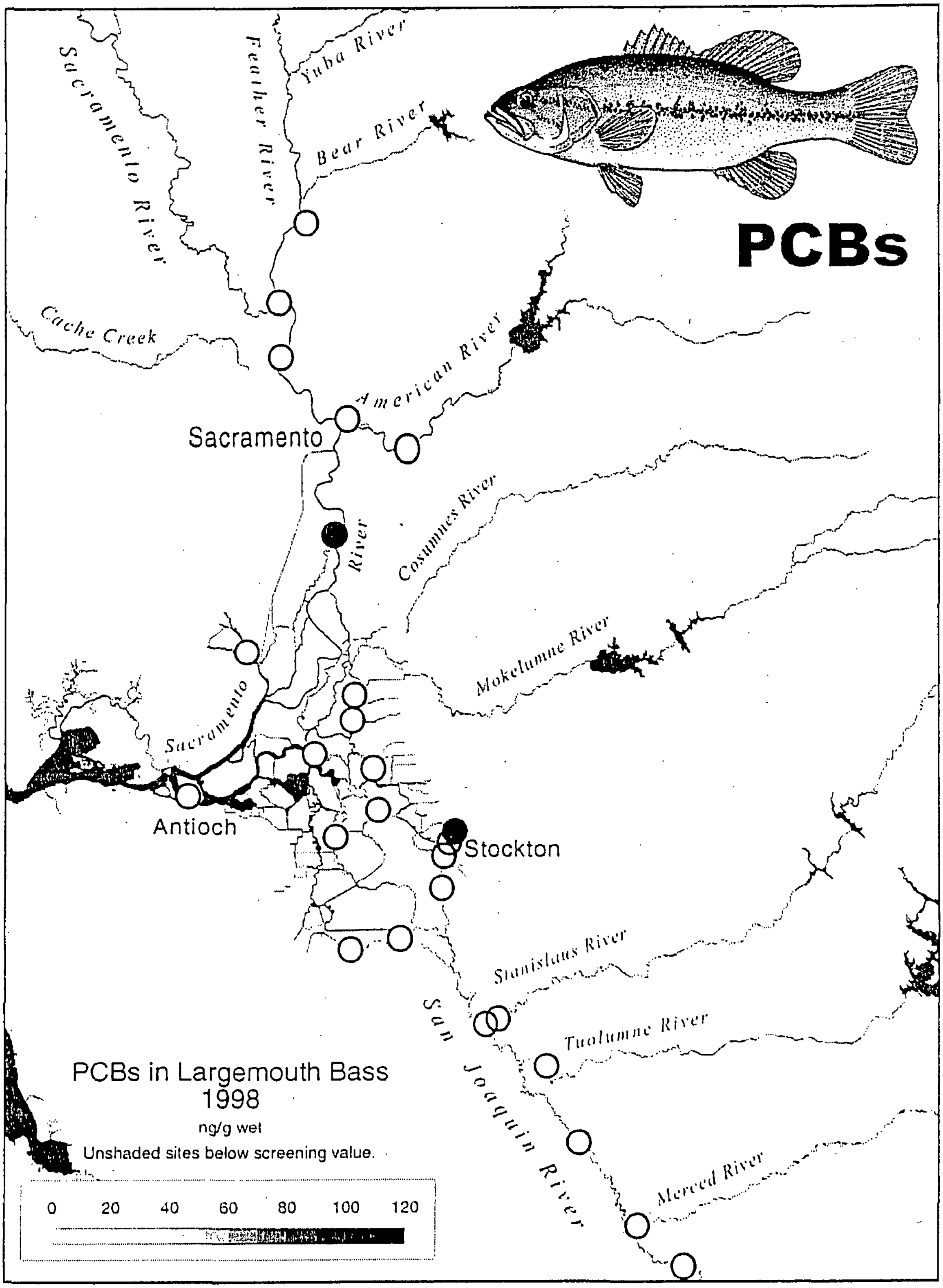


Figure 12. PCB concentrations in largemouth bass at each sampling location. Data from this study and the SRWP (see figure 1).



Port of Stockton). The third was at the Stanislaus River location. One of the SRWP locations (Sacramento River at RM44) exceeded the screening value (Figure 12). PCB concentrations in the largemouth bass analyzed individually ranged from 0.2 ng/g (San Joaquin River at Vernalis) to 46 ng/g (Port of Stockton).

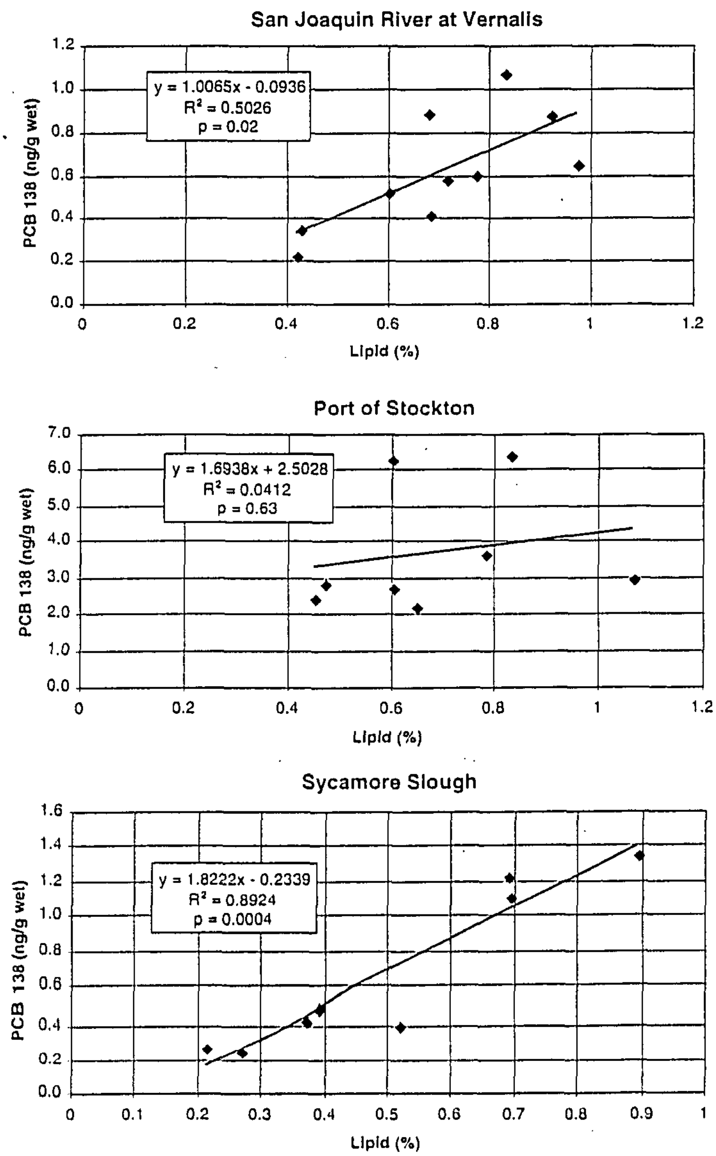
None of the black bullhead composites exceeded the screening value.

Two *Corbicula* composite samples, from the Port of Stockton and Sacramento River at Rio Vista, were analyzed for organics. The sample from the Port of Stockton had an unusually high concentration of PCBs (112 ng/g wet). Expressed on a dry weight basis (for comparison with other *Corbicula* datasets) this sample had 870 ng/g of PCBs. This concentration is higher than any concentration observed in *Corbicula* in RMP sampling, and compares to the highest concentrations observed for any bivalve species in RMP sampling (SFEI 2000). The wet weight concentration was well above the screening value. The sample from Rio Vista had a much lower concentration (16 ng/g wet, 160 ng/g dry).

Controlling factors

PCBs accumulate in lipid, and, other factors being equal, fish fillets with higher lipid content are expected to contain higher PCB concentrations. The analysis of organics in individual largemouth bass at three locations provided an opportunity to examine variation among individuals and correlations with lipid at single locations (Figure 13). PCB 138 was detected in every sample and was the best quantified PCB congener; this congener was used in the regressions to avoid the noise that would be introduced by the influence of non-quantitative (below reporting limit) results on sums of PCBs. A highly significant regression was obtained for Sycamore Slough (R^2=0.89, p=0.0004). San Joaquin River at Vernalis also yielded a significant result (R^2=0.50, p=0.02). The regression for Port of Stockton was not significant, however this appears to be due to two fish with unusually high concentrations. These fish may have foraged in a relatively contaminated area. Overall, the individual largemouth bass data indicate that lipid content is an important variable influencing PCB concentrations in Delta largemouth bass. Small scale spatial

Figure 13. PCB 138 concentrations versus lipid in largemouth bass at three locations.



variation in concentrations may also play a role in contaminated areas like the Port of Stockton.

Spatial Patterns

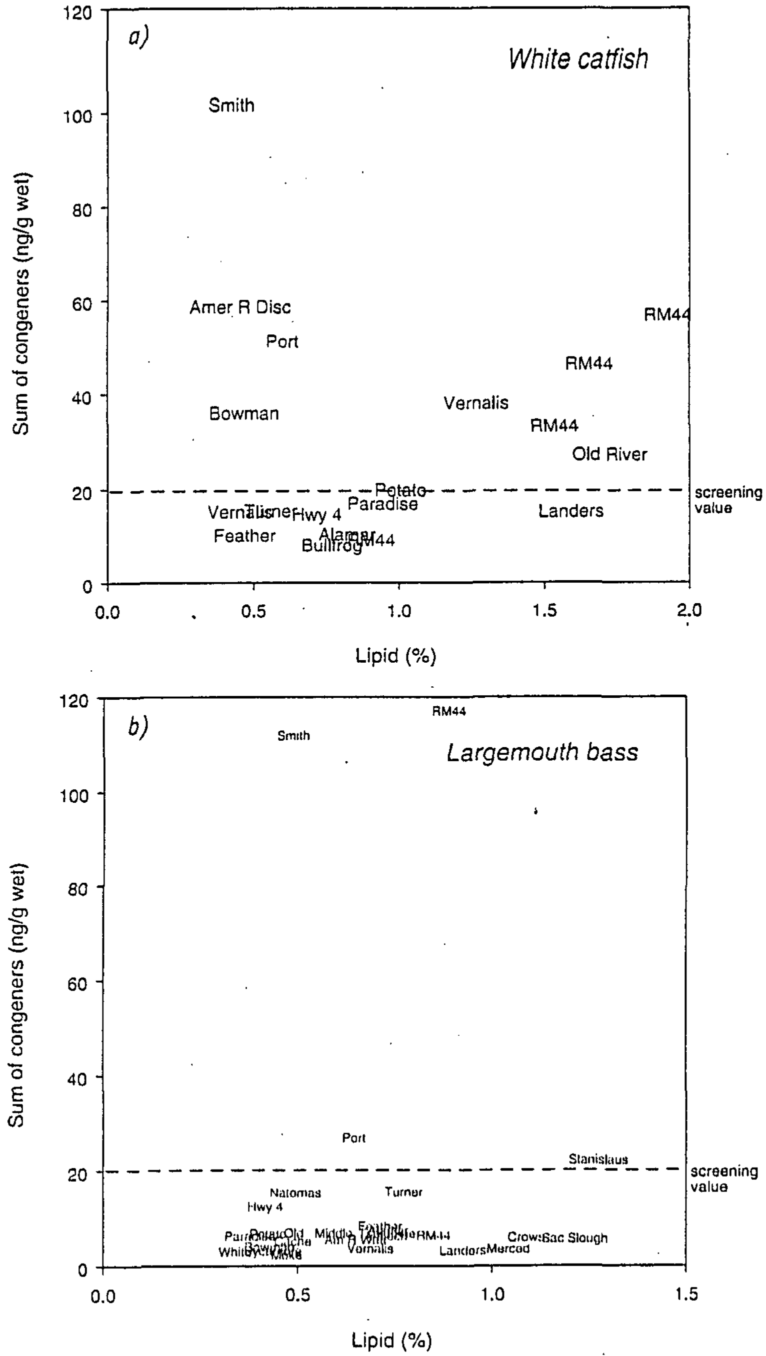
Data from this study, along with data from the SRWP and TSMP, suggest the presence of localized PCB hotspots with concentrations of concern in the Central Valley, rather than broad regional patterns such as were seen for mercury. The locations with relatively high concentrations included Smith Canal (102 ng/g in white catfish and 112 ng/g in largemouth bass), Sacramento River at RM 44 (largemouth bass up to 117 ng/g and white catfish up to 57 ng/g), American River at Discovery Park (59 ng/g in white catfish), Port of Stockton (51 ng/g in white catfish and 27 ng/g in largemouth bass), San Joaquin River at Vernalis (up to 38 ng/g in white catfish), and San Joaquin River at Bowman Road (36 ng/g in white catfish). The *Corbicula* sample from the Port of Stockton also indicated relatively high PCB concentrations at that location.

Given the relationship between trace organic accumulation and lipid content, accounting for variation in lipid yields a clearer picture of spatial or temporal variation. Plots of PCB concentration versus lipid content (Figures 14 a and b) allow visual comparisons that factor out differences related to varying lipid content. In white catfish (Figure 14a), samples from Smith Canal, American River at Discovery Park, Port of Stockton, and San Joaquin River at Bowman Road had relatively high concentrations in spite of their low lipid content, suggesting relatively high rates of PCB accumulation. White catfish from San Joaquin River at Vernalis and Sacramento River at RM44 reached relatively high concentrations (greater than 35 ng/g), but this appears to be attributable to the high lipid content of these samples. In largemouth bass (Figure 14b), samples from Smith Canal and Sacramento River at RM44 stood out with much higher concentrations than other largemouth samples with similar lipid content. The congener profile of the Sacramento River at RM44 sample was very unusual; results of further sampling will help determine whether this result is truly indicative of persistent PCB contamination at this location. Largemouth bass from the Port of Stockton were also somewhat elevated relative to other largemouth samples with similar lipid content.

PCB congener profiles, or "fingerprints," also provide information on spatial variation. Spatial variation in PCB fingerprints is evidence of spatial variation in PCB sources. The white catfish and largemouth bass samples from Smith Canal both were elevated in congeners 149, 180, 187, and other congeners indicative of Aroclor 1260. The *Corbicula* composite from the Port of Stockton was high in congeners 28, 44, 49, and 52, which are indicative of Aroclor 1248, and also in congeners 95, 101, 110, and 118, which are indicative of Aroclor 1254. Several largemouth bass from the Port also had relatively high proportions of Aroclor 1248 and 1254 congeners. Other largemouth from the Port lacked these distinct profiles. This variation in PCB fingerprints at the Port is probably indicative of small scale variation in contamination of foraging areas. Another distinct fingerprint was observed for the largemouth bass sample from Stanislaus River, which had relatively high proportions of congeners 201, 203, 206, and 209, which are indicative of the most highly chlorinated Aroclors (Aroclor 1262 or higher).

Some of the locations identified as having persistent PCB contamination in the Delta Study and SRWP sampling also had high concentrations in TSMP sampling. High PCB concentrations at the Sacramento River at Hood have been observed in white catfish (up to 198 ppb in 1983 and 124 ppb as recently as 1992) and carp (up to 480 ppb in 1985). Past sampling also found high concentrations in the south Delta, including the Stockton Deep Water Channel (240 ppb in white catfish in 1986 and 100 ppb in largemouth bass in 1990), the San Joaquin River at Vernalis (up to 282 ppb, the statewide maximum, in white catfish in 1986 and up to 314 ppb in channel catfish in 1984), Old River, and Paradise Cut near Tracy. Other locations in the watershed with high PCB concentrations in past sampling include the Feather River downstream of Highway 99, Beach Lake, Natomas East Main Drain, the Stanislaus River, and the Tuolumne River at the San Joaquin River.

Figure 14. PCB concentrations (sum of congeners) versus percent lipid in composite samples: a) white catfish; b) largemouth bass.



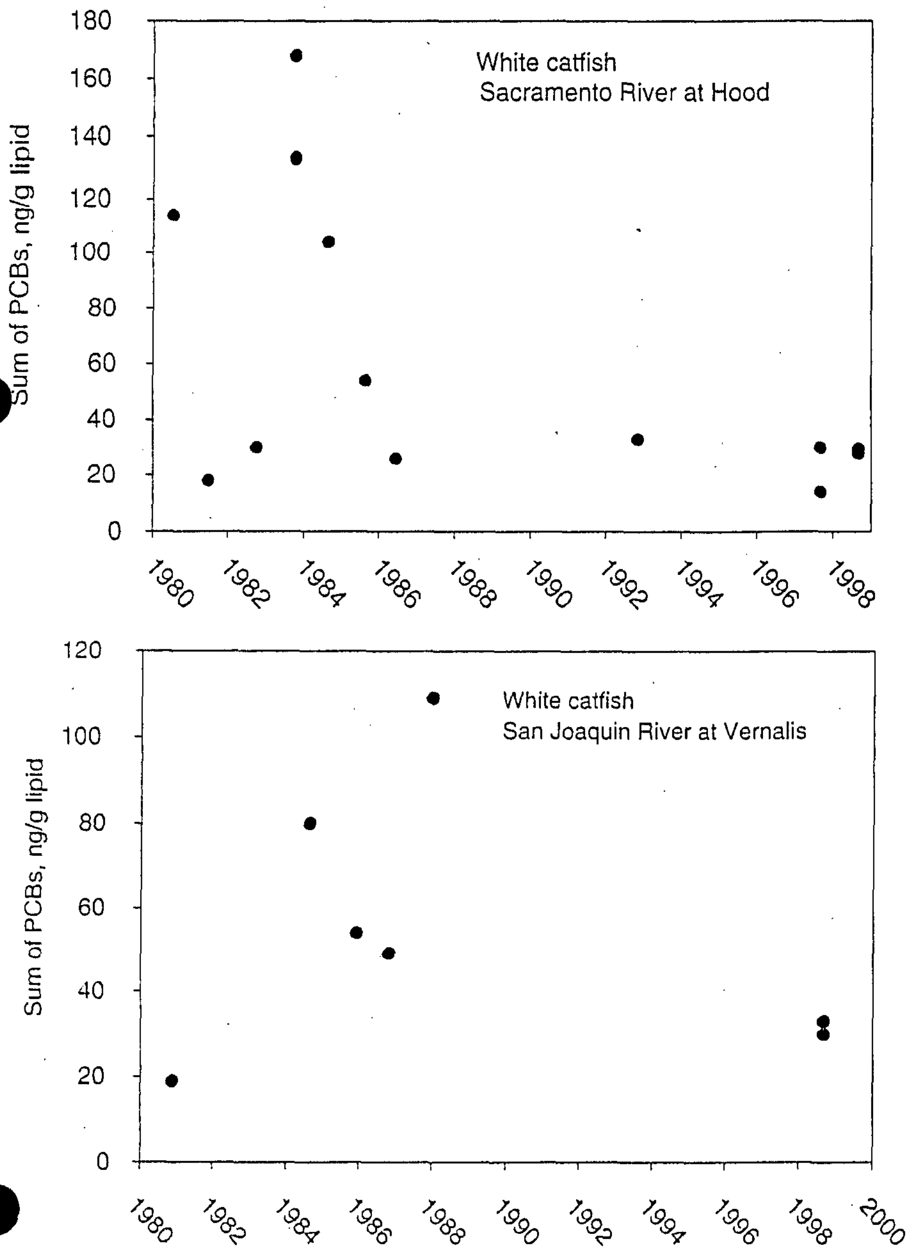
Overall, the available data indicate that PCB contamination has been widespread in the Central Valley, and that significant contamination remains in some locations, including the Sacramento River in the north Delta, and the Port of Stockton, Smith Canal, and other locations in the south Delta. Available information on historic uses of PCBs suggest the likelihood that significant localized PCB contamination also exists in other areas not covered in the SRWP and Delta Study.

Temporal trends

The limited data available for evaluating long term trends suggest that PCB concentrations have declined in the Delta, although the apparent drop is not as distinct as that observed for the OC pesticides and some samples still exceed the PCB screening value. In addition to the paucity of data points, the use of different and relatively insensitive analytical methods in the older TSMP obscures the long term record.

The best historical time series were generated by the TSMP for white catfish at the Sacramento River at Hood and the San Joaquin River at Vernalis, and sampling at these locations has been continued by the SRWP and the Delta Study to further extend the series (Figures 15a and b). Some of the highest concentrations recorded for white catfish in the TSMP were obtained at these two locations. At the Sacramento River at Hood, concentrations measured in 1997 and 1998 (ranging from 14 to 30 ng/g lipid as the sum of congeners) were at the low end of the range of concentrations recorded by the TSMP from 1980 to 1993 (18 to 168 ng/g lipid as the sum of Aroclors). At the San Joaquin River at Vernalis the 1998 results (30 and 33 ng/g lipid) are lower than the TSMP maximum for this location (109 ng/g lipid in 1987), but comparable to other historic values. Other values obtained for white catfish from other locations compare to the higher concentrations measured historically, especially the 102 ng/g wet (232 ng/g lipid) measured at Smith Canal and the 51 ng/g wet (84 ng/g lipid) measured at the Port of Stockton. In largemouth bass, the historical TSMP data have too many below detection

Figure 15. PCB concentrations (ng/g lipid) in white catfish from two locations. *Data from this study, the SRWP, and the TSMP.*



limit results for a useful comparison.

It should be noted that the recent data are not directly comparable with the older data from the TSMP. One reason for this is that the recent data (1997 and 1998) are sums of congeners, while the older data are Aroclor measurements. When expressed on an Aroclor basis, the recent data would be slightly higher than indicated by the sum of the congeners. Another reason that the data may not be comparable is the use of different methods for measuring lipids. From the late 1970s to 1998, the TSMP used a gravimetric method for lipid determination employing a petroleum ether extraction. The method employed in the recent studies is also gravimetric, but based on an accelerated solvent extraction in dichloromethane and acetone. The use of different lipid methods can introduce a 2 to 3-fold difference in lipid data (Henry Lee, U.S. EPA, personal communication).

In summary, the limited long term trend data available suggest possible declines in PCB concentrations, but concentrations in a few locations remain high relative to historical results and above human health screening values. There are likely other locations not yet identified where elevated concentrations persist. The variability of the data and the use of an insensitive analytical method in the TSMP contribute to the difficulty in drawing firmer conclusions.

Organochlorine Pesticides

Organochlorine (OC) pesticides (including DDT, chlordane, dieldrin, toxaphene, and others) were used in a wide variety of applications in agricultural, domestic, and industrial settings. Since these chemicals are so persistent, concentrations remain elevated in areas where they were used decades ago. Runoff from these areas continues to transport OC residues into creeks, rivers, and, ultimately, the Estuary.

The primary use of these chemicals was in agriculture. From the first widespread use of DDT in World War II to its cancellation in 1972, a total of approximately 1,350,000,000 pounds was used in the U.S. (U.S. EPA 1975). In the 1960s DDT was used heavily on cotton, a crop which was particularly reliant on insecticides. Cotton accounted for 50% of all agricultural crop insecticide use in the 1960s, and the approximately 20,000,000 lbs/yr of DDT used on cotton accounted for 30% of the total cotton insecticides (U.S. EPA 1975). This was 75% of the total DDT used on all crops. Areas of cotton production in the 1950s and 1960s in the Central Valley therefore are potential sites of historical contamination with both DDT. Limited data are available on DDT use in California. Pesticide use reporting began in 1970, when DDT use was waning rapidly. DDT use in 1970 was 1,165,000 lbs, dropping to 111,000 lbs in 1971 and 81,000 lbs in 1972. From 1973 on less than 200 lbs per year were used (Mischke et al. 1985). A 1984 statewide survey of DDT concentrations in soils from agricultural areas found DDT residues wherever DDT was used historically, and concluded that residues from legal agricultural applications of DDT appeared to be the source of continuing DDT contamination in California rivers at that time (Mischke et al. 1985). This conclusion is probably still true today.

Dieldrin is another OC pesticide that still is sometimes found at concentrations of potential concern in fish tissue in the Central Valley. In addition to being used in agriculture, dieldrin was used extensively for structural termite control. Dieldrin was used on more than 40 agricultural crops and for soil treatment around various fruits, nuts, and vegetables, and also in mosquito control, as a wood preservative, and in moth proofing (Harte et al. 1991, U.S. EPA 1995). All uses on food products were suspended in 1974. All uses except subsurface termite control, dipping of nonfood roots and tops, and moth proofing in a closed system were banned in 1985. These remaining uses were voluntarily canceled by industry. Due to its widespread use in termite control in addition to agricultural pest control, dieldrin residues are found in both urban and agricultural areas.

In spite of the fact that the use of OC pesticides has been restricted for decades, these chemicals remain environmental contaminants of concern because of their persistence in the environment, their strong tendency to accumulate in biota, and their toxicity. The carcinogenicity of OC insecticides is the toxic effect of greatest concern from a regulatory perspective. DDT and dieldrin are considered probable human carcinogens (U.S. EPA 1995). In San Francisco Bay, the cancer risk associated with the concentrations of DDT, dieldrin, and chlordane in fish is responsible for the inclusion of these chemicals in the current fish consumption advisory (OEHHA 1994). Inclusion of these chemicals in the fish consumption advisory has subsequently resulted in these chemicals being targeted as priorities for regulatory action by the Regional Water Quality Control Board and U.S. EPA.

Endocrine disruption is another human health concern associated with OC insecticides. Many OC pesticides, including DDT and dieldrin, have endocrine activity. Endocrine disruption is also a concern in wildlife exposed to OC pesticides. In particular, piscivorous birds and mammals have much higher OC exposure than humans and face greater risks. Effects of OC pesticides on development and survival of early life stages are a particular concern in wildlife.

Although other OC pesticides were also analyzed (see Appendix A), only DDT and dieldrin had concentrations above screening values. The following discussion therefore focuses on these two contaminants. Other OC pesticides are briefly discussed in a subsequent section.

Analytical considerations

Seven DDT compounds (isomers and metabolites) were analyzed. Following U.S. EPA (1995) guidance, six DDT compounds were summed to derive "sum of DDTs": p,p'-DDT, o,p'-DDT, p,p'-DDE, o,p'-DDE, p,p'-DDD, and o,p'-DDD. The screening value for DDTs, 100 ng/g, applies to the sum of DDTs. Detectable DDT compounds were present in all of the 47 samples analyzed. p,p-DDE was the most abundant compound and the only one present in every sample. The reporting limits for individual DDT compounds ranged between 2 and 5 ng/g.

Dieldrin was present above the reporting limit (2 ng/g) in only 3 of 47 samples analyzed.

Data distribution and summary statistics

White catfish had the highest median DDT concentration (138 ng/g) of the three fish species sampled (Table 1, Figure 16). DDT concentrations in white catfish ranged from a low of 42 ng/g at Smith Canal to a high of 407 ng/g at San Joaquin River at Bowman Road. Six of eleven locations had concentrations above the 100 ng/

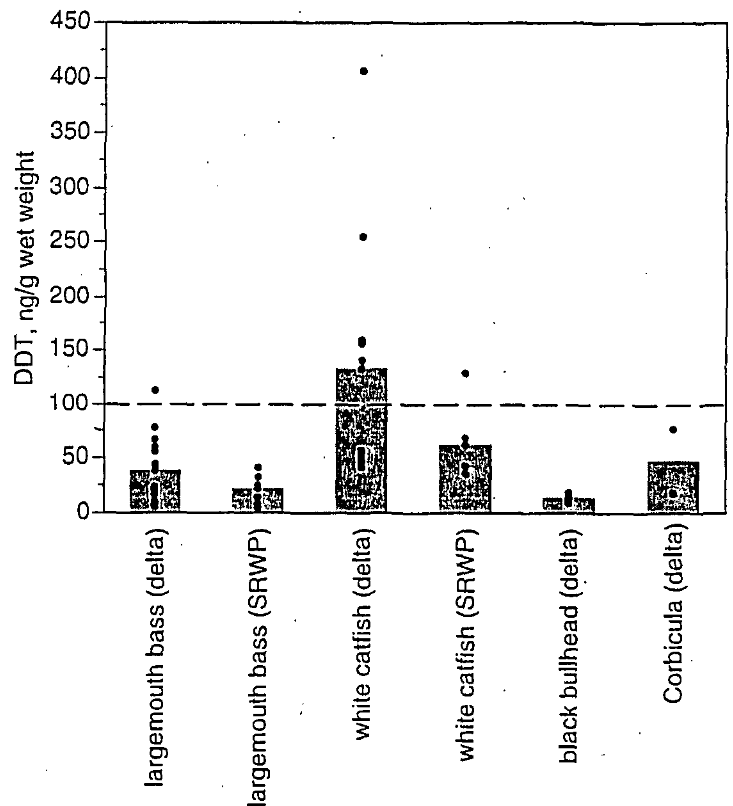
g screening value (Table 2). Locations above the screening value were concentrated in the south Delta (Figure 17).

The median DDT concentration in largemouth bass was 39 ng/g (Table 1, Figure 16), and ranged from a minimum of 6 ng/g at Sycamore Slough to a maximum of 113 ng/g at Stanislaus River. Only one of nineteen samples (at Stanislaus River) exceeded the 100 ng/g screening value (Table 2, Figure 18).

None of the black bullhead samples approached the 100 ng/g screening value.

DDT concentrations in the two *Corbicula* samples were 77 ng/g wet (590 ng/g dry) at Port of Stockton and 19 ng/g wet (180 ng/g dry) at Sacramento River at Rio Vista. These Port of Stockton concentration is higher than the concentrations measured in clams at RMP stations in the western Delta (SFEI 2000), but lower than concentrations measured further upstream in the San Joaquin River watershed (Pereira et al. 1996, Brown 1998). Concentrations of DDT in *Corbicula* as high as 4300 ng/g dry have been reported from Orestimba Creek in the western San Joaquin Valley (Pereira et al. 1996). Neither of the two *Corbicula* samples exceeded the DDT screening value.

Figure 16. DDT concentrations in Delta fish and* Corbicula*, and Sacramento River watershed fish, 1998.



Dieldrin was detected in only 3 of 47 samples. The reporting limit for dieldrin was the same as the screening value (2 ng/g), so all three samples with detectable dieldrin were above the screening value (Table 2). A white catfish composite from San Joaquin River at Landers Avenue had 2.9 ng/g (Figure 19). An individual largemouth bass from Sycamore Slough had 2.3 ng/g (Figure 20). None of the other individual largemouth bass from Sycamore Slough had detectable dieldrin. A *Corbicula* composite from Port of Stockton had 5.4 ng/g wet weight (42 ng/g dry weight), a relatively high concentration compared to concentrations for Corbicula reported in other studies (Pereira et al. 1996, Brown 1998, SFEI 2000). The highest concentration observed in the USGS studies was in the San Joaquin Valley (Pereira et al. 1996, Brown 1998) was 9.8 ng/g wet in Orestimba Creek. In the SRWP six samples have exceeded the dieldrin screening value: three largemouth bass (Figure 20), one white catfish (Figure 19), one Sacramento pike minnow, and one carp.

Figure 17. DDT concentrations in white catfish at each sampling location. Data from this study and the SRWP (see figure 1).

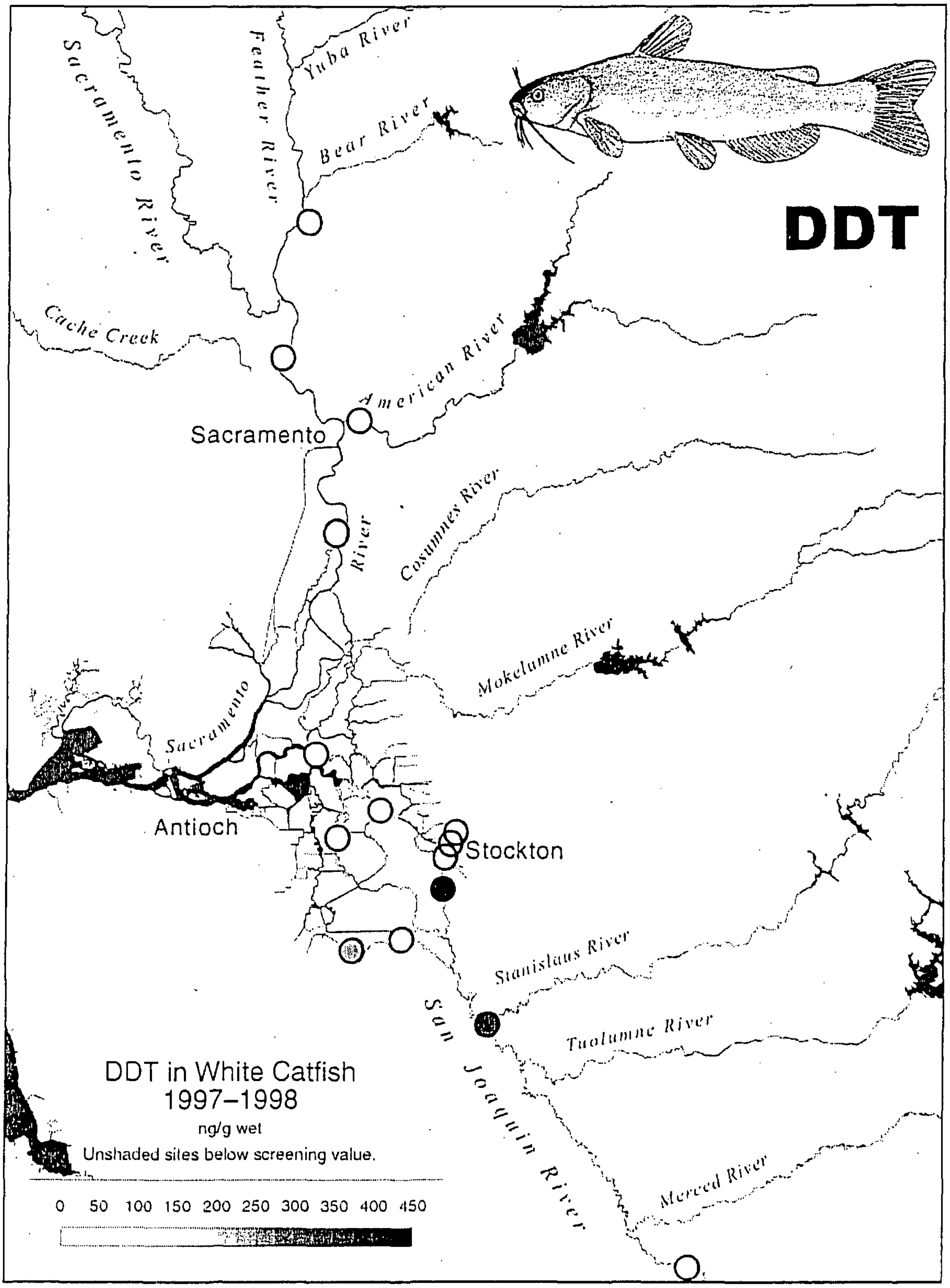


Figure 18. DDT concentrations in largemouth bass at each sampling location. Data from this study and the SRWP (see figure 1).

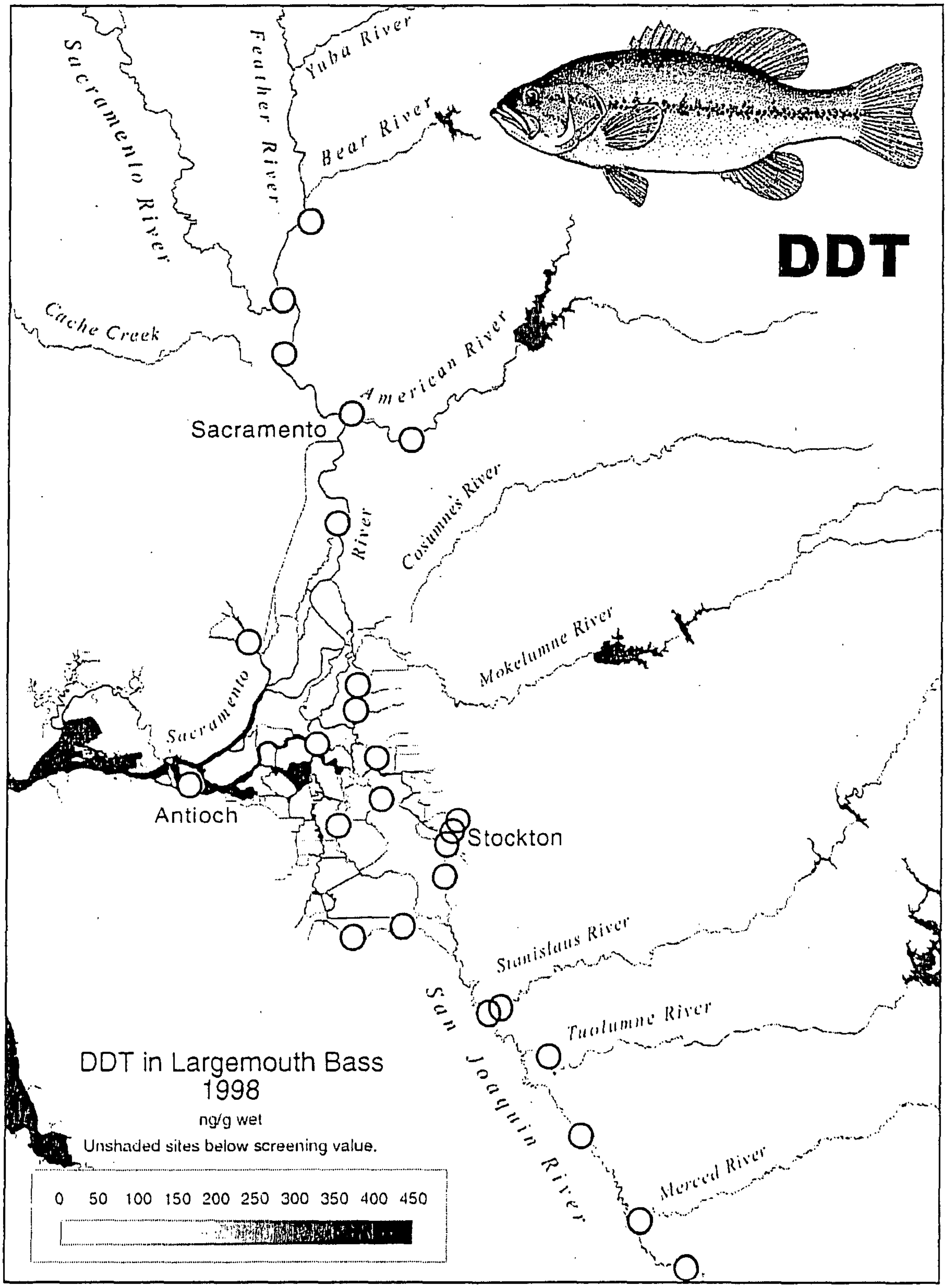


Figure 19. Dieldrin concentrations in white catfish at each sampling location. Data from this study and the SRWP (see figure 1).

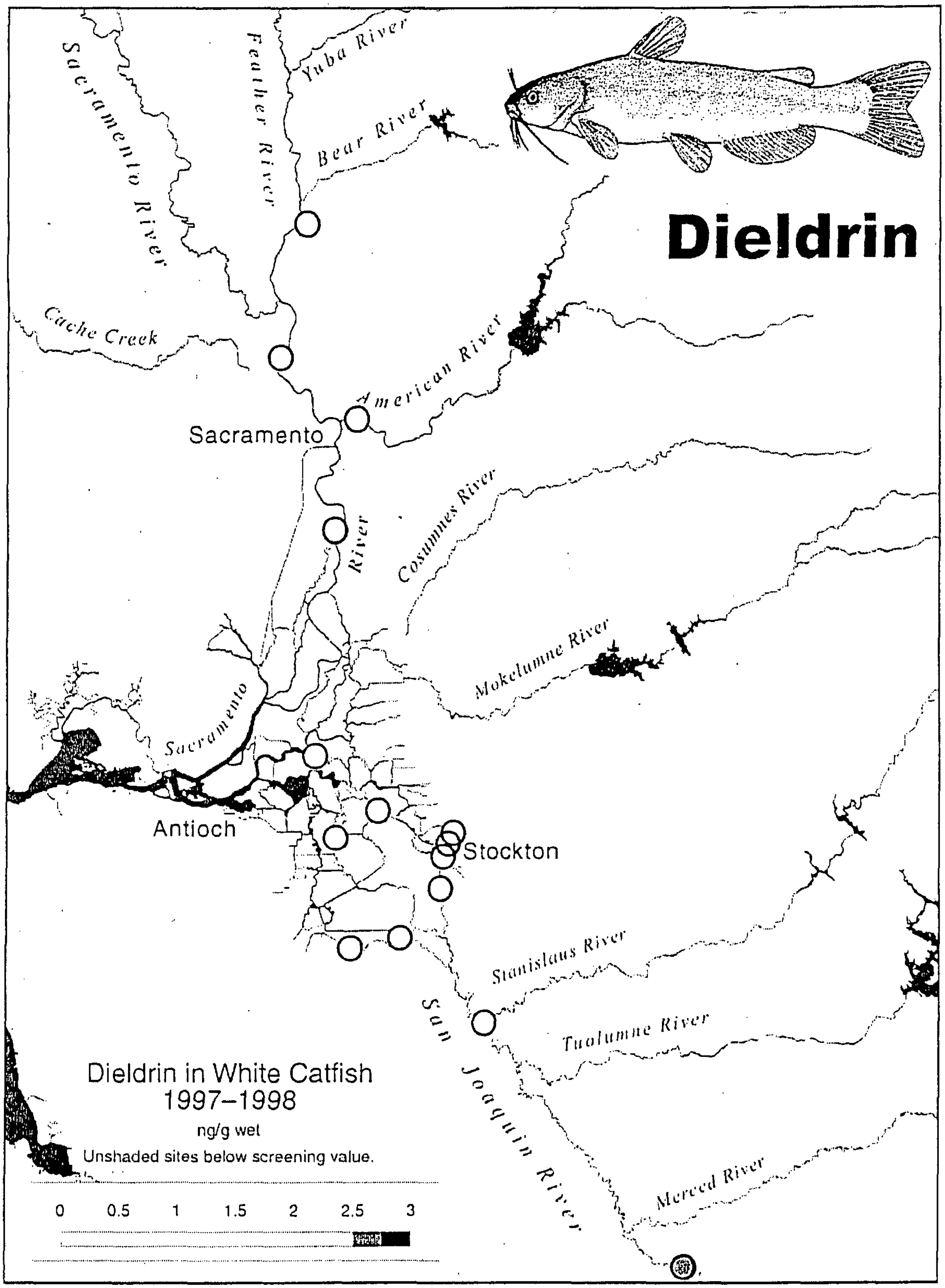
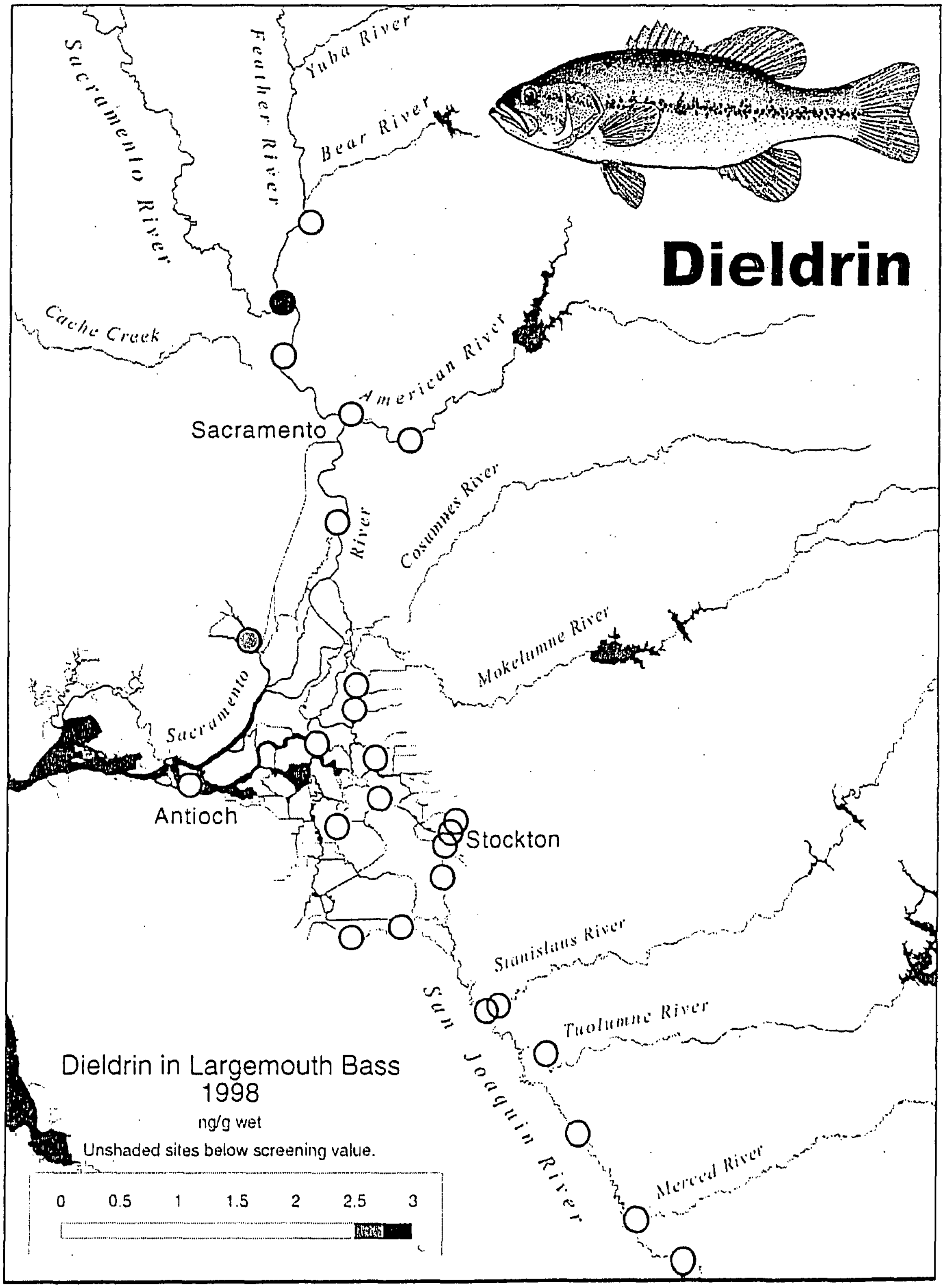


Figure 20. Dieldrin concentrations in largemouth bass at each sampling location. Data from this study and the SRWP (see figure 1).



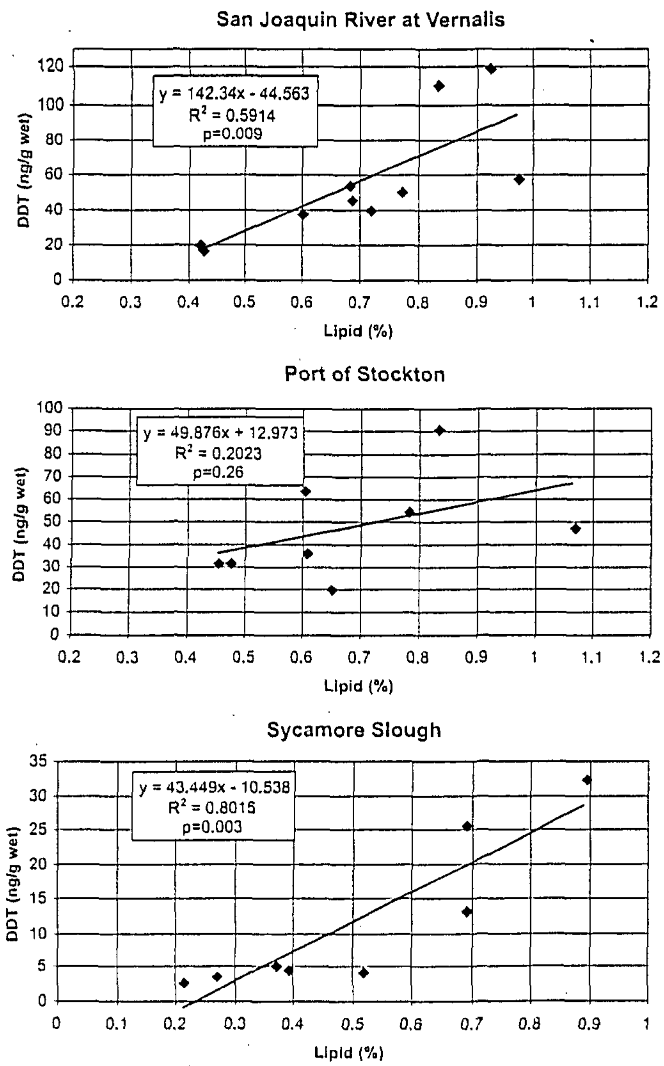
Controlling Factors

Like PCBs, DDT accumulates in lipid, and fish fillets with higher lipid content are expected to contain higher concentrations. The analysis of organics in individual largemouth bass at three locations afforded an opportunity to examine correlations of lipid and DDT at single locations (Figure 21). In spite of the small number of samples available for each location, highly significant regressions were obtained at two of the three locations: Sycamore Slough (R^2=0.80, p=0.003) and San Joaquin River at Vernalis (R^2=0.59, p=0.009). The relationship at Port of Stockton was not statistically significant (R^2=0.20, p=0.26). Overall, these data confirm that lipid content is an important variable influencing DDT concentrations in Delta largemouth bass.

Spatial Patterns

Data from this study are consistent with past sampling indicating that the lower San Joaquin Valley watershed is a focal point for OC pesticide contamination. In white catfish, two south Delta locations had unusually high DDT concentrations: San Joaquin River at Vernalis (389 ppb) and San Joaquin River at Bowman Road (407 ppb). Several other white catfish samples from the south Delta were also above the screening value (Figure 17).

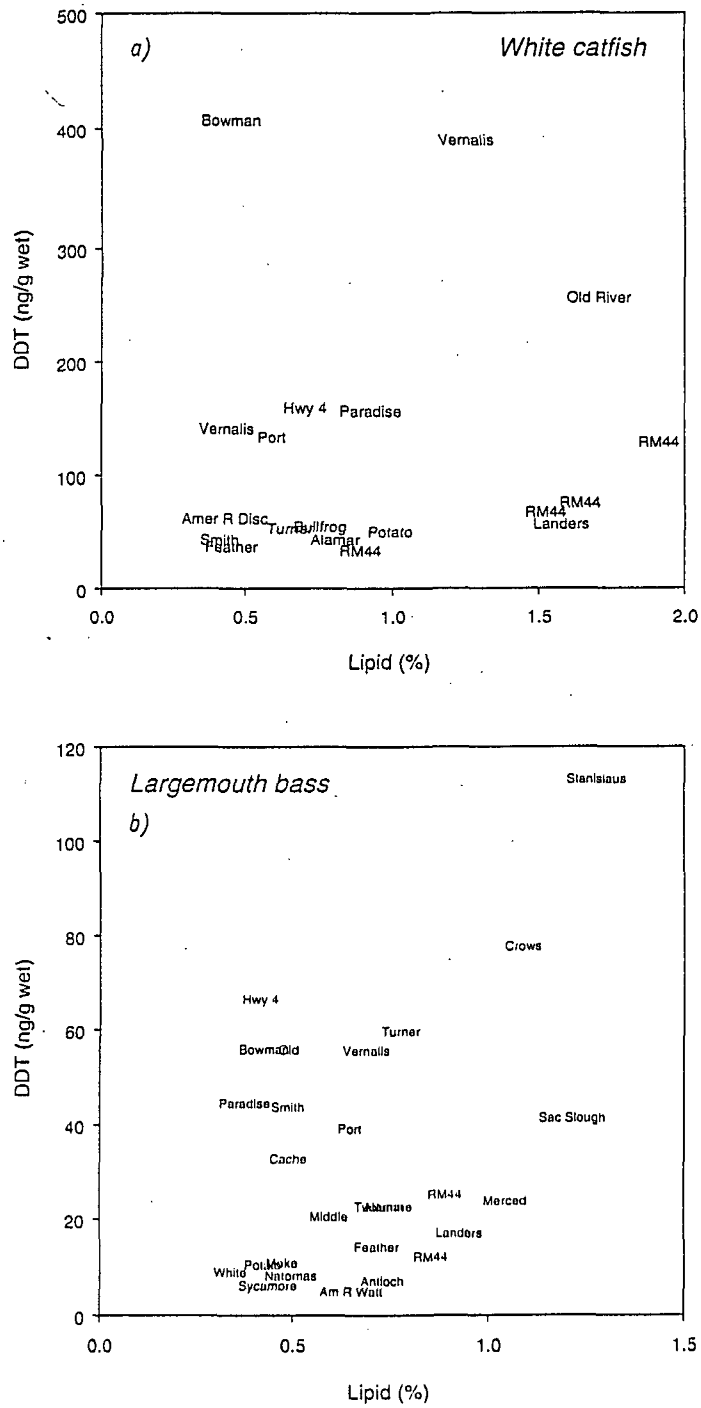
Figure 21. DDT concentrations versus lipid in largemouth bass at three locations.



Given the relationship between DDT accumulation and lipid content, accounting for variation in lipid yields a clearer picture of spatial or temporal variation. Plots of DDT concentration versus lipid content (Figures 22 a,b) allow comparison of samples with similar lipid content. In white catfish a contiguous group of south Delta locations exhibited distinctly elevated DDT concentrations compared to other samples with similar lipid content (San Joaquin River at Bowman Road, San Joaquin River at Vernalis, San Joaquin River north of Highway 4, the Port of Stockton, Paradise Cut, and Old River), with the highest concentration at San Joaquin River at Bowman Road (Figure 22a). In largemouth bass, this same cluster of locations stands out with high concentrations relative to lipid content (Figure 22b).

The TSMP also found persistently high concentrations of OC pesticides in the south Delta. Common carp, channel catfish, and largemouth bass have been sampled frequently in the TSMP. White catfish have been sampled less frequently. High DDT concentrations in carp have been observed in the south Delta at Paradise Cut (up to 5332 ppb in 1986) and the San Joaquin River at Vernalis (up to 1268 ppb in 1978). In channel catfish, some of the highest concentrations measured in California were obtained at the San Joaquin River at Vernalis, with concentrations over 2000 ppb in 1979, 1984, 1986, and 1987. Channel catfish from the Stanislaus River (4149 ppb in 1990) and the Tuolumne River near the San Joaquin River (2570 ppb in 1979) have also had very high DDT concentrations. In white catfish, the highest values measured in California have been from the San Joaquin River at Vernalis, with a maximum of 2220 ppb in 1987. The south Delta is clearly influenced by historic DDT use and environmental contamination.

Figure 22. DDT concentrations versus percent lipid in composite samples: a) white catfish; b) largemouth bass.



The highest dieldrin concentrations in the watershed have also been measured in the south Delta. Several channel catfish samples from the San Joaquin River at Vernalis have had high concentrations, with a maximum of 44 ppb in 1984. White catfish from the San Joaquin River at Vernalis have had several of the highest dieldrin concentrations in the State, including the statewide maximum for white catfish of 53 ppb. Carp from another south Delta location, Paradise Cut near Tracy, also had some of the highest dieldrin concentrations in the State, including measurements of 60 ppb in 1986 and 37 ppb in 1989. Other high dieldrin concentrations have been recorded in samples from the north Delta, including carp and white catfish from the Sacramento River at Hood, and channel catfish from the Colusa Basin Drain.

Overall, the results of this study are consistent with historic data from the TSMP, indicating that the south Delta is an area with particularly high OC pesticide concentrations. Studies by USGS have also found high concentrations of OC pesticides in sediment and biota in the lower San Joaquin River watershed (Pereira et al. 1996, Brown 1998) and documented transport of contaminated sediments from this region to the San Joaquin River (Kratzer 1998).

Temporal trends

In general, OC pesticide concentrations in the Central Valley have declined considerably since the late 1970s and early 1980s. Most concentrations in the recent samples are lower than those measured in the TSMP. Relatively good time series were generated by the TSMP for white catfish at the Sacramento River at Hood and the San Joaquin River at Vernalis, and sampling at these locations has been continued by the Delta Study and SRWP to further extend the series. At the San Joaquin River at Vernalis, the 1998 DDT results are lower than the maximum concentration measured in 1988, but are comparable to several other concentrations measured in the early and mid-1980s (Figure 23a). At the Sacramento River at Hood, where concentrations have been historically lower than those at the San Joaquin River at Vernalis, recent SRWP results suggest a distinct decline ($R^2=0.50$, $p=0.003$) from those measured in the early and mid-1980s (Figure 23b). These two time series suggest that the rate of decline varies among locations. It should be noted that due to the use of different methods of lipid determination, the recent data may not be directly comparable to the older TSMP data.

High concentrations observed in recent sampling also suggest that the rate of decline is slow at some locations. The 684 ppb of DDT in carp in the Colusa Basin Drain measured in the 1998 SRWP, for example, is higher than the concentrations in the Drain measured by the TSMP in the 1980s. Some of the more recent TSMP samples had relatively high concentrations, such as the 1990 channel catfish sample from the Stanislaus River (4149 ppb of DDT).

The most encouraging finding in the recent sampling is that chlordane was not above the 30 ppb screening value in any of the 1998 Delta Study or SRWP. The highest concentration of chlordane measured in this study was 16 ng/g in white catfish from San Joaquin River at Vernalis. Chlordane concentrations above 30 ppb had frequently been observed in the TSMP.

While OC pesticide contamination in Central Valley waterways is dissipating, some locations show a slow rate of decline. Significant concentrations persist in many locations, with some samples elevated well above screening values.

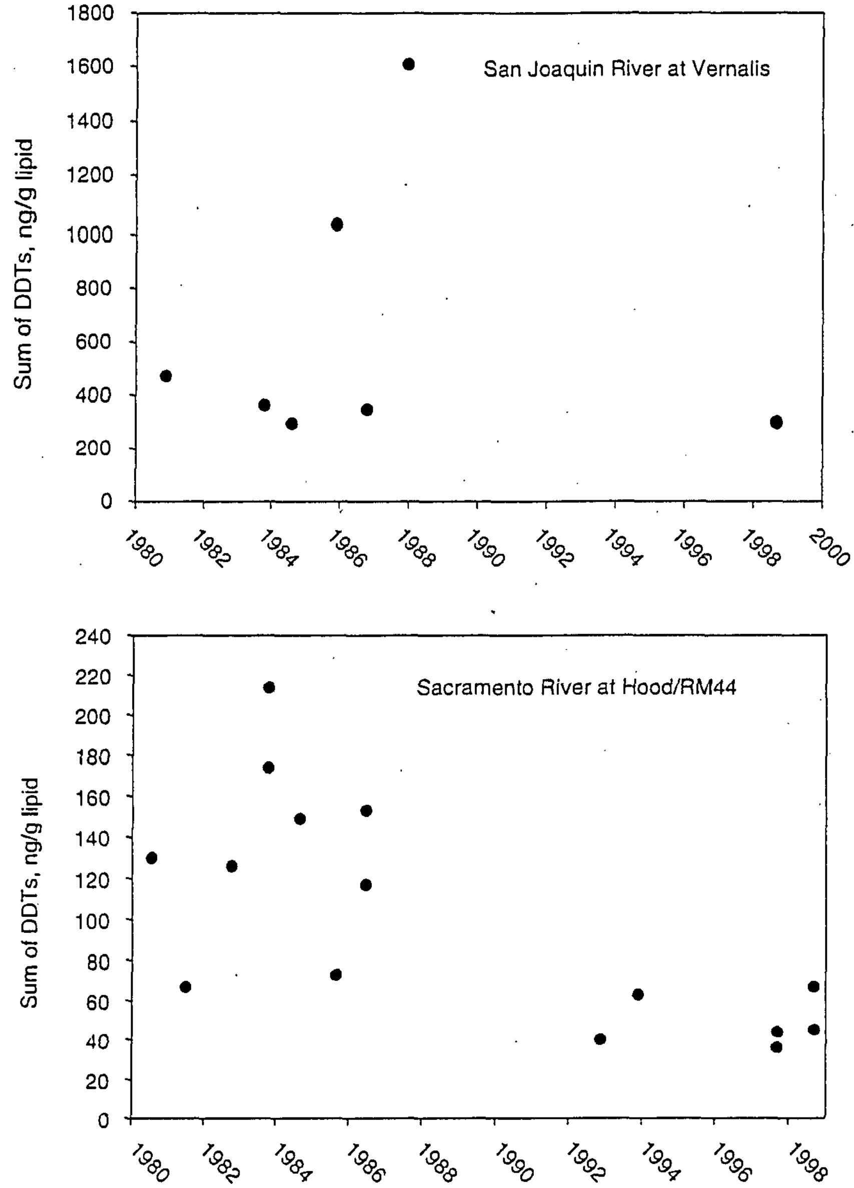
Other Contaminants

This section provides brief discussions of the measured or potential exceedance of screening values of other contaminants measured in this study and of contaminants that were not measured in this study. Background information on the sources, chemistry, and toxicity of the chemicals in this section are provided in U.S. EPA (1995).

Arsenic

The screening value for arsenic is 1000 ng/g. This screening value applies to inorganic arsenic (U.S. EPA 1995). Organic arsenic, which comprises most of the arsenic in fish and shellfish tissue, is considered to be nontoxic. Total arsenic was

Figure 23. DDT concentrations (ng/g lipid) in white catfish from two locations. Data from this study, the SRWP, and the TSMP.



measured in this study. The maximum total arsenic concentration measured in fish was 180 ng/g, indicating that inorganic arsenic in these samples must be far below the screening value. Two of three *Corbicula* samples had total arsenic concentrations above 1000 ng/g. Inorganic arsenic in these samples was probably well below the screening value. If arsenic concentrations in *Corbicula* are spatially variable, it is possible that locations exist with higher concentrations than those measured in this study. Further sampling of *Corbicula* that includes analysis of inorganic arsenic is warranted.

Selenium

The screening value for selenium is 20,000 ng/g. Selenium was measured in this study, with a maximum concentration of 770 ng/g in largemouth bass from San Joaquin River at Vernalis, far below the screening value.

Other organochlorine pesticides

Several other OC pesticides were measured in this study at concentrations below screening values, including chlordane, toxaphene, endosulfan, endrin, hexachlorobenzene, lindane (gamma-HCH), and mirex. Of these, toxaphene may have the greatest potential to be a human health concern. The screening value for toxaphene is 30 ng/g, lower than the reporting limit of 50 ng/g. No samples in this study were above 50 ng/g. However, one sample in the SRWP in 1998 had detectable toxaphene (a carp composite from the Colusa Basin Drain with 120 ng/g). It is possible that more samples above the screening value would have been detected in these studies if the reporting limit was 30 ng/g or lower. The highest concentration of chlordane (16 ng/g in white catfish at San Joaquin River at Vernalis) was well below the 30 ng/g screening value. Endosulfan, endrin, lindane, hexachlorobenzene, and mirex were not detected in any samples, and the reporting limits (5 ng/g, 2 ng/g, 1 ng/g, 0.3 ng/g, and 3 ng/g, respectively) were far below screening values (20,000 ng/g, 1000 ng/g, 30 ng/g, 20 ng/g, and 1000 ng/g, respectively).

Organophosphate pesticides

Two organophosphate (OP) pesticides were measured in this study: chlorpyrifos and diazinon. Diazinon, with a reporting limit of 20 ng/g, was not detected in any sample. The screening value for diazinon is 300 ng/g. Chlorpyrifos was detected in 11 of 47 samples analyzed. The maximum concentration was 7 ng/g in white catfish from San Joaquin River at Landers Avenue. This concentration was way below the screening value of 20,000 ng/g.

Polynuclear aromatic hydrocarbons (PAHs)

PAHs are efficiently metabolized by fish and do not accumulate in muscle tissue. Clams and other bivalves, on the other hand, do not readily metabolize PAHs, and PAHs do accumulate in these species. PAHs were measured in two clam composites. PAHs were only detected in the sample from Port of Stockton. A screening value exists for PAHs (U.S. EPA 1995) that is based on toxicology data for benzo(a)pyrene. U.S. EPA (1995) recommends that "benzo(a)pyrene equivalents" be calculated for seven PAHs. Doing this for the Port of Stockton sample yields a total of 0.02 ng/g of benzo(a)pyrene equivalent, well below the screening value of 3 ng/g. The reporting limit for PAHs was 10 ng/g. More extensive sampling with lower detection limits is needed to determine whether PAHs in *Corbicula* represent a potential human health concern.

Other contaminants not measured in this study

Dioxins are a class of contaminants that were not measured in this study. Dioxins are probably present in the study area at concentrations above the 0.3 pg/g screening value for ITEQs. Dioxin analysis was not included in this study primarily because it is expensive to perform, and its inclusion would have significantly reduced the scope of the sampling performed for other contaminants. In San Francisco Bay, limited dioxin analysis in 1994 (SFBRWQCB 1995) and in 1997 (SFEI 1999) found that every sample analyzed exceeded the screening value for ITEQs. Studies by CDHS (1997a,b) in the Port of Stockton also found that all samples analyzed (including largemouth bass, white catfish, carp, and bluegill) had concentrations above the ITEQ screening value. Based on these other findings, dioxins are probably present in the study area at concentrations above the 0.3 pg/g screening value for ITEQ.

Screening values also exist for the following compounds that were not analyzed in this study: cadmium, tributyltin, dicofol (an OC pesticide), disulfoton (OP pesticide), ethion (OP pesticide), terbufos (OP pesticide), and oxyfluorfen (chlorophenoxy herbicide). Data from the TSMP and OEHHA (1999) indicate that concentrations of cadmium, dicofol, and ethion are likely to be well below screening values. Data on concentrations of tributyltin, disulfoton, terbufos, and oxyfluorfen in fish tissue in California are not available.

Summary and Conclusions

Of the chemicals measured in this study, the greatest concerns from a human health perspective are mercury, PCBs, and DDT, which were frequently above screening values.

Mercury

This study detected concentrations of mercury in sport fish that were frequently above the mercury screening value and generally similar to those for which consumption advice has been issued for the Bay. Half of the largemouth bass and white catfish samples analyzed in this study exceeded the mercury screening value (11 of 19 largemouth bass and 4 of 11 white catfish). Regional variation has been observed, with the highest concentrations in the lower Sacramento River watershed, moderately high concentrations in the lower San Joaquin River watershed, and generally low concentrations in the central Delta. Length and age are important variables influencing mercury concentrations, but other unidentified factors cause substantial additional variation. Other factors that may be causing the observed spatial variation include environmental concentrations of total mercury, mercury methylation, and trophic position. Concentrations appear to have declined from the late-1970s to the mid-1980s, but not from the mid-1980s to 1998. Studies of mercury in sport fish in the Delta and the Sacramento River are continuing with funding from CALFED and the Sacramento River Watershed Program. The objective of these studies is to provide the data needed to determine whether additional field studies or additional consumption advisories are needed for these regions.

PCBs

Concentrations of PCBs were frequently above the PCB screening value. Thirty percent of the largemouth bass and white catfish samples were above the screening value (6 of 11 white cat and 3 of 19 largemouth). Data from this study and the SRWP suggest that PCBs are elevated in localized hotspots rather than on a regional basis. Smith Canal particularly stood out in this study with high PCB concentrations in both white catfish and largemouth bass. The Port of Stockton also had relatively high PCB concentrations in the two fish species and in *Corbicula*. PCB congener profiles (or "fingerprints") indicated the presence of varying sources at different locations: Aroclor 1260 in Smith Canal, Aroclors 1248 and 1254 at Stockton, and Aroclor 1262 at Stanislaus River. Lipid was demonstrated to be an important variable influencing PCB concentrations. The limited long term trend data for the Delta suggest declines in PCB concentrations, but concentrations in a few locations remain high relative to historical results and above human health screening values.

DDT

Concentrations of DDT exceeded the DDT screening value in 23% of the samples (6 of 11 white catfish and 1 of 19 largemouth bass). All of the samples above the screening value were obtained from the south Delta or lower San Joaquin River watershed. The results of this study are consistent with historic data from the TSMP and data from USGS studies indicating that the south Delta and lower San Joaquin River watershed are areas with particularly high OC pesticide concentrations. Lipid was demonstrated to be an important variable influencing DDT concentrations. In general, OC pesticide concentrations in the Central Valley have declined considerably since the late 1970s and early 1980s. Time series from two locations in the Delta suggest that the rate of decline varies among locations, with a slow rate of decline at some locations.

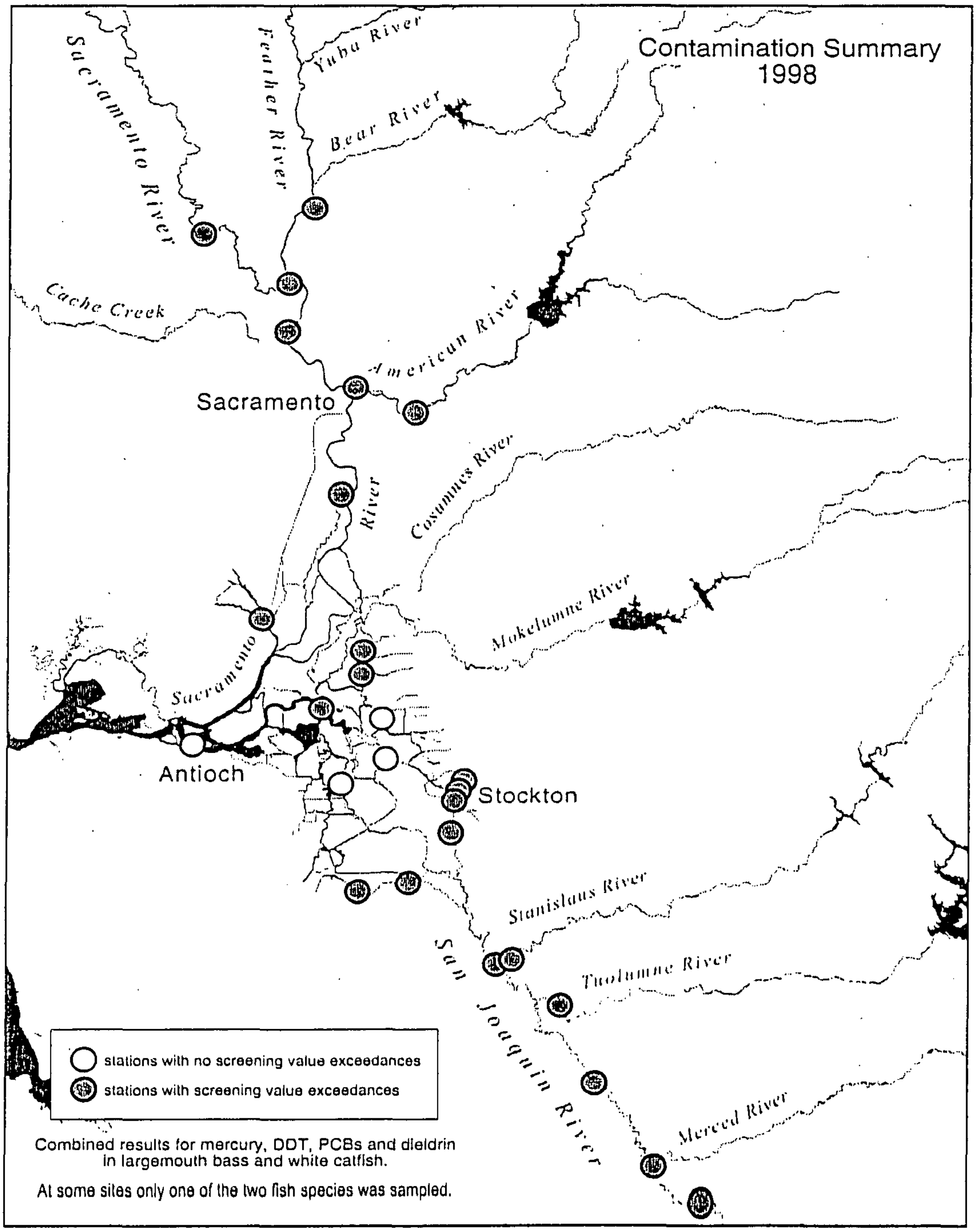
Other Contaminants

Other chemicals which are possible concerns in the Delta include dieldrin, toxaphene, arsenic, PAHs, and dioxins. Dieldrin exceeded the screening value in one sample in this study. Data from this study were inconclusive for toxaphene, arsenic, and PAHs. Additional sampling with lower detection limits are needed to determine whether toxaphene concentrations in Delta fish exceed the screening value. Additional sampling of arsenic and PAHs in clams would be needed to determine whether screening values are exceeded in the region. Inorganic arsenic should be measured in future studies. Lower detection limits for PAHs should be employed to provide more definitive comparisons with screening values. Dioxins were not measured in this study due to a limited budget, but are likely to be above the screening value in Delta fish as they have been in previous studies in San Francisco Bay and the Port of Stockton. Data from this study indicate that the following contaminants do not represent a potential human health concern in the Delta: chlordane, selenium, endosulfan, endrin, hexachlorobenzene, lindane (gamma-HCH), mirex, diazinon, and chlorpyrifos.

Overall Summary

Most of the samples analyzed exceeded at least one screening value. Of the 28 locations sampled in the Delta region in 1997 and 1998, only 4 were "clean" (i.e., not exceeding any screening value) (Figure 24).

Figure 24. Summary of stations with contaminant concentrations above screening values. *Stations with no concentrations above screening values for any species sampled are unshaded. Stations with one or more concentrations above screening values are shaded. Data from this study and the SRWP (see figure 1).*



Recommendations

Long term monitoring should be conducted to track trends in contaminants of concern relative to screening values.

Contaminants found above screening values in this study (mercury, PCBs, DDT, dieldrin) should continue to be tracked. The data should be gathered that will allow OEHHA to decide whether or not a broader consumption advisory than the one currently in place for striped bass and sturgeon is warranted for the Delta.

Contaminants where existing data are inconclusive (arsenic, PAHs, toxaphene) should be analyzed using methods that would yield definitive comparisons with screening values.

Dioxin analysis should be incorporated into this monitoring to determine the spatial extent of screening value exceedances and to begin assessment of long term trends in dioxin concentrations. The analyses should include dioxins, dibenzofurans, and dioxin-like PCBs, all of which contribute to the overall dioxin-like potency of environmental samples.

Further *Corbicula* sampling should be included in this long term monitoring. *Corbicula* are relatively good accumulators of trace organics. *Corbicula* sampling is particularly effective for PAHs, since PAHs are quickly metabolized in fish. *Corbicula* also accumulated high concentrations of arsenic.

Further fish sampling should be conducted in the San Joaquin River watershed to characterize human health concerns related to chemical contamination.

Existing data suggest the lower San Joaquin River watershed is a focal point for organochlorine pesticide contamination. In addition, historic gold mining in this watershed is a potential source of mercury contamination. The spatial extent of screening value exceedances in this region should be characterized, examining the range of species that are popular with anglers.

A fishery resource use study should be conducted in the Delta and Central Valley.

The Delta is a popular location for sport fishing, and a substantial subsistence fishing community is also thought to be present. A fishery resource use study would provide many benefits. First, it could identify human populations facing the greatest risk from consuming contaminated fish. This would improve our understanding of human health risks and guide outreach efforts to inform fishers of ways to reduce health risks. Second, the study could identify popular fishing locations and species. This information would be extremely valuable in effectively designing future sampling efforts.

References

Ahlborg, U.G., G.C. Becking, L.S. Birnbaum, A. Brouwer, H.J.G.M. Derks, M. Feeley, G. Golor, A. Hanberg, J.C. Larsen, A.K.D. Liem, S.H. Safe, C. Schlatter, F. Waern, M. Younes, E. Yrjanheikki. 1994. Toxic equivalency factors for dioxin-like PCBs: Report on a WHO-ECEH and IPCS consultation, December 1993. Chemosphere 28(6): 1049-1067.

Arnold, S. F., D.M. Klotz, B.M. Collins, P. Vonier, L.J. Guilette, and J.A. McLachlan. 1996. Synergistic activation of estrogen receptor with combinations of environmental chemicals. Science 272 (5267): 1489-1492.

Brinkmann, U.A.T. and A. de Kok. 1980. Production, properties and usage. Chapter 1 in Kimbrough, R.D. (ed.), Halogenated Biphenyls, Terphenyls, Naphthalenes, Dibenzodioxins and Related Products, Topics in Environmental Health, Volume 4. Elsevier/North-Holland Biomedical Press, Amsterdam, Netherlands.

Brown, L.R. 1998. Concentrations of chlorinated organic compounds in biota and bed sediment in streams of the lower San Joaquin River drainage, California. Open-File Report 98-171. U.S. Geological Survey, Sacramento, CA.

California State Department of Public Health. 1971. Mercury in the California environment: Compiled by the Interagency Committee on Environmental Mercury, July 1970- July 1971. California State Department of Public Health, Berkeley, CA.

CDFG. 1999. Resident Fish Population Monitoring: July 1, 1993 through June 30, 1998. Final Project Report (5-Year). Grant Agreement F-51-R-10. California Department of Fish and Game, Stockton, CA.

CDHS. 1997a. Health consultation: McCormick & Baxter Creosoting Company, Stockton, San Joaquin County, California, CERCLIS No. CAD009106527, January 15, 1997. California Department of Health Services, Berkeley, CA.

CDHS. 1997b. Health consultation: McCormick & Baxter Creosoting Company, Stockton, San Joaquin County, California, CERCLIS No. CAD009106527, April 9, 1997. California Department of Health Services, Berkeley, CA.

Davis, J.A. 1997. Concentrations and Effects of Organochlorine Contaminants in Double-crested Cormorant Embryos from San Francisco Bay. Doctoral Dissertation, University of California, Davis, CA.

Davis, J.A. R. Hoenicke, R.W. Risebrough, W.M. Jarman, C.A. Bacon, J. Vedder, and J.L. Sericano. 1997. PCB intercalibration exercise with Regional Monitoring Program water sample extracts. *In* 1996 Annual Report: San Francisco Estuary Regional Monitoring Program. San Francisco Estuary Institute, Richmond, CA. pp. 234-239.

Davis, J.A., K.A. Abu-Saba, and A.J. Gunther. 2000. Technical Report of the Sources, Pathways, and Loadings Workgroup. San Francisco Estuary Institute, Richmond, CA.

Doyon, J.F., R. Schetagne, and R. Verdon. 1998. Different mercury bioaccumulation rates between sympatric populations of dwarf and normal lake whitefish (*Coregonus clupeaformis*) in the La Grande complex watershed, James Bay, Quebec. Biogeochemistry 40: 203-216.

Fairey, R., K. Taberski, S. Lamerdin, E. Johnson, R.P. Clark, J.W. Downing, J. Newman and M. Petreas. 1997. Organochlorines and other environmental contaminants in muscle tissues of sportfish collected from San Francisco Bay. Marine Pollution Bulletin 34(12): 1058-1071.

Gobas, F.A.P.C., J.R. McCorquodale, and G.D. Haffner. 1993. Intestinal absorption and biomagnification of organochlorines. Environ. Toxicol. Chem 12: 567-576.

Harte, J., C. Holdren, R. Schneider, and C. Shirley. 1991. Toxics A to Z: A Guide to Everyday Pollution Hazards. University of California Press, Berkeley, CA.

Hebert, C.E. and K.A. Keenleyside. 1995. To normalize or not to normalize? Fat is the question. Environ. Toxicol. Chem. 14(5): 801-807.

Kratzer, C.R. 1998. Transport of sediment-bound organochlorine pesticides to the San Joaquin River, California. Open-File Report 97-655. U.S. Geological Survey, Sacramento, CA.

Larry Walker Associates. 2000. Sacramento River Watershed Program Annual Monitoring Report:

1998-1999. Prepared for Sacramento River Watershed Program by Larry Walker Associates, Davis, CA.

Lee, D.P. 2000. The Sacramento San-Joaquin Delta largemouth bass fishery. Interagency Ecological Program Newsletter 13: 37-40.

Lowe, S., R. Hoenicke, and J.A. Davis. 1999. 1999 Quality Assurance Project Plan Regional Monitoring Program for Trace Substances. San Francisco Estuary Institute, Richmond, CA.

McFarland, V.A. and J.U. Clarke 1989. Environmental occurrence, abundance, and potential toxicity of polychlorinated biphenyl congeners: Considerations for a congener-specific analysis. Environ. Health Perspectives 81: 225-239.

Mischke, T., K. Brunetti, V. Acosta, D. Weaver, M. Brown. 1985. Agricultural sources of DDT residues in California's environment. Report Prepared in Response to House Resolution No. 53 (1984). California Department of Food and Agriculture, Sacramento, CA.

Moyle, P.B. 1976. Inland Fishes of California. University of California Press, Berkeley, CA.

Newman, J.W., J.S. Becker, G. Blondina, and R.S. Tjeerdema. 1998. Quantitation of Aroclors using congener-specific results. Environ. Toxicol. Chem. 17: 2159-2167.

OEHHA. 1994a. Health advisory on catching and eating fish: Interim sport fish advisory for San Francisco Bay. Office of Environmental Health Hazard Assessment, California Environmental Protection Agency, Sacramento, CA. (http://www/oehha.org/scientific/fish/int-ha.html)

OEHHA. 1994b. Methylmercury in sport fish: Answers to questions on health effects. Office of Environmental Health Hazard Assessment, California Environmental Protection Agency, Sacramento, CA. (http://www/oehha.org/scientific/fish/memerc.html)

OEHHA. 1999. Prevalence of selected target chemical contaminants in sport fish from two California lakes: Public health designed screening study. Office of Environmental Health Hazard Assessment, California Environmental Protection Agency, Sacramento, CA.

Pereira, W.E., J.L. Domagalski, F.D. Hostettler, and L.R. Brown. 1996. Occurrence and accumulation of pesticides and organic contaminants in river sediment, water and clam tissues from the San Joaquin River and tributaries, California. Environ. Toxicol. Chem. 15(2): 172-180.

Rasmussen, D. 1997. Toxic Substances Monitoring Program, 1994-95 Data Report. State Water Resources Control Board, Sacramento, CA. (http://www.swrcb.ca.gov/html/smw.html)

SAS Institute. 1990. SAS/STAT User's Guide, Version 6, Fourth Edition. SAS Institute, Cary, NC.

SFRWQCB (San Francisco Regional Water Quality Control Board), State Water Resources Control Board, and California Department of Fish and Game. 1995. Contaminant Levels in Fish Tissue from San Francisco Bay: Final Report. San Francisco Regional Water Quality Control Board, Oakland, CA.

SFEI. 1999. Contaminant Concentrations in Fish from San Francisco Bay, 1997. San Francisco Estuary Institute, Richmond, CA.

SFEI. 2000. 1998 Annual Report: Regional Monitoring Program for Trace Substances in the San Francisco Estuary. www.sfei.org. San Francisco Estuary Institute, Richmond, CA.

Suedel, B.C., J.A. Boraczek, R.K. Peddicord, P.A. Clifford, and T.M. Dillon. 1994. Trophic transfer and biomagnification potential of contaminants in aquatic ecosystems. Rev. Environ. Contam. Toxicol. 136: 21-89.

U.S. EPA. 1975. DDT: A Review of Scientific and Economic Aspects of the Decision to Ban its Use as a Pesticide. EPA-540/1-75-022. U.S. Environmental Protection Agency, Washington, D.C.

U.S. EPA. 1995a. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories: Volume 1, Fish Sampling and Analysis, Second Edition. EPA 823-R-93-002. U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

Wolfe, M.F., S. Schwarzbach, and R.A. Sulaiman. 1998. Effects of mercury on wildlife: A comprehensive review. Environ. Toxicol. Chem. 17(2): 146-160.

Table 1. Trace element concentrations in fish and clam tissue

Date (1998)	Location	Species	Replicate	# fish combined	Length or average length (mm)	Age (estimated)	% moisture	Mercury (µg/g wet)	Arsenic (µg/g wet)	Selenium (µg/g wet)
Aug 27	Merced River upstream of Hatfield State Park	largemouth bass		5	349		79	0.349	0.035	0.546
Aug 18–25	Middle River at Bullfrog	largemouth bass		5	344		78	0.163	0.133	0.451
Aug 26	Mokelumne River between Beaver and Hog Sloughs	largemouth bass		5	362		79	0.361	0.070	0.217
Sep 3	Old River near Paradise Cut	largemouth bass		5	372		79	0.160	0.087	0.570
Aug 10–18	Paradise Cut	largemouth bass		5	334		79	0.372	0.137	0.599
Aug 12–19	Port of Stockton turning basin	largemouth bass	Fish #1	1	310	2	78	0.269	0.140	0.487
Aug 12–19	Port of Stockton turning basin	largemouth bass	Fish #2	1	315	2	79	0.280	0.163	0.456
Aug 12–19	Port of Stockton turning basin	largemouth bass	Fish #3	1	345	3	81	0.315	0.063	0.319
Aug 12–19	Port of Stockton turning basin	largemouth bass	Fish #4	1	340	3	78	0.317	0.178	0.285
Aug 12–19	Port of Stockton turning basin	largemouth bass	Fish #5	1	395	.	80	0.272	0.073	0.395
Aug 12–19	Port of Stockton turning basin	largemouth bass	Large Fish #1	1	410	6	77	0.478	0.154	0.346
Aug 12–19	Port of Stockton turning basin	largemouth bass	Large Fish #2	1	525	.	79	0.521	0.062	0.292
Aug 10–19	San Joaquin River around Bowman Road	largemouth bass		5	335		78	0.404	0.113	0.680
Aug 18–19	San Joaquin River around Turner Cut	largemouth bass		5	386		77	0.241	0.122	0.517
Aug 27	San Joaquin River at Landers Ave/RT 165	largemouth bass		5	375		79	0.582	0.057	0.511
Sep 11	San Joaquin River between Crow's Landing and Las Palmas	largemouth bass		5	374		78	0.455	0.069	0.660
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Fish #1	1	360	3	79	0.317	0.099	0.540
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Fish #2	1	310	2	79	0.312	0.069	0.716
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Fish #3	1	310	1	78	0.318	0.069	0.773
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Fish #4	1	380	.	78	0.486	0.036	0.422
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Fish #5	1	375	4	78	0.608	0.076	0.483
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Duplicate Fish #1	1	390	3	78	0.424	0.092	0.461
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Duplicate Fish #2	1	345	2	79	0.519	0.057	0.666
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Duplicate Fish #3	1	350	3	77	0.477	0.051	0.433
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Duplicate Fish #4	1	335	2	78	0.261	0.066	0.627
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Duplicate Fish #5	1	325	2	79	0.516	0.126	0.576
Aug 20–21	San Joaquin River near Potato Slough	largemouth bass		5	341		78	0.284	0.107	0.311
Aug 11–19	San Joaquin River north of Highway 4	largemouth bass		5	351		80	0.547	0.100	0.507
Sep 10	San Joaquin River off Point Antioch near fishing pier	largemouth bass		5	352		77	0.168	0.087	0.322
Aug 18–19; Sep 10	Smith Canal by Yosemite Lake	largemouth bass		5	364		79	0.084	0.079	0.395
Aug 26	Stanislaus River upstream of Caswell State Park	largemouth bass		5	381		77	0.670	0.060	0.381
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Fish #1	1	370	6	80	0.462	0.067	0.218
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Fish #2	1	420	.	78	0.392	0.064	0.212
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Fish #3	1	355	3	77	0.351	0.038	0.206
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Fish #4	1	320	4	78	0.243	0.062	0.186
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Fish #5	1	340	4	77	0.320	0.041	0.188
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Large Fish #1	1	480	6	79	0.704	0.033	0.170
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Large Fish #2	1	480	6	79	0.565	0.042	0.170
Sep 11	Tuolumne River upstream of Shiloh Road	largemouth bass		5	399		79	0.376	0.032	0.309
Aug 18–25	White Slough downstream of Disappointment Slough	largemouth bass		5	382		80	0.226	0.031	0.163
Aug 18–25	Middle River at Bullfrog	white catfish		5	286		81	0.156	0.048	0.147
Sep 3	Old River near Paradise Cut	white catfish		5	260		80	0.282	0.038	0.180
Aug 10–18	Paradise Cut	white catfish		5	257		76	0.293	0.015	0.243
Aug 12–19	Port of Stockton turning basin	white catfish		5	277		81	0.199	0.010	0.182
Aug 10–19	San Joaquin River around Bowman Road	white catfish		5	261		83	0.469	0.010	0.174
Aug 18–19	San Joaquin River around Turner Cut	white catfish		5	268		81	0.157	0.026	0.163
Aug 27	San Joaquin River at Landers Ave/RT 165	white catfish		5	233		81	0.251	0.012	0.196
Aug 10–26	San Joaquin River downstream of Vernalis	white catfish		5	244		82	0.308	0.013	0.201
Aug 10–26	San Joaquin River downstream of Vernalis	white catfish	Duplicate	5	247		81	0.347	0.007	0.168
Aug 20–21	San Joaquin River near Potato Slough	white catfish		5	258		80	0.301	0.031	0.147
Aug 11–19	San Joaquin River north of Highway 4	white catfish		5	249		81	0.417	0.037	0.197
Aug 18–19; Sep 10	Smith Canal by Yosemite Lake	white catfish		5	235		81	0.085	0.010	0.181
Aug 26	Mokelumne River between Beaver and Hog Sloughs	black bullhead		5	288		82	0.141	0.059	0.169
Sep 3	Sycamore Slough near Mokelumne River	black bullhead		5	282		81	0.167	0.039	0.142
Aug 18–25	White Slough downstream of Disappointment Slough	black bullhead		4	311		82	0.070	0.049	0.132
Aug 18–25	Middle River at Bullfrog	Corbicula		50	31		92	0.012	1.014	0.239
Sep 10	Port of Stockton near Mormon Slough	Corbicula		24	33		87	0.012	1.054	0.384
	Sacramento River at Rio Vista	Corbicula		68	25		90	0.021	0.835	0.312

Stars - Not Delta or SJR
Gray - SJR
Everything else - Delta

Table 2. Pesticide concentrations in fish and clam tissue. Part 1 of 2.
ng/g wet, surrogate corrected
ND= not detected or below reporting limit

Date (1998)	Location	Species	Replicate	# fish combined	% moisture	% lipid	Sum of Chlordanes	chlordane, cis	chlordane, trans	nonachlor, cis	nonachlor, trans	oxychlordane	chlordene, alpha	chlordene, gamma	heptachlor	heptachlor epoxide	Sum of DDTs	DDD, o,p'	DDD, p,p'	DDE, o,p'	DDE, p,p'	DDT, o,p'	DDT, p,p'
Aug 27	Merced River upstream of Hatfield State Park ☆	largemouth bass		5	76	1.1	1.0	ND	ND	ND	1.0	ND	ND	ND	ND	ND	24	ND	ND	ND	24	ND	ND
Aug 18-25	Middle River at Bullfrog	largemouth bass		5	77	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	20	ND	ND	ND	20	ND	ND
Aug 26	Mokelumne River between Beaver and Hog Sloughs	largemouth bass		5	77	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	11	ND	ND	ND	11	ND	ND
Sep 3	Old River near Paradise Cut	largemouth bass		5	77	0.5	1.9	ND	ND	ND	1.9	ND	ND	ND	ND	ND	56	ND	3.9	ND	52	ND	ND
Aug 10-18	Paradise Cut	largemouth bass		5	79	0.4	1.3	ND	ND	ND	1.3	ND	ND	ND	ND	ND	44	ND	ND	ND	44	ND	ND
Aug 12-19	Port of Stockton turning basin	largemouth bass	Fish #1	1	79	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	32	ND	2.3	ND	29	ND	ND
Aug 12-19	Port of Stockton turning basin	largemouth bass	Fish #2	1	81	0.5	1.1	ND	ND	ND	1.1	ND	ND	ND	ND	ND	32	ND	2.7	ND	30	ND	ND
Aug 12-19	Port of Stockton turning basin	largemouth bass	Fish #3	1	80	0.6	1.1	ND	ND	ND	1.1	ND	ND	ND	ND	ND	20	ND	2.2	ND	18	ND	ND
Aug 12-19	Port of Stockton turning basin	largemouth bass	Fish #4	1	78	1.1	1.8	ND	ND	ND	1.8	ND	ND	ND	ND	ND	48	ND	5.3	ND	42	ND	ND
Aug 12-19	Port of Stockton turning basin	largemouth bass	Fish #5	1	78	0.6	2.2	ND	ND	ND	2.2	ND	ND	ND	ND	ND	64	ND	4.4	ND	59	ND	ND
Aug 12-19	Port of Stockton turning basin	largemouth bass	Large Fish #1	1	78	0.8	3.7	ND	ND	ND	3.7	ND	ND	ND	ND	ND	91	ND	9.3	ND	82	ND	ND
Aug 12-19	Port of Stockton turning basin	largemouth bass	Large Fish #2	1	79	0.8	2.3	ND	ND	ND	2.3	ND	ND	ND	ND	ND	54	ND	6.0	ND	48	ND	ND
Aug 10-19	San Joaquin River around Bowman Road	largemouth bass		5	78	0.5	1.3	ND	ND	ND	1.3	ND	ND	ND	ND	ND	56	ND	2.3	ND	54	ND	ND
Aug 18-19	San Joaquin River around Turner Cut	largemouth bass		5	78	0.8	1.8	ND	ND	ND	1.8	ND	ND	ND	ND	ND	60	ND	2.9	ND	57	ND	ND
Aug 27	San Joaquin River at Landers Ave/RT 165	largemouth bass		5	78	1.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	17	ND	ND	ND	17	ND	ND
Sep 11	San Joaquin River between Crow's Landing and Las Palmas	largemouth bass		5	77	1.1	1.5	ND	ND	ND	1.5	ND	ND	ND	ND	ND	78	ND	3.7	ND	68	ND	6.4
Aug 10-26	San Joaquin River downstream of Vernalis	largemouth bass	Fish #1	1	77	1.0	1.0	ND	ND	ND	1.0	ND	ND	ND	ND	ND	58	ND	2.6	ND	50	ND	5.4
Aug 10-26	San Joaquin River downstream of Vernalis	largemouth bass	Fish #2	1	78	0.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	17	ND	ND	ND	17	ND	ND
Aug 10-26	San Joaquin River downstream of Vernalis	largemouth bass	Fish #3	1	77	0.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	20	ND	ND	ND	20	ND	ND
Aug 10-26	San Joaquin River downstream of Vernalis	largemouth bass	Fish #4	1	78	0.7	1.4	ND	ND	ND	1.4	ND	ND	ND	ND	ND	54	ND	3.0	ND	51	ND	ND
Aug 10-26	San Joaquin River downstream of Vernalis	largemouth bass	Fish #5	1	78	0.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	41	ND	2.0	ND	39	ND	ND
Aug 10-26	San Joaquin River downstream of Vernalis	largemouth bass	Duplicate Fish #1	1	78	0.8	2.1	ND	ND	ND	2.1	ND	ND	ND	ND	ND	111	ND	5.5	ND	96	ND	9.4
Aug 10-26	San Joaquin River downstream of Vernalis	largemouth bass	Duplicate Fish #2	1	79	0.9	2.5	ND	ND	ND	2.5	ND	ND	ND	ND	ND	120	ND	5.8	ND	106	ND	8.4
Aug 10-26	San Joaquin River downstream of Vernalis	largemouth bass	Duplicate Fish #3	1	79	0.8	1.0	ND	ND	ND	1.0	ND	ND	ND	ND	ND	51	ND	3.0	ND	48	ND	ND
Aug 10-26	San Joaquin River downstream of Vernalis	largemouth bass	Duplicate Fish #4	1	78	0.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	46	ND	2.9	ND	43	ND	ND
Aug 10-26	San Joaquin River downstream of Vernalis	largemouth bass	Duplicate Fish #5	1	77	0.6	1.3	ND	ND	ND	1.3	ND	ND	ND	ND	ND	38	ND	ND	ND	38	ND	ND
Aug 20-21	San Joaquin River near Potato Slough	largemouth bass		5	79	0.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	10	ND	ND	ND	10	ND	ND
Aug 11-19	San Joaquin River north of Highway 4	largemouth bass		5	78	0.4	1.8	ND	ND	ND	1.8	ND	ND	ND	ND	ND	67	ND	2.9	ND	64	ND	ND
Sep 10	San Joaquin River off Point Antioch near fishing pier	largemouth bass		5	77	0.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	7	ND	ND	ND	7	ND	ND
Aug 18-19, Sep 10	Smith Canal by Yosemite Lake	largemouth bass		5	78	0.5	5.2	2.3	ND	ND	2.9	ND	ND	ND	ND	ND	43	ND	14.7	ND	29	ND	ND
Aug 26	Stanislaus River upstream of Caswell State Park ☆	largemouth bass		5	76	1.3	2.7	ND	ND	ND	2.7	ND	ND	ND	ND	ND	113	ND	4.2	ND	100	ND	9.3
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Large Fish #1	1	80	0.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3	ND	ND	ND	3	ND	ND
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Large Fish #2	1	78	0.9	1.6	ND	ND	ND	1.6	ND	ND	ND	ND	ND	32	ND	3.3	ND	29	ND	ND
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Fish #1	1	80	0.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	13	ND	ND	ND	13	ND	ND
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Fish #2	1	80	0.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4	ND	ND	ND	4	ND	ND
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Fish #3	1	79	0.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4	ND	ND	ND	4	ND	ND
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Fish #4	1	80	0.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	5	ND	ND	ND	5	ND	ND
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Fish #5	1	79	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4	ND	ND	ND	4	ND	ND
Sep 11	Tuolumne River upstream of Shiloh Road ☆	largemouth bass		5	78	0.7	1.0	ND	ND	ND	1.0	ND	ND	ND	ND	ND	22	ND	ND	ND	22	ND	ND
Aug 18-25	White Slough downstream of Disappointment Slough	largemouth bass		5	78	0.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	9	ND	ND	ND	9	ND	ND
Aug 18-25	Middle River at Bullfrog	white catfish		5	80	0.8	1.2	ND	ND	ND	1.2	ND	ND	ND	ND	ND	55	ND	3.1	ND	52	ND	ND
Sep 3	Old River near Paradise Cut	white catfish		5	80	1.8	12.8	3.4	ND	2.3	7.2	ND	ND	ND	ND	ND	255	ND	13.3	2.1	228	ND	12.1
Aug 10-18	Paradise Cut	white catfish		5	79	1.0	4.9	ND	ND	ND	4.9	ND	ND	ND	ND	ND	157	ND	7.8	ND	149	ND	ND
Aug 12-19	Port of Stockton turning basin	white catfish		5	81	0.6	5.9	2.2	ND	ND	3.7	ND	ND	ND	ND	ND	134	ND	7.8	ND	126	ND	ND
Aug 10-19	San Joaquin River around Bowman Road	white catfish		5	82	0.5	12.2	2.2	ND	2.5	7.5	ND	ND	ND	ND	ND	407	ND	9.9	ND	388	ND	9.0
Aug 18-19	San Joaquin River around Turner Cut	white catfish		5	81	0.6	1.3	ND	ND	ND	1.3	ND	ND	ND	ND	ND	47	ND	2.4	ND	44	ND	ND
Aug 27	San Joaquin River at Landers Ave/RT 165	white catfish		5	82	1.6	1.5	ND	ND	ND	1.5	ND	ND	ND	ND	ND	57	ND	3.8	ND	53	ND	ND
Aug 10-26	San Joaquin River downstream of Vernalis	white catfish		5	80	1.3	15.8	3.7	ND	3.0	9.1	ND	ND	ND	ND	ND	389	ND	18.1	ND	356	ND	15.5
Aug 10-26	San Joaquin River downstream of Vernalis	white catfish	Duplicate	5	81	0.5	3.0	ND	ND	ND	3.0	ND	ND	ND	ND	ND	141	ND	5.2	ND	130	ND	5.6
Aug 20-21	San Joaquin River near Potato Slough	white catfish		5	80	1.0	2.2	ND	ND	ND	2.2	ND	ND	ND	ND	ND	50	ND	4.4	ND	46	ND	ND
Aug 11-19	San Joaquin River north of Highway 4	white catfish		5	81	0.7	6.3	2.1	ND	ND	4.2	ND	ND	ND	ND	ND	160	ND	8.5	ND	144	ND	6.7
Aug 18-19; Sep 10	Smith Canal by Yosemite Lake	white catfish		5	81	0.4	5.0	2.7	ND	ND	2.3	ND	ND	ND	ND	ND	42	ND	15.9	ND	27	ND	ND
Aug 26	Mokelumne River between Beaver and Hog Sloughs	black bullhead		5	82	0.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	18	ND	2.4	ND	16	ND	ND
Sep 3	Sycamore Slough near Mokelumne River	black bullhead		5	81	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	10	ND	ND	ND	10	ND	ND
Aug 18-25	White Slough downstream of Disappointment Slough	black bullhead		4	81	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	15	ND	ND	ND	15	ND	ND
Sep 10	Port of Stockton near Mormon Slough	Corbicula		24	87	1.8	14.9	4.7	3.3	2.1	4.9	ND	ND	ND	ND	ND	77	6.1	27.7	ND	43	ND	ND
	Sacramento River at Rio Vista	Corbicula		68	90	1.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	19	ND	2.6	ND	16	ND	ND

39

x̄ = 82.5

300 73%
100 27%

47

Table 2. Pesticide concentrations in fish and clam tissue. Part 2 of 2.
ng/g wet, surrogate corrected
ND= not detected or below reporting limit

Date (1998)	Location	Species	Replicate	# fish combined	% moisture	% lipid	DDMU, p,p'	aldrin	chlorpyrifos	dacthal	diazinon	dieldrin	endosulfan I	endosulfan II	endrin	HCH, alpha	HCH, beta	HCH, delta	HCH, gamma	hexachlorobenzene	mirex	toxaphene
Aug 27	Merced River upstream of Hatfield State Park	largemouth bass		5	76	1.1	ND	ND	3.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 18–25	Middle River at Bullfrog	largemouth bass		5	77	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 26	Mokelumne River between Beaver and Hog Sloughs	largemouth bass		5	77	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sep 3	Old River near Paradise Cut	largemouth bass		5	77	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 10–18	Paradise Cut	largemouth bass		5	79	0.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 12–19	Port of Stockton turning basin	largemouth bass	Fish #1	1	79	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 12–19	Port of Stockton turning basin	largemouth bass	Fish #2	1	81	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 12–19	Port of Stockton turning basin	largemouth bass	Fish #3	1	80	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 12–19	Port of Stockton turning basin	largemouth bass	Fish #4	1	78	1.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 12–19	Port of Stockton turning basin	largemouth bass	Fish #5	1	78	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 12–19	Port of Stockton turning basin	largemouth bass	Large Fish #1	1	78	0.8	3.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 12–19	Port of Stockton turning basin	largemouth bass	Large Fish #2	1	79	0.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 10–19	San Joaquin River around Bowman Road	largemouth bass		5	78	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 18–19	San Joaquin River around Turner Cut	largemouth bass		5	78	0.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 27	San Joaquin River at Landers Ave/RT 165	largemouth bass		5	78	1.1	ND	ND	6.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sep 11	San Joaquin River between Crow's Landing and Las Palmas	largemouth bass		5	77	1.1	ND	ND	5.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Fish #1	1	77	1.0	ND	ND	2.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Fish #2	1	78	0.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Fish #3	1	77	0.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Fish #4	1	78	0.7	ND	ND	2.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Fish #5	1	78	0.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Duplicate Fish #1	1	78	0.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Duplicate Fish #2	1	79	0.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Duplicate Fish #3	1	79	0.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Duplicate Fish #4	1	78	0.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Duplicate Fish #5	1	77	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 20–21	San Joaquin River near Potato Slough	largemouth bass		5	79	0.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 11–19	San Joaquin River north of Highway 4	largemouth bass		5	78	0.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sep 10	San Joaquin River off Point Antioch near fishing pier	largemouth bass		5	77	0.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 18-19; Sep 10	Smith Canal by Yosemite Lake	largemouth bass		5	78	0.5	4.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 26	Stanislaus River upstream of Caswell State Park	largemouth bass		5	76	1.3	ND	ND	ND	ND	ND	ND	ND	.	ND	ND	ND	ND	ND	ND	ND	ND
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Large Fish #1	1	80	0.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Large Fish #2	1	78	0.9	ND	ND	ND	ND	ND	2.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Fish #1	1	80	0.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Fish #2	1	80	0.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Fish #3	1	79	0.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Fish #4	1	80	0.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Fish #5	1	79	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sep 11	Tuolumne River upstream of Shiloh Road	largemouth bass		5	78	0.7	ND	ND	3.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 18–25	White Slough downstream of Disappointment Slough	largemouth bass		5	78	0.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 18–25	Middle River at Bullfrog	white catfish		5	80	0.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sep 3	Old River near Paradise Cut	white catfish		5	80	1.8	4.6	ND	4.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 10–18	Paradise Cut	white catfish		5	79	1.0	ND	ND	2.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 12–19	Port of Stockton turning basin	white catfish		5	81	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 10–19	San Joaquin River around Bowman Road	white catfish		5	82	0.5	8.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 18–19	San Joaquin River around Turner Cut	white catfish		5	81	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 27	San Joaquin River at Landers Ave/RT 165	white catfish		5	82	1.6	ND	ND	7.1	ND	ND	2.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 10–26	San Joaquin River downstream of Vernalis	white catfish		5	80	1.3	5.8	ND	2.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 10–26	San Joaquin River downstream of Vernalis	white catfish	Duplicate	5	81	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 20–21	San Joaquin River near Potato Slough	white catfish		5	80	1.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 11–19	San Joaquin River north of Highway 4	white catfish		5	81	0.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 18-19; Sep 10	Smith Canal by Yosemite Lake	white catfish		5	81	0.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 26	Mokelumne River between Beaver and Hog Sloughs	black bullhead		5	82	0.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sep 3	Sycamore Slough near Mokelumne River	black bullhead		5	81	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 18–25	White Slough downstream of Disappointment Slough	black bullhead		4	81	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sep 10	Port of Stockton near Mormon Slough	Corbicula		24	87	1.8	3.4	ND	5.9	ND	ND	5.4	ND	ND	ND	ND	ND	ND	ND	0.4	ND	ND
	Sacramento River at Rio Vista	Corbicula		68	90	1.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Table 3. PCB congener concentrations in fish and clam tissue. Part 1 of 3.
ng/g wet, surrogate corrected
ND= not detected or below reporting limit
J = value approximate

Date (1998)	Location	Species	Replicate	# fish combined	% moisture	% lipid	Sum of PCBs	8	18	27	28	29	31	33	44	49	52	56	60	66	70	74
Aug 27	Merced River upstream of Hatfield State Park	largemouth bass		5	76	1.1	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2	ND	ND	0.2	0.2	ND
Aug 18–25	Middle River at Bullfrog	largemouth bass		5	77	0.6	7	ND	ND	ND	0.3	ND	0.2	ND	0.2	ND	0.3	ND	ND	0.3	0.3	ND
Aug 26	Mokelumne River between Beaver and Hog Sloughs	largemouth bass		5	77	0.5	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2	ND	ND	ND	0.2	ND
Sep 3	Old River near Paradise Cut	largemouth bass		5	77	0.5	7	ND	ND	ND	0.2	ND	0.2	ND	ND	ND	0.3	ND	ND	0.4	0.3	ND
Aug 10–18	Paradise Cut	largemouth bass		5	79	0.4	6	ND	ND	ND	0.3	ND	0.2	ND	0.2	ND	0.3	ND	ND	0.3	0.3	ND
Aug 12–19	Port of Stockton turning basin	largemouth bass	Fish #1	1	79	0.5	21	ND	ND	ND	0.3	ND	0.2	0.2 J	0.4	0.5	0.7	ND	ND	0.5	0.5	0.2
Aug 12–19	Port of Stockton turning basin	largemouth bass	Fish #2	1	81	0.5	24	ND	ND	ND	0.4	ND	0.3	0.2 J	0.4	0.7	0.9	ND	ND	0.6	0.6	0.3
Aug 12–19	Port of Stockton turning basin	largemouth bass	Fish #3	1	80	0.6	18	ND	ND	ND	0.3	ND	0.2	0.2 J	0.3	0.4	0.7	ND	ND	0.5	0.5	ND
Aug 12–19	Port of Stockton turning basin	largemouth bass	Fish #4	1	78	1.1	26	0.3 J	0.3	ND	0.5	ND	0.4	0.3 J	0.5	0.5	0.9	ND	0.2 J	0.8	0.8	0.3
Aug 12–19	Port of Stockton turning basin	largemouth bass	Fish #5	1	78	0.6	44	ND	ND	ND	0.4	ND	0.3	0.2 J	0.4	0.7	1.2	ND	0.2 J	1.1	0.6	0.5
Aug 12–19	Port of Stockton turning basin	largemouth bass	Large Fish #1	1	78	0.8	46	ND	0.2	ND	0.4	ND	0.3	0.2 J	0.5	0.7	1.0	ND	0.3 J	1.0	0.8	0.4
Aug 12–19	Port of Stockton turning basin	largemouth bass	Large Fish #2	1	79	0.8	32	0.3 J	0.3	ND	0.6	ND	0.5	0.3 J	0.6	0.7	1.1	ND	0.2 J	0.8	0.9	0.3
Aug 10–19	San Joaquin River around Bowman Road	largemouth bass		5	78	0.5	5	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2	ND	ND	0.3	0.3	ND
Aug 18–19	San Joaquin River around Turner Cut	largemouth bass		5	78	0.8	15	ND	ND	ND	0.3	ND	0.3	ND	0.3	0.3	0.5	ND	ND	0.5	0.4	ND
Aug 27	San Joaquin River at Landers Ave/RT 165	largemouth bass		5	78	1.1	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2	ND
Sep 11	San Joaquin River between Crow's Landing and Las Palma	largemouth bass		5	77	1.1	6	ND	ND	ND	0.4	ND	0.3	ND	0.2	ND	ND	ND	ND	0.4	0.5	ND
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Fish #1	1	77	1.0	3	ND	ND	ND	ND	ND	0.2	ND	ND	ND	ND	ND	ND	0.3	0.2	ND
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Fish #2	1	78	0.4	3	ND	ND	ND	0.2	ND	0.2	ND	ND	ND	0.3	ND	ND	ND	0.3	ND
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Fish #3	1	77	0.4	0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Fish #4	1	78	0.7	4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.3	ND	ND
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Fish #5	1	78	0.7	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2	ND	ND
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Duplicate Fish #1	1	78	0.8	9	ND	ND	ND	0.2	ND	ND	ND	ND	ND	ND	ND	ND	0.4	0.3	ND
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Duplicate Fish #2	1	79	0.9	5	ND	ND	ND	0.2	ND	0.2	ND	ND	ND	ND	ND	ND	0.4	0.3	ND
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Duplicate Fish #3	1	79	0.8	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2	ND	ND	0.3	0.2	ND
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Duplicate Fish #4	1	78	0.7	2	ND	ND	ND	0.2	ND	0.2	ND	ND	ND	0.2	ND	ND	0.2	0.2	ND
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Duplicate Fish #5	1	77	0.6	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2	ND	ND	0.3	0.2	ND
Aug 20–21	San Joaquin River near Potato Slough	largemouth bass		5	79	0.4	7	ND	ND	ND	0.3	ND	0.2	ND	0.2	ND	0.3	ND	ND	0.3	0.4	ND
Aug 11–19	San Joaquin River north of Highway 4	largemouth bass		5	78	0.4	12	ND	ND	ND	0.3	ND	0.3	0.2 J	0.3	ND	0.4	ND	ND	0.5	0.4	ND
Sep 10	San Joaquin River off Point Antioch near fishing pier	largemouth bass		5	77	0.7	6	ND	ND	ND	0.2	ND	0.2	ND	0.2	ND	0.3	ND	ND	0.3	0.3	ND
Aug 18–19; Sep 10	Smith Canal by Yosemite Lake	largemouth bass		5	78	0.5	112	0.2 J	0.3	ND	0.6	ND	0.4	ND	0.5	1.0	1.5	ND	0.4 J	0.8	0.6	0.3
Aug 26	Stanislaus River upstream of Caswell State Park	largemouth bass		5	76	1.3	22	ND	ND	ND	0.2	ND	ND	ND	0.2	ND	0.4	ND	ND	0.5	0.4	ND
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Large Fish #1	1	80	0.2	2	ND	ND	ND	0.2	ND	ND	ND	ND	ND	0.3	ND	ND	ND	0.3	ND
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Large Fish #2	1	78	0.9	9	ND	ND	ND	0.3	ND	0.2	ND	0.2	ND	0.5	ND	ND	0.4	0.4	ND
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Fish #1	1	80	0.7	7	ND	ND	ND	0.3	ND	0.2	ND	ND	ND	0.3	ND	ND	0.3	0.3	ND
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Fish #2	1	80	0.3	0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Fish #3	1	79	0.4	3	ND	ND	ND	0.2	ND	ND	ND	ND	ND	0.3	ND	ND	ND	0.3	ND
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Fish #4	1	80	0.4	3	ND	ND	ND	0.2	ND	0.2	0.2 J	ND	ND	0.3	ND	ND	ND	0.3	ND
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Fish #5	1	79	0.5	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2	ND	ND	ND	0.2	ND
Sep 11	Tuolumne River upstream of Shiloh Road	largemouth bass		5	78	0.7	7	0.3 J	ND	ND	0.4	ND	0.4	0.3 J	0.3	ND	0.3	ND	ND	0.4	0.4	ND
Aug 18–25	White Slough downstream of Disappointment Slough	largemouth bass		5	78	0.3	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2	ND	ND	ND	0.2	ND
Aug 18–25	Middle River at Bullfrog	white catfish		5	80	0.8	8	ND	ND	ND	ND	ND	ND	0.3 J	ND	ND	0.2	ND	ND	0.3	0.2	ND
Sep 3	Old River near Paradise Cut	white catfish		5	80	1.8	27	ND	ND	ND	0.3	ND	ND	ND	0.3	0.3	0.5	ND	0.2 J	1.1	0.2	0.2
Aug 10–18	Paradise Cut	white catfish		5	79	1.0	17	ND	ND	ND	0.3	ND	0.2	ND	0.2	ND	0.4	ND	ND	0.8	0.2	ND
Aug 12–19	Port of Stockton turning basin	white catfish		5	81	0.6	51	ND	ND	ND	0.5	ND	0.2	ND	0.5	0.9	1.3	ND	0.4 J	1.2	0.3	0.5
Aug 10–19	San Joaquin River around Bowman Road	white catfish		5	82	0.5	36	ND	ND	ND	0.2	ND	ND	ND	0.2	0.3	0.4	ND	0.2 J	1.4	ND	0.2
Aug 18–19	San Joaquin River around Turner Cut	white catfish		5	81	0.6	16	0.3 J	0.2	ND	0.4	ND	0.4	0.3 J	0.3	ND	0.5	ND	ND	0.4	0.4	ND
Aug 27	San Joaquin River at Landers Ave/RT 165	white catfish		5	82	1.6	16	0.2 J	ND	ND	0.5	ND	0.5	0.5 J	0.4	0.3	0.6	0.2 J	0.2 J	0.7	0.8	0.3
Aug 10–26	San Joaquin River downstream of Vernalis	white catfish		5	80	1.3	38	0.2 J	ND	ND	0.4	ND	0.3	0.3 J	0.4	0.3	0.6	ND	ND	1.5	0.4	0.3
Aug 10–26	San Joaquin River downstream of Vernalis	white catfish	Duplicate	5	81	0.5	15	ND	ND	ND	0.3	ND	0.2	ND	0.2	0.2	0.4	ND	ND	0.7	0.2	ND
Aug 20–21	San Joaquin River near Potato Slough	white catfish		5	80	1.0	20	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.3	ND	ND	0.5	ND	ND
Aug 11–19	San Joaquin River north of Highway 4	white catfish		5	81	0.7	15	ND	ND	ND	0.2	ND	ND	ND	0.2	0.2	0.4	ND	ND	0.7	ND	ND
Aug 18–19; Sep 10	Smith Canal by Yosemite Lake	white catfish		5	81	0.4	102	ND	ND	ND	0.3	ND	ND	ND	0.3	1.0	1.0	ND	0.5 J	0.5	ND	0.3
Aug 26	Mokelumne River between Beaver and Hog Sloughs	black bullhead		5	82	0.8	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.3	ND	ND
Sep 3	Sycamore Slough near Mokelumne River	black bullhead		5	81	0.6	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 18–25	White Slough downstream of Disappointment Slough	black bullhead		4	81	0.5	5	ND	ND	ND	0.3	ND	0.4	0.2 J	0.2	ND	0.3	ND	ND	0.3	0.3	ND
Sep 10	Port of Stockton near Mormon Slough	Corbicula		24	87	1.8	112	0.4 J	3.2	0.6	1.7	ND	1.4	0.6 J	5.9	3.9	6.2	0.6 J	0.7 J	2.8	2.5	1.1
	Sacramento River at Rio Vista	Corbicula		68	90	1.1	17	ND	0.4	ND	0.3	ND	0.3	0.2 J	1.0	0.2	0.7	ND	ND	0.4	0.4	ND

Table 3. PCB congener concentrations in fish and clam tissue. Part 2 of 3.
ng/g wet, surrogate corrected
ND= not detected or below reporting limit
J = value approximate

Date (1990)	Location	Species	Replicate	# fish combined	% moisture	% lipid	Sum of PCBs	87	95	97	99	101	105	110	118	128	132	137	138	141	149	151	153
Aug 27	Merced River upstream of Hatfield State Park	largemouth bass		5	76	1.1	3	0.2	0.2	ND	ND	0.4	0.2	0.4	0.6 J	ND	ND	ND	0.6	ND	0.2	ND	0.4
Aug 18-25	Middle River at Bullfrog	largemouth bass		5	77	0.6	7	0.3	0.3	ND	0.3	0.7	0.4	0.6	0.9 J	ND	ND	ND	1.0	ND	0.3	ND	0.9
Aug 26	Mokelumne River between Beaver and Hog Sloughs	largemouth bass		5	77	0.5	2	ND	ND	ND	ND	0.3	ND	0.3	0.5 J	ND	ND	ND	0.6	ND	ND	ND	0.4
Sep 3	Old River near Paradise Cut	largemouth bass		5	77	0.5	7	0.4	0.4	ND	0.2	0.5	0.2	0.6	0.8 J	ND	ND	ND	1.0	ND	0.4	0.2	0.7
Aug 10-18	Paradise Cut	largemouth bass		5	79	0.4	6	0.4	0.4	ND	ND	0.5	0.2	0.5	0.7 J	ND	ND	ND	0.9	ND	0.4	ND	0.6
Aug 12-19	Port of Stockton turning basin	largemouth bass	Fish #1	1	79	0.5	21	0.6	0.7	0.4	0.8	1.5	0.8	1.7	2.4	0.3	0.6	ND	2.4	0.3 J	1.3	0.4	1.6
Aug 12-19	Port of Stockton turning basin	largemouth bass	Fish #2	1	81	0.5	24	0.7	0.9	0.4	0.9	1.7	0.8	2.2	2.5	0.4	0.5	ND	2.8	0.3 J	1.5	0.5	1.9
Aug 12-19	Port of Stockton turning basin	largemouth bass	Fish #3	1	80	0.6	18	0.4	0.6	0.3	0.5	0.9	0.5	1.2	1.4	0.2	0.4	ND	2.2	0.2 J	1.3	0.5	1.8
Aug 12-19	Port of Stockton turning basin	largemouth bass	Fish #4	1	78	1.1	26	0.8	0.9	0.4	0.8	1.5	0.7	1.9	2.2	0.3	0.5	ND	2.9	0.2 J	1.7	0.6	2.3
Aug 12-19	Port of Stockton turning basin	largemouth bass	Fish #5	1	78	0.6	44	0.9	1.0	0.6	1.7	3.2	1.6	2.8	4.6	0.6	ND	ND	6.3	0.6 J	2.4	0.8	4.5
Aug 12-19	Port of Stockton turning basin	largemouth bass	Large Fish #1	1	78	0.8	46	1.0	1.3	0.6	1.4	2.4	1.2	2.9	3.5	0.6	0.8	ND	6.4	0.5 J	3.3	1.3	5.0
Aug 12-19	Port of Stockton turning basin	largemouth bass	Large Fish #2	1	79	0.8	32	0.9	1.2	0.5	0.9	2.0	0.9	2.5	2.7	0.4	0.7	ND	3.6	0.3 J	2.0	0.7	2.5
Aug 10-19	San Joaquin River around Bowman Road	largemouth bass		5	78	0.5	5	0.4	0.3	ND	ND	0.5	0.2	0.5	0.8 J	ND	ND	ND	0.9	ND	0.4	ND	0.5
Aug 18-19	San Joaquin River around Turner Cut	largemouth bass		5	78	0.8	15	0.6	0.5	0.2	0.5	1.0	0.4	1.1	1.4	0.2	ND	ND	2.1	ND	0.8	0.4	2.1
Aug 27	San Joaquin River at Landers Ave/RT 165	largemouth bass		5	78	1.1	1	ND	ND	ND	ND	0.2	ND	0.3	0.5 J	ND	ND	ND	0.4	ND	ND	ND	0.3
Sep 11	San Joaquin River between Crow's Landing and Las Palmas	largemouth bass		5	77	1.1	6	0.6	0.3	ND	0.2	0.5	ND	0.5	0.8 J	ND	ND	ND	0.9	ND	0.3	ND	0.5
Aug 10-26	San Joaquin River downstream of Vernalis	largemouth bass	Fish #1	1	77	1.0	3	0.4	0.2	ND	ND	0.3	ND	0.4	0.7 J	ND	ND	ND	0.6	ND	ND	ND	0.4
Aug 10-26	San Joaquin River downstream of Vernalis	largemouth bass	Fish #2	1	78	0.4	3	0.2	0.3	ND	ND	0.3	ND	0.4	0.5 J	ND	ND	ND	0.3	ND	ND	ND	ND
Aug 10-26	San Joaquin River downstream of Vernalis	largemouth bass	Fish #3	1	77	0.4	0	ND	ND	ND	ND	ND	ND	ND	0.3 J	ND	ND	ND	0.2	ND	ND	ND	ND
Aug 10-26	San Joaquin River downstream of Vernalis	largemouth bass	Fish #4	1	78	0.7	4	0.4	0.2	ND	ND	0.3	0.2	0.3	0.9 J	ND	0.3	ND	0.9	ND	ND	ND	0.7
Aug 10-26	San Joaquin River downstream of Vernalis	largemouth bass	Fish #5	1	78	0.7	2	0.3	ND	ND	ND	0.2	ND	0.3	0.6 J	ND	0.2	ND	0.6	ND	0.3	ND	0.4
Aug 10-26	San Joaquin River downstream of Vernalis	largemouth bass	Duplicate Fish #1	1	78	0.8	9	0.8	0.3	ND	0.2	0.4	0.3	0.6	1.4	ND	0.3	0.3	1.1	ND	0.4	0.4	0.7
Aug 10-26	San Joaquin River downstream of Vernalis	largemouth bass	Duplicate Fish #2	1	79	0.9	5	1.1	0.3	ND	ND	0.4	0.2	0.5	0.9 J	ND	ND	ND	0.9	ND	ND	ND	0.5
Aug 10-26	San Joaquin River downstream of Vernalis	largemouth bass	Duplicate Fish #3	1	79	0.8	3	0.4	0.2	ND	ND	0.4	ND	0.4	0.8 J	ND	ND	ND	0.6	ND	ND	ND	0.4
Aug 10-26	San Joaquin River downstream of Vernalis	largemouth bass	Duplicate Fish #4	1	78	0.7	2	0.4	ND	ND	ND	ND	ND	0.3	0.6 J	ND	ND	ND	0.4	ND	ND	ND	0.3
Aug 10-26	San Joaquin River downstream of Vernalis	largemouth bass	Duplicate Fish #5	1	77	0.6	3	0.4	ND	ND	ND	0.3	ND	0.4	0.6 J	ND	ND	ND	0.5	ND	0.2	ND	0.3
Aug 20-21	San Joaquin River near Potato Slough	largemouth bass		5	79	0.4	7	0.2	0.3	ND	0.2	0.5	0.3	0.6	0.9 J	ND	ND	ND	1.0	ND	0.3	ND	0.8
Aug 11-19	San Joaquin River north of Highway 4	largemouth bass		5	78	0.4	12	0.6	0.5	0.2	0.3	0.8	0.5	0.9	1.1	ND	ND	ND	1.6	ND	0.7	0.3	1.1
Sep 10	San Joaquin River off Point Antioch near fishing pier	largemouth bass		5	77	0.7	6	0.2	0.3	ND	0.2	0.4	0.3	0.7	0.7 J	ND	ND	ND	0.9	ND	0.3	ND	0.7
Aug 18-19; Sep 10	Smith Canal by Yosemite Lake	largemouth bass		5	78	0.5	112	0.7	1.9	0.5	1.9	4.9	0.7	3.2	2.4	0.8	1.6	ND	###	2.9 J	9.6	3.6	###
Aug 26	Stanislaus River upstream of Caswell State Park	largemouth bass		5	76	1.3	22	ND	0.4	ND	0.5	1.0	0.3	0.8	1.3	0.2	0.2	ND	2.5	0.3 J	0.9	0.3	2.2
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Large Fish #1	1	80	0.2	2	ND	0.2	ND	ND	0.3	ND	0.4	0.4 J	ND	ND	ND	0.3	ND	ND	ND	ND
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Large Fish #2	1	78	0.9	9	0.4	0.4	ND	0.3	0.7	0.3	0.8	1.0 J	ND	ND	ND	1.3	ND	0.6	0.2	0.9
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Fish #1	1	80	0.7	7	0.2	0.3	ND	0.3	0.5	0.3	0.6	1.0 J	ND	ND	ND	1.2	ND	0.3	ND	0.9
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Fish #2	1	80	0.3	0	ND	ND	ND	ND	ND	ND	ND	0.2 J	ND	ND	ND	0.2	ND	ND	ND	ND
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Fish #3	1	79	0.4	3	ND	0.2	ND	ND	0.3	0.3	0.4	0.6 J	ND	ND	ND	0.5	ND	ND	ND	0.3
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Fish #4	1	80	0.4	3	ND	0.2	ND	ND	0.4	0.3	0.4	0.6 J	ND	ND	ND	0.4	ND	ND	ND	0.3
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Fish #5	1	79	0.5	2	ND	ND	ND	ND	0.2	0.2	0.4	0.5 J	ND	ND	ND	0.4	ND	ND	ND	0.2
Sep 11	Tuolumne River upstream of Shiloh Road	largemouth bass		5	78	0.7	7	0.3	0.4	ND	0.2	0.5	0.3	0.6	0.8 J	ND	ND	ND	0.8	ND	0.3	ND	0.5
Aug 18-25	White Slough downstream of Disappointment Slough	largemouth bass		5	78	0.3	3	ND	0.2	ND	ND	0.4	0.2	0.4	0.5 J	ND	ND	ND	0.6	ND	0.2	ND	0.4
Aug 18-25	Middle River at Bullfrog	white catfish		5	80	0.8	8	0.3	0.3	ND	0.4	0.9	0.3	0.7	1.0 J	ND	ND	ND	1.6	ND	0.6	ND	1.5
Sep 3	Old River near Paradise Cut	white catfish		5	80	1.8	27	1.5	0.6	0.4	0.8	1.4	0.5	1.5	2.7	0.4	1.1	0.3	4.3	0.3 J	1.8	0.4	3.0
Aug 10-18	Paradise Cut	white catfish		5	79	1.0	17	0.9	0.5	0.2	0.5	1.0	0.2	1.0	1.3	ND	ND	ND	2.7	0.2 J	1.3	0.3	2.0
Aug 12-19	Port of Stockton turning basin	white catfish		5	81	0.6	51	1.1	1.4	0.4	1.9	3.2	1.0	3.0	4.2	0.7	ND	0.3	7.0	0.8 J	2.9	0.9	6.2
Aug 10-19	San Joaquin River around Bowman Road	white catfish		5	82	0.5	36	1.6	0.5	0.3	0.9	1.6	0.6	1.6	2.7	0.5	1.3	ND	7.5	0.4 J	2.4	0.5	3.8
Aug 18-19	San Joaquin River around Turner Cut	white catfish		5	81	0.6	16	0.5	0.5	0.2	0.5	1.0	0.4	1.1	1.3	ND	ND	ND	2.1	ND	0.9	0.2	1.9
Aug 27	San Joaquin River at Landers Ave/RT 165	white catfish		5	82	1.6	16	0.7	0.7	0.3	0.5	1.1	0.6	1.3	1.6	0.2	ND	ND	1.4	ND	0.5	ND	1.0
Aug 10-26	San Joaquin River downstream of Vernalis	white catfish		5	80	1.3	38	2.8	0.9	0.5	1.0	1.8	0.7	2.0	3.1	0.5	0.9	ND	6.2	0.4 J	2.2	ND	4.0
Aug 10-26	San Joaquin River downstream of Vernalis	white catfish	Duplicate	5	81	0.5	15	0.9	0.5	0.2	0.5	1.2	0.3	ND	1.2	0.2	ND	ND	2.3	ND	1.1	0.3	1.7
Aug 20-21	San Joaquin River near Potato Slough	white catfish		5	80	1.0	20	0.5	0.4	ND	0.6	1.2	0.3	1.0	1.6	0.3	ND	ND	3.1	ND	1.3	0.3	3.9
Aug 11-19	San Joaquin River north of Highway 4	white catfish		5	81	0.7	15	1.2	0.4	ND	0.5	0.9	0.3	0.9	1.3	0.3	0.3	ND	2.3	ND	0.8	0.3	1.4
Aug 18-19; Sep 10	Smith Canal by Yosemite Lake	white catfish		5	81	0.4	102	0.5	1.6	0.2	1.4	3.3	ND	2.5	1.6	0.6	1.9	ND	###	2.8 J	8.3	2.9	###
Aug 26	Mokelumne River between Beaver and Hog Sloughs	black bullhead		5	82	0.8	3	ND	ND	ND	ND	0.3	0.2	0.4	0.6 J	ND	ND	ND	0.8	ND	0.3	ND	0.2
Sep 3	Sycamore Slough near Mokelumne River	black bullhead		5	81	0.6	1	ND	ND	ND	ND	0.2	ND	0.3	0.4 J	ND	ND	ND	0.4	ND	ND	ND	ND
Aug 18-25	*White Slough downstream of Disappointment Slough*	*black bullhead*		*4*	*81*	*0.5*	*5*	*0.2*	*0.3*	*ND*	*ND*	*0.3*	*0.3*	*0.5*	*0.6 J*	*ND*	*ND*	*ND*	*0.6*	*ND*	*0.2*	*ND*	*ND*
Sep 10	Port of Stockton near Mormon Slough	Corbicula		24	87	1.8	112	1.7	6.2	3.0	3.0	7.4	2.3	7.6	###	1.0	1.1	0.2	###	ND	6.9	1.9	###
	Sacramento River at Rio Vista	Corbicula		68	90	1.1	17	0.3	0.8	0.4	0.3	0.8	0.5	1.0	1.5	ND	0.2	ND	1.8	ND	1.0	0.3	2.8

Table 3. PCB congener concentrations in fish and clam tissue. Part 3 of 3.
ng/g wet, surrogate corrected
ND= not detected or below reporting limit
J = value approximate

Date (1998)	Location	Species	Replicate	# fish combined	% moisture	% lipid	Sum of PCBs	156	157	158	170	174	177	180	183	187	189	194	195	200	201	203	206	209
Aug 27	Merced River upstream of Hatfield State Park	largemouth bass		5	76	1.1	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 18–25	Middle River at Bullfrog	largemouth bass		5	77	0.6	7	ND	ND	ND	ND	ND	ND	ND	ND	0.2	ND	ND	ND	ND	ND	ND	ND	ND
Aug 26	Mokelumne River between Beaver and Hog Sloughs	largemouth bass		5	77	0.5	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sep 3	Old River near Paradise Cut	largemouth bass		5	77	0.5	7	ND	ND	ND	ND	ND	ND	0.3	ND	0.2	ND	ND	ND	ND	ND	ND	ND	ND
Aug 10–18	Paradise Cut	largemouth bass		5	79	0.4	6	ND	ND	ND	ND	ND	ND	0.2	ND	0.2	ND	ND	ND	ND	ND	ND	ND	ND
Aug 12–19	Port of Stockton turning basin	largemouth bass	Fish #1	1	79	0.5	21	ND	ND	0.2	0.3	ND	ND	0.6	0.2	0.4	ND	ND	ND	ND	ND	ND	ND	ND
Aug 12–19	Port of Stockton turning basin	largemouth bass	Fish #2	1	81	0.5	24	ND	ND	0.2	0.4	0.2	ND	0.8	0.3	0.5	ND	ND	ND	ND	ND	ND	ND	ND
Aug 12–19	Port of Stockton turning basin	largemouth bass	Fish #3	1	80	0.6	18	ND	ND	ND	0.4	0.3	0.2	1.0	0.3	0.7	ND	ND	ND	ND	0.2	ND	ND	ND
Aug 12–19	Port of Stockton turning basin	largemouth bass	Fish #4	1	78	1.1	26	ND	ND	0.2	0.4	0.3	0.2	1.0	0.4	0.8	ND	ND	ND	ND	0.2	ND	ND	ND
Aug 12–19	Port of Stockton turning basin	largemouth bass	Fish #5	1	78	0.6	44	0.4	ND	0.5	0.8	0.4	0.3	1.9	0.6	1.7	ND	0.4	ND	ND	0.5	0.3	ND	ND
Aug 12–19	Port of Stockton turning basin	largemouth bass	Large Fish #1	1	78	0.8	46	0.3	ND	0.5	0.9	0.6	0.5	2.2	0.8	1.8	ND	0.4	ND	ND	0.4	0.3	ND	ND
Aug 12–19	Port of Stockton turning basin	largemouth bass	Large Fish #2	1	79	0.8	32	0.2	ND	0.3	0.5	0.3	0.3	1.1	0.4	0.9	ND	0.2	ND	ND	0.3	ND	ND	ND
Aug 10–19	San Joaquin River around Bowman Road	largemouth bass		5	78	0.5	5	ND	ND	ND	ND	ND	ND	0.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 18–19	San Joaquin River around Turner Cut	largemouth bass		5	78	0.8	15	ND	ND	ND	0.2	ND	ND	0.6	0.2	0.5	ND	ND	ND	ND	ND	ND	ND	ND
Aug 27	San Joaquin River at Landers Ave/RT 165	largemouth bass		5	78	1.1	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sep 11	San Joaquin River between Crow's Landing and Las Palmas	largemouth bass		5	77	1.1	6	ND	ND	ND	ND	ND	ND	0.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Fish #1	1	77	1.0	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Fish #2	1	78	0.4	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Fish #3	1	77	0.4	0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Fish #4	1	78	0.7	4	ND	ND	ND	ND	ND	ND	0.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Fish #5	1	78	0.7	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Duplicate Fish #1	1	78	0.8	9	ND	ND	ND	0.3	ND	ND	0.3	0.2	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Duplicate Fish #2	1	79	0.9	5	ND	ND	ND	ND	ND	ND	0.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Duplicate Fish #3	1	79	0.8	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Duplicate Fish #4	1	78	0.7	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 10–26	San Joaquin River downstream of Vernalis	largemouth bass	Duplicate Fish #5	1	77	0.6	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 20–21	San Joaquin River near Potato Slough	largemouth bass		5	79	0.4	7	ND	ND	ND	ND	ND	ND	0.3	ND	0.3	ND	ND	ND	ND	ND	ND	ND	ND
Aug 11–19	San Joaquin River north of Highway 4	largemouth bass		5	78	0.4	12	ND	ND	ND	0.2	ND	ND	0.5	ND	0.6	ND	ND	ND	ND	ND	ND	ND	ND
Sep 10	San Joaquin River off Point Antioch near fishing pier	largemouth bass		5	77	0.7	6	ND	ND	ND	ND	ND	ND	0.3	ND	0.3	ND	ND	ND	ND	ND	ND	ND	ND
Aug 18–19; Sep 10	Smith Canal by Yosemite Lake	largemouth bass		5	78	0.5	112	0.7	ND	1.1	5.3	2.9	2.0	13.6	3.0	7.4	ND	1.8	0.7	ND	1.6	0.9	0.2	ND
Aug 26	Stanislaus River upstream of Caswell State Park	largemouth bass		5	76	1.3	22	ND	ND	ND	0.8	0.2	0.2	1.9	0.4	1.7	ND	0.8	ND	ND	1.3	0.8	1.0	0.8
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Large Fish #1	1	80	0.2	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Large Fish #2	1	78	0.9	9	ND	ND	ND	ND	ND	ND	0.3	ND	0.4	ND	ND	ND	ND	ND	ND	ND	ND
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Fish #1	1	80	0.7	7	ND	ND	ND	ND	ND	ND	0.4	ND	0.3	ND	ND	ND	ND	ND	ND	ND	ND
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Fish #2	1	80	0.3	0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Fish #3	1	79	0.4	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Fish #4	1	80	0.4	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sep 3	Sycamore Slough near Mokelumne River	largemouth bass	Fish #5	1	79	0.5	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sep 11	Tuolumne River upstream of Shiloh Road	largemouth bass		5	78	0.7	7	ND	ND	ND	ND	ND	ND	0.3	ND	0.3	ND	ND	ND	ND	ND	ND	ND	ND
Aug 18–25	White Slough downstream of Disappointment Slough	largemouth bass		5	78	0.3	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 18–25	Middle River at Bullfrog	white catfish		5	80	0.8	8	ND	ND	ND	ND	ND	ND	0.4	ND	0.5	ND	ND	ND	ND	ND	ND	ND	ND
Sep 3	Old River near Paradise Cut	white catfish		5	80	1.8	27	0.2	ND	0.3	0.5	0.3	0.4	1.0	0.5	ND	ND	ND	ND	ND	0.3	0.2	ND	ND
Aug 10–18	Paradise Cut	white catfish		5	79	1.0	17	ND	ND	ND	0.4	0.2	0.2	0.8	0.3	0.8	ND	ND	ND	ND	0.3	ND	ND	ND
Aug 12–19	Port of Stockton turning basin	white catfish		5	81	0.6	51	0.5	ND	0.6	1.2	0.8	0.5	2.7	1.0	2.1	ND	0.6	ND	ND	0.8	0.6	0.3	ND
Aug 10–19	San Joaquin River around Bowman Road	white catfish		5	82	0.5	36	0.3	ND	ND	0.8	0.6	0.5	1.7	0.7	1.4	ND	0.4	ND	ND	0.6	0.4	0.2	ND
Aug 18–19	San Joaquin River around Turner Cut	white catfish		5	81	0.6	16	ND	ND	ND	0.3	0.2	0.2	0.6	0.2	0.8	ND	ND	ND	ND	0.2	ND	ND	ND
Aug 27	San Joaquin River at Landers Ave/RT 165	white catfish		5	82	1.6	16	ND	ND	ND	0.3	ND	ND	0.4	ND	0.9	ND	ND	ND	ND	ND	ND	ND	ND
Aug 10–26	San Joaquin River downstream of Vernalis	white catfish		5	80	1.3	38	0.3	ND	0.3	0.7	0.5	0.5	1.5	0.7	1.6	ND	0.3	ND	ND	0.6	0.3	ND	ND
Aug 10–26	San Joaquin River downstream of Vernalis	white catfish	Duplicate	5	81	0.5	15	ND	ND	ND	0.3	0.2	ND	0.7	0.3	0.9	ND	ND	ND	ND	0.3	ND	ND	ND
Aug 20–21	San Joaquin River near Potato Slough	white catfish		5	80	1.0	20	ND	ND	0.2	0.3	0.2	0.4	1.1	0.5	1.5	ND	ND	ND	ND	0.2	0.3	ND	ND
Aug 11–19	San Joaquin River north of Highway 4	white catfish		5	81	0.7	15	ND	ND	ND	0.3	ND	ND	0.6	0.3	0.7	ND	ND	ND	ND	0.3	ND	ND	ND
Aug 18–19, Sep 10	Smith Canal by Yosemite Lake	white catfish		5	81	0.4	102	0.6	ND	0.9	5.5	4.3	2.8	14.2	3.1	8.2	ND	2.3	0.9	ND	2.3	1.3	0.4	ND
Aug 26	Mokelumne River between Beaver and Hog Sloughs	black bullhead		5	82	0.8	3	ND	ND	ND	ND	ND	ND	0.3	ND	0.4	ND	ND	ND	ND	ND	ND	ND	ND
Sep 3	Sycamore Slough near Mokelumne River	black bullhead		5	81	0.6	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aug 18–25	White Slough downstream of Disappointment Slough	black bullhead		4	81	0.5	5	ND	ND	ND	ND	ND	ND	ND	ND	0.2	ND	ND	ND	ND	ND	ND	ND	ND
Sep 10	Port of Stockton near Mormon Slough	Corbicula		24	87	1.8	112	0.5	ND	0.8	0.4	0.3	0.8	2.2	1.0	2.3	ND	ND	ND	ND	ND	0.4	ND	ND
	Sacramento River at Rio Vista	Corbicula		68	90	1.1	17	ND	ND	ND	ND	ND	ND	0.6	ND	0.5	ND	ND	ND	ND	ND	ND	ND	ND

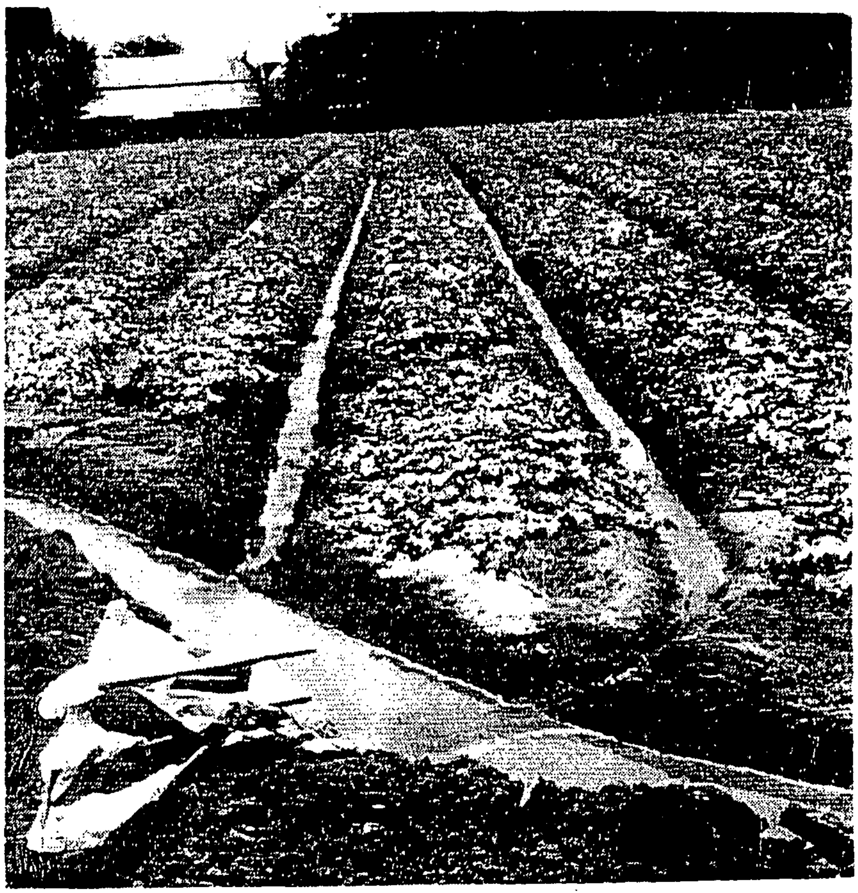
Table 4. PAH concentrations in clam tissue.
ng/g wet, surrogate corrected
ND= not detected or below reporting limit

Date (1998)	Location	Species	% moisture	naphthalene	2-methylnaphthalene	1-methylnaphthalene	biphenyl	2,6-dimethylnaphthalene	acenaphthylene	acenaphthene	2,3,5-trimethylnaphthalene	fluorene	phenanthrene	anthracene	1-methylphenanthrene	fluoranthene	pyrene	benz[a]anthracene	chrysene	benzo[b]fluoranthene	benzo[k]fluoranthene	benzo[e]pyrene	benzo[a]pyrene	perylene	indeno[1,2,3-cd]pyrene	dibenz[a,h]anthracene	benzo[ghi]perylene
Sep 10	Port of Stockton near Mormon Slough	Corbicula	87	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	59.6	58.4	ND	15.3	ND	ND	11.4	ND	ND	ND	ND	ND
	Sacramento River at Rio Vista	Corbicula	90	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Pesticides

ER copy

INSECTICIDE CONCENTRATIONS AND INVERTEBRATE BIOASSAY MORTALITY IN AGRICULTURAL RETURN WATER FROM THE SAN JOAQUIN BASIN



Central Valley Regional Water Quality Control Board
3443 Routier Rd, Suite A
Sacramento, CA, 95827-3098

December 1995

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL VALLEY REGION

Staff involved in the preparation of this report:

Christopher Foe

This document was prepared, in part, through agreement numbers 0-104-150-1 and 0-103-150-1 with the California State Water Resources Control Board.

FORWARD

This project has been funded by the United States Environmental Protection Agency using both Federal 201(G)(1)(B) and 205 (J) grant funds under Assistance Agreements C-9009532-90-0 and C-060000-29-0 to the State Water Resources Control Board, and by Agreement No. 0-104-150-1 in the amount of $99,190.00 and by Agreement No. 0-103-150-1 in the amount of $88,000.00 to perform toxicity and pesticide analyses in the San Joaquin River Basin. The contents of this document do not necessarily reflect the views and policies of the U.S. Environmental Protection Agency or the California State Water Resources Control Board, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

EXECUTIVE SUMMARY

A two and a half year bioassay study was undertaken between 1988 and 1990 to assess the quality of all the major types of water moving through the San Joaquin Basin employing the EPA three species freshwater test (Foe and Connor, 1991;EPA, 1985). The principal conclusion of the study was that there was a 43 mile reach of the San Joaquin River between the confluence of the Merced and Stanislaus Rivers which tested toxic about half the time to *Ceriodaphnia dubia*, the invertebrate component of the EPA three species bioassay test. Toxicity appeared to be caused by pesticides in storm and tailwater runoff from row and orchard crops. The chemicals were believed to be transported to the River by seventy-six agricultural drains which were estimated during the 1988-90 irrigation season to comprise 40 to 45 percent of the River's flow above the confluence of the Stanislaus River. Orestimba Creek and Turlock Irrigation District Lateral Number 5 (TID 5) were monitored as representative of west and eastside agriculturally dominated surface water inputs. The two tested toxic 42 and 75 percent of the time, respectively. Both years of study were during a drought and it is not known whether the findings are applicable to other water years.

The 1988-90 findings are of regulatory significance as the Central Valley Regional Water Quality Control Board's Basin Plan contains a narrative toxicity objective for this River stating that "all waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses...in aquatic life". In 1985 the U.S. EPA recommended that the EPA three species bioassay procedure be considered one method of assessing compliance with state narrative toxicity objectives (54FR23868). Board staff have concluded that the toxicity observed in water samples collected from the San Joaquin River Basin is a violation of the narrative toxicity objective (Foe and Connor, 1991).

The present bioassay study was designed to follow-up on the earlier San Joaquin results and had three objectives. The first was to determine whether the water quality of TID 5 and Orestimba Creek was representative of other east and westside agricultural drains and, if so, to ascertain the seasonal pattern of toxicity on either side of the River. The second was to determine whether the critical 43 mile reach of the San Joaquin which previously tested toxic about half the time would continue to do so during a second time period. The final objective was to identify, if possible, the primary agricultural chemicals responsible for invertebrate bioassay mortality and the farming practices that contribute to the offsite pesticide movement.

The major finding of the present study was that 22 percent of water samples[1] collected from the San Joaquin Basin in 1991-92 tested toxic[2] in *Ceriodaphnia* bioassays. Insecticide concentrations were sufficiently elevated in 70 percent of these to, at least partially, explain the observed mortality. Pesticide concentrations were also measured in 120 water samples[3] testing non-toxic. One or more insecticides were detected in 83 percent of these samples. However, only on one occasion was a pesticide measured in a non-toxic sample at a concentration known to cause mortality. Board staff again conclude that the presence of insecticides in surface water at concentrations that cause death to bioassay organisms is a violation of the Basin Plan narrative toxicity objective.

The first objective of the study was to evaluate the assumption that TID 5 and Orestimba Creek were representative of other east and westside inputs. Toxicity at Orestimba Creek was compared with that of three other westside inputs (Del Puerto Creek, Ingram-Hospital Creeks and the Spanish Grant Combined Drain) while bioassay mortality at TID 5 was compared with values obtained at TID 3 and 6. The frequency of toxicity in the four westside drains was similar. Likewise, mortality in the three eastside drains was the same. Based on the present survey, it appears that bioassay water quality from Orestimba Creek and TID 5 can be considered representative of other discharges from their respective sides of the River. Comparisons of mortality at Orestimba Creek demonstrate no changes in the frequency of toxicity between 1988-90 and 1991-92 (41.6 and 44.7 percent, respectively). However, the frequency of mortality at TID 5 decreased from 75.0 to 26.8 percent. This decline was statistically significant ($P<0.05$, Chi-Square). The cause of the decrease is not known. It may result from the increasing severity of the drought as the discharge from all TID drains decreased by 37 percent between 1988-90 and the present study[4]. The decrease in irrigation return flow is due, at least in part, to substantial decreases in tailwater volume. This is important as tailwater is assumed to be the major mechanism responsible for transporting pesticides off fields during the irrigation season. Decreases in tailwater runoff should result in lower pesticide concentrations in surface return flow.

The second objective of the study was to determine whether the San Joaquin River would continue to be toxic under conditions of different water availability in the Basin. The toxicity of water samples collected from the River at Laird Park was monitored weekly to evaluate

---

[1]121 of 559 samples.

[2]Toxicity was defined as a statistically ($P<0.05$) greater mortality rate than measured in the laboratory control.

[3]22 percent of all samples analyzed with bioassays.

[4]This drop is on top of an 85 percent decrease between 1984 (the last normal water year in the Basin) and 1988-90.

this objective. Less toxicity was noted in the present study (4.6 percent) than during 1988-90 (41.7 percent). The decrease was statistically significant (P<0.05, Chi-Square). The cause of the decline is not known but may be related to the drop in toxicity of eastside inputs. Decreases in toxicity between years strongly suggests that changing farm practices, probably induced by the drought, can significantly lower pesticide concentrations in the San Joaquin River.

The final objective of the study was to identify the principal crops, associated water management practices and pesticides responsible for inducing toxic conditions in the return flows. Analysis of the seasonal pattern of toxicity demonstrated that most of the mortality was restricted to two time periods: January-March and April-June. No evidence was obtained during either period indicating any illegal use. The data suggest that the recommended application instructions for some insecticides may be inadequate to protect aquatic life.

January-March is in the rainy season in California so most water in agriculturally dominated creeks and large constructed drains is assumed to be from subsurface seepage and from storm runoff. Half of all samples taken between January and March tested toxic. Toxicity was ascribed to off-target movement of insecticides from orchards, alfalfa, sugarbeets and truck farming. Toxicity data for each is reviewed below. The primary use of diazinon, chlorpyrifos and parathion in the San Joaquin basin between December and February is as a dormant spray on stonefruit[5] and apple, pear, and almond orchards for boring insect control. Dormant spray insecticides were detected 182 times in surface water between December and March of 1991 and 1992. Sixty-seven of the detections were at concentrations toxic to *Ceriodaphnia*.

A major use of diazinon, malathion and chlorpyrifos in March and April is on alfalfa for aphid and weevil control. Chlorpyrifos is also used at this time on sugarbeets for worm control. The three insecticides were detected 106 times in March and April of 1991 and 1992. Twenty-five of these were at concentrations toxic to *Ceriodaphnia*.

Truck farming is also an emerging industry on the west side of the River. The principal winter use of methomyl is on cauliflower while the only reported winter use of fonofos is on broccoli. Methomyl and fonofos were detected five times in December and January in Ingram-Hospital Creek. Three measurements were at concentrations toxic to *Ceriodaphnia*.

April is the beginning of the irrigation season. In both years of the study, the last precipitation fell by mid-April. Most water in agriculturally dominated creeks and constructed drains after the end of March is assumed to be irrigation return flow with tailwater making up the largest proportion of the flow. Tailwater is believed to be the

---

[5]Apricots, cherries, nectarines, peaches, plums and prunes.

primary vehicle responsible for transporting pesticides into surface water. Slightly less than half of the water samples (47%) collected from the westside of the Valley between April and June tested toxic. This is in contrast to the eastside where the frequency of toxicity was only 17%. The difference was significant (Chi-Squared, $P<0.05$) and is believed to result from differences in cropping patterns.

Four insecticides--chlorpyrifos, diazinon, fonofos and carbaryl--appear responsible for most of the toxicity. The toxicity of the four are summarized below. Chlorpyrifos is a wide spectrum insecticide used extensively during the irrigation season so the precise crops from which the chemicals originated are not known. Chlorpyrifos was detected 85 times between April and June of 1991 and 1992. Eighteen of these were at concentrations toxic to *Ceriodaphnia*. Major uses of chlorpyrifos are on walnuts and almonds, minor uses are on apples and corn. Diazinon is another commonly used agricultural insecticide. It was detected 81 times between April and June of 1991 and 1992. Four of these were at concentrations toxic to *Ceriodaphnia*. Diazinon runoff originates predominately from the westside of the River. The principal seasonal westside use is on melons, tomatoes and apricots. Unlike chloryrifos and diazinon, fonofos is broadcast and incorporated into the soil by tillage prior to planting. The chemical was only observed in water samples collected from the westside. Fonofos was measured 24 times between April and June of 1991 and 1992. Four of these were at concentrations toxic to *Ceriodaphnia*. The major use of fonofos in western Stanislaus County is on beans and tomatoes for wireworm control. The fourth insecticide, carbaryl, is a common foliar spray and was detected five times in May in water samples collected from the westside. One of these was at a concentration toxic to *Ceriodaphnia*. Common westside uses during the early irrigation season are on beans and tomatoes.

Overall, thirteen pesticides were detected in the study: diazinon, chlorpyrifos, ethyl parathion, fonofos, malathion, carbaryl, methomyl, DEF, ethion, methyl parathion, isofenfos, disyston, and carbofuran. Twelve of these are insecticides, one (DEF) is an herbicide. The Central Valley Regional Water Quality Control Plan has a conditional prohibition of discharge[6] for irrigation return flows containing carbofuran, malathion, and methyl parathion. Basin Plan performance goals for carbofuran and malathion were exceeded in 1 and 6 samples, respectively. No exceedances were noted for methyl parathion. Numerical performance goals are not available for any of the other compounds. However, of these diazinon and chlorpyrifos appear to pose the greatest threat to aquatic life as the two were detected 328 times in the year and a half study. Over half of these measurements were at concentrations greater than the recommended draft California Department of Fish and Game Hazard Assessment criteria to protect freshwater aquatic life of 0.04 and 0.015 ppb,

---

[6]The prohibition of discharge is lifted if the discharger is following management practices approved by the Board. To receive approval, the management practices must be expected to meet performance goals set by the Board.

respectively (Menconi and Cox, 1994; Menconi and Paul, 1994). Ninety measurements were at concentrations toxic to *Ceriodaphnia.* Finally, almost half of all water samples analyzed during this study for pesticides (toxic and non-toxic) contained both chemicals and the toxicity of the two are additive (Huang et al., 1994). This suggests that future water quality objectives for the two insecticides should consider additivity.

INTRODUCTION

The San Joaquin River Basin is located in the southern half of the great Central Valley of California. It is known as the bread basket of the nation with an estimated two million acres of land under irrigated agriculture. Agriculture is also the main water user in the Valley. The San Joaquin River carries all water, including agricultural return flow, out of the Basin and into the Sacramento-San Joaquin Delta Estuary. The River is the second largest tributary of the Estuary with an unimpaired flow of 3.4 to 7.4 million acre-feet per year depending upon annual precipitation (Kratzer *et al.*, 1987).

A two and a half year bioassay study was undertaken between 1988 and 1990 to assess the quality of all the major types of water moving through the San Joaquin River (Foe and Connor, 1991). The study employed the EPA three species freshwater test (EPA, 1985) to assess potential water quality threats to the main stem of the River from mining and silviculture in the mountains, from municipal and industrial discharges throughout the northern half of the Valley and from trace elements, fertilizers, and pesticides in agricultural return flow from the Valley floor. The study was conducted during a drought period and it is not known whether the findings are applicable to other hydrologic conditions.

The principal conclusion of the study was that there was a 43-mile reach of the San Joaquin River between the confluence of the Merced and Stanislaus Rivers which tested toxic about half the time to *Ceriodaphnia dubia*, the invertebrate component of the EPA three species bioassay test. It was assumed that the decrease in toxicity below the confluence of the Stanislaus was because the Stanislaus's flow was always of sufficient quality and magnitude to dilute contaminant concentrations in the San Joaquin River to non-toxic levels for *Ceriodaphnia*.

Invertebrate toxicity in the San Joaquin River appeared to be caused by pesticides which were carried in storm and tailwater runoff from row and orchard crops. The chemicals seemed to be transported to the River by seventy-six agricultural drains located along the River (James *et al.*, 1989). These drains were estimated during the 1988-90 irrigation season to comprise 40 to 45 percent of river flow above the confluence of the Stanislaus. Orestimba Creek and Turlock Irrigation District Lateral Number 5 (TID 5) were monitored as representative of west and eastside agriculturally dominated surface water inputs. The two tested toxic 42 and 75 percent of the time, respectively. On five occasions toxic water samples were submitted for chemical analysis. Diazinon, parathion, carbaryl, and carbofuran were measured in both drain and River water at concentrations in excess of EPA recommended criteria to protect freshwater aquatic life or of concentrations reported in the literature to be toxic to sensitive invertebrates including *Ceriodaphnia*.

The conclusions of the San Joaquin River bioassay study are of regulatory significance as the Water Quality Control Plan for this River contains a narrative toxicity objective stating that "all waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses...in aquatic life". In 1985 the U.S. EPA recommended that the EPA three species bioassay procedure be considered one method of assessing compliance with State narrative toxicity objectives (54FR23868). Board staff have concluded that the toxicity observed in water samples collected from the San Joaquin River Basin is a violation of the narrative toxicity objective (Foe and Connor, 1991).

The present study was designed to follow-up on the earlier San Joaquin River bioassay results and had three main objectives. The first was to determine whether the water quality of TID 5 and Orestimba Creek was representative of other east and westside agricultural drains and, if so, what was the seasonal pattern of toxicity on either side of the River. The second was to identify, if possible, the primary agricultural chemicals responsible for invertebrate bioassay mortality and the water management practices which contributed to the off-target movement. The final objective was to determine whether the critical 43-mile reach of the San Joaquin River which previously tested toxic about half the time, would continue to do so.

BACKGROUND

Water Year

The study was conducted during an unusually dry period. The San Joaquin River Water Quality Control Plan (1975) defines water years based upon each year's percentage of the average annual flow during the period of record (1906-94). Both years of this study were classified as critically dry. They were preceded by three similar critically dry water years. The five year period is the driest on record in the Basin.

Seasonal and annual unimpaired flows for the San Joaquin River Basin for a wet (1983), normal (1984), dry (1985), and both critically dry years of the present study are compared in Appendix A. Total irrigation season unimpaired flows in 1991-92[1] were about 95% less than in 1983. Interestingly, the San Joaquin input-output model (Kratzer *et al.*, 1987) predicts that the proportion of River volume composed of irrigation return water should increase during dry years. For example, between 1983 and 1991-92 the model predicts an increase from 2.5 to 32 percent. The increase is caused by the much larger relative decrease in flow from the three eastside tributary Rivers[2] than from irrigation return flow. Some caution must be used in interpreting these numbers, however, as no estimate was made of drought induced changes in irrigation efficiency[3].

Precipitation

Rainfall is summarized from the Stockton Weather Service Office in Table 1. Also included are sampling dates. As is typical for the Basin, most rain fell between November and March. No month received an unusually large amount of rain, most months were very dry. The monitoring schedule was arranged with the bioassay laboratory about a month in advance of sampling, so the selection of monitoring dates was independent of rainfall.

Hydrology of agriculturally dominated creeks and constructed drains

The agricultural year has been divided into four seasons to help illustrate general changes in the sources of water in agriculturally dominated creeks and constructed drains. The patterns described are obviously very general and change from year to year based on precipitation, temperature and crop rotation. This information is used later as the rationale for dividing the bioassay data into the same time intervals to help ascertain whether changes

[1]From 10,572,590 to 569,321 acre-feet per year.

[2]The Merced, Tuolumne and Stanislaus Rivers.

[3]The Input-Output model assumes that 30% of the irrigation supply water is returned to the River as tailwater regardless of the amount initially available (Kratzer *et al.*, 1987).

in water sources can help explain seasonal changes in the performance of the bioassay organisms.

Flows during the first time period, January-March, are primarily the result of subsurface seepage and overland runoff from large storms. Little to no agricultural water use occurs. A possible exception is that during dry years some pre-irrigation of stonefruit may occur prior to bloom. The second time period, April-June, is characterized by a decreasing probability of rain and an increasing incidence of tailwater[4] runoff. Extensive pre-irrigation of row and field crops occurs between mid March and early May to help fill the soil profile with moisture and provide additional water for later crop use. The first irrigation of crops typically occurs between late April and early June. Therefore, tailwater is the primary source of most of the flow during the second time period. Some operational spill water[5] may also be present. The third period, June-September, is a season of intense irrigation and no rain. A large portion of the return flow is pumped out and reused on agriculture. Finally, October to December is a time of little irrigation but increasing probability of rain runoff. Flows tend to be small, erratic and controlled by subsurface seepage, periodic irrigation and rainfall.

Cropping Patterns

The study area was roughly located between Highway 99 to the east, Interstate 5 to the west, Airport Way (County Road J3) to the north, and the confluence of Salt Slough to the south (figure 1). The area has about 228,000 acres in agricultural production (Bailey *et al.*, 1989). One hundred and forty-nine thousand acres are located on the east and 79,000 on the westside of the River. Cropping patterns in 1991-92 are provided for representative east and westside irrigation districts in Table 2. The westside was dominated by a fairly even mix of field, vegetable and orchard crops. Most field and vegetable crops were grown for human consumption--beans, tomatoes, and melons. An exception was the 4,500 acres of alfalfa. A small westside winter truck farming industry of spinach, broccoli, cauliflower, celery and peas was also present. Principal orchard products were apricots and smaller stands of almonds and walnuts. In contrast, the eastside was composed mostly of field and orchard crops. The field crops were grown primarily to support the large local dairy industry--field corn, oats, alfalfa, and pasture. The total number of acres of orchards on the eastside was about twice that of the westside. Principal tree crops were almonds, peaches, and walnuts.

---

[4]Water from irrigated orchard, row and field crops.

[5]Irrigation supply water discharged as a result of canal operations.

METHOD AND MATERIALS

Bioassay and water collection procedures

The invertebrate component of the EPA three species test was employed to ascertain whether dissolved contaminants were present at concentrations causing mortality within four to seven days. Water samples were collected as one time subsurface grabs in amber glass containers[6] and held in the laboratory at <4.0°C. until use. All bioassays were started within 24 hours of water collection. The tests were conducted at Sierra Foothill Laboratory[7] employing, with two exceptions, the procedures described in EPA (1989). The first exception was that dissolved oxygen, pH, and electrical conductivity were only measured at the beginning and end of the test instead of daily. These parameters were monitored to insure that all were within limits known not to cause mortality. The same parameters were remeasured at the end of any 24-hour period when greater than 50 percent mortality occurred in a treatment. Ammonia was only measured at the start of a test[8]. No hardness or alkalinity measurements were made. The second exception to the EPA method was that when a sample had an electrical conductivity greater than 2,000 μmho/cm, it was diluted back to 2,000 μmho/cm with glass distilled laboratory water[9]. No dilution over 50 percent was made. If a sample required dilution, then a dilution control was also run. The dilution control was prepared by amending glass distilled laboratory water with salts to an EPA moderately hard conductivity (U.S. EPA, 1985a). Ninety samples, 16 percent of the total, were diluted. What impact dilution may have had on reducing contaminant concentrations and toxicity is not known.

Dissolved oxygen, electrical conductivity and pH were measured with a calibrated Hach portable 16046 meter, an Amber Science 604 meter, and an Orion 611 meter with a Ross combination electrode. Ammonia was measured with a calibrated Orion 9512 ion selective electrode (EPA method 350.3). The laboratory distilled water was collected from a Synbron Barnstead FI-instream glass still. Calaveras Spring water was used as the laboratory control water. Finally, bioassay organisms were obtained from an in-house culture and were less than 24 hours old at the start of the test.

---

[6]Environmental Sampling Supply QC glass sampling bottles.

[7]Sierra Foothill Laboratory, 823 South Highway 49, P.O. Box 1268, Jackson CA 95642.

[8]No ammonia measurements were made on 16, 23, and 30 March and 6 April, 1992, as the probe in use at the laboratory was found to be defective and a new one was on order.

[9]Electrical conductivity control experiments demonstrate that Ceriodaphnia bioassay performance is independent of the addition of seawater to an EC of 2,000 μmho/cm (Foe, 1988).

Water quality data, including the amount of all dilutions, is summarized by survey date in Appendix B. All parameters measured, with the occasional exception of ammonia, appear to have been within limits known to support aquatic life. The possible role that ammonia may have played in contributing to the *Ceriodaphnia* toxicity is discussed later.

Bioassay Quality Control Testing was conducted to assess bioassay precision both within and between tests. Within test precision was determined on 45 occasions by collecting a duplicate water sample from a randomly selected site and submitting it to the laboratory under the name of a second location which was scheduled for sampling but was not visited. The difference in mortality between the two sets of samples was compared.

Between test precision was ascertained monthly by determining the 96 hour LC_{50} concentration of a sodium chloride reference toxicant. Monthly variations in LC_{50} concentrations were analyzed by procedures recommended in U.S. EPA (1989).

Definition of bioassay toxicity A water sample was classified as toxic if *Ceriodaphnia* mortality was statistically greater ($P<0.05$, Fisher exact test) than the laboratory and, if applicable, the dilution control treatment[10].

Pesticide analysis

Additional water was collected from all sites and stored in amber glass containers in the dark at <4.0°C for possible pesticide analysis. When the bioassay results suggested the presence of toxicants, then samples were analyzed for total recoverable organophosphate and carbamate pesticides at the U.S. Geological Survey Laboratory at Arvada, Colorado. Both analyses were liquid-liquid extractions followed by a gas chromatograph determination with flame-photometric detectors for the organophosphates (Wershaw et al. 1987). For carbamates the extract was concentrated and analyzed by high performance liquid chromatography using a C_{18} reverse phase column and a dual channel variable wavelength ultraviolet detector. Compounds in each scan, reporting limits, and U.S. Geological Survey estimates of accuracy and precision are listed in Tables 3 and 4.

On average, field samples were held 7 to 12 days before extraction. This is longer than the seven days recommended by U.S. EPA (1994). The excessively long holding time resulted from the fact that the bioassay screening took 4-7 days, express mailing samples to Arvada

---

[10]If no mortality occurred in the controls, then a 40 percent or higher death rate was statistically significant. This is much greater than the 5 to 10 percent death rate recommended as ecologically safe by the Netherlands Working Group on Statistics and Ecotoxicology (Straalen *et al.*, 1994).

Colorado an additional 2 days and extraction a further 2 days. It is not known how exceeding the recommended holding time may have affected the analytical results.

One hundred and thirty-four samples[11] which tested non-toxic in bioassays were also submitted for pesticide analysis. This analysis was done to help ascertain both the baseline pesticide concentration present in ambient waters and also the range of pesticide concentrations which did not induce a bioassay response. Forty-two of these samples were analyzed for both carbamate and organophosphate pesticides while another ninety-two were only analyzed for organophosphorus pesticides. The emphasis was placed on the organophosphate scan as these insecticides appeared to be responsible for most of the toxicity observed in field samples.

Finally, a quality control program was undertaken to ascertain the accuracy of the pesticide data. Seven samples were spiked with selected insecticides by the California Department of Pesticide Regulation and submitted for analysis to both their Sacramento laboratory and to the U.S. Geological Survey Central Laboratory in Arvada, Colorado. In addition, 34 field samples from two Lagrangian special studies (Ross, 1991; 1992b) were collected and split by the Department of Pesticide Regulation for organophosphate pesticide analysis at both their Sacramento Laboratory and at the U.S. Geological Survey Central Laboratory. Finally, six travel blanks were submitted during the course of the study for both organophosphate and carbamate analysis.

Sampling Locations

The lower San Joaquin River was sampled at 13 sites (Figure 1). The location of each is described in Appendix C. Sites were chosen to collect information about all of the principal types of water being discharged to the River throughout an annual hydrologic cycle. All sources were monitored as close to their confluence with the San Joaquin River as possible.

There are 4 main sources of River water: eastside tributary Rivers, eastside constructed agricultural drains, Salt and Mud Sloughs, and westside agriculturally dominated creeks and constructed drains. Seasonal and annual unimpaired flows for each are provided in Appendix A. The three eastside tributary Rivers contributed about 58 percent of the annual unimpaired flow of the River. Each was monitored regularly. Turlock Irrigation District (TID) Lateral No. 6, 5 and 3 were sampled as representative of eastside agricultural drains while Orestimba, Del Puerto, and Ingram-Hospital Creeks and the Spanish Grant Combined Drain were monitored as representative of a combination of westside agriculturally dominated creeks and constructed drains. These seven sites were estimated in an earlier critically-dry

[11]35 percent of all samples submitted for pesticide analysis.

water year (1981) to comprise about 56% of the total surface agricultural return flow from the study area (Kratzer *et al.*, 1987). Salt Slough was sampled about half the time as representative of inputs from Salt and Mud Sloughs. These two drainages were estimated to provide between 10 and 14 percent of River volume during the study. The Slough was not sampled between 25 February and 2 July, 1991, and again between 9 October and 24 February, 1992, because of lack of money. Three San Joaquin River sites were also monitored regularly. The San Joaquin River at Hills Ferry Road, the most upstream site, is believed to primarily reflect the water quality of its principal source, Salt Slough. Laird Park is located near the midpoint of the study area and was monitored as representative of the critical 43-mile reach of River which tested toxic about half the time between 1988 and 1990. Finally, the San Joaquin River at Airport Way is, by definition, the legal boundary of the Sacramento-San Joaquin Delta Estuary. Water quality at this location is thought to be indicative of what the Basin exports to the Estuary.

RESULTS

BIOASSAYS

Test Acceptability U.S. EPA (1989, 1991a) recommends that *Ceriodaphnia* bioassay results be considered acceptable if control survival is at least 90 percent in four-day and 80 percent in seven-day tests. Control survival met these criteria on all dates[12] except the 20 January 1992 survey and the 27 January-3 February 1992 Lagrangian special study. On both occasions high control mortality was traced to the use of a new brand of plastic wrap used to cover the top of the test containers. Bioassay results with high control mortality are listed in the summary appendices but were not used in any subsequent analysis.

On four occasions[13] there was excessive mortality in the glass distilled dilution control water. Glass distilled water was used to dilute samples with electrical conductivities in excess of 2,000 μmho/cm. However, no toxicity was observed in any of the diluted field samples, suggesting that the glass distilled water did not contribute measurable toxicity to any of them. All bioassay data from these dilutions have been used in the subsequent analysis.

Within and between test precision Within and between survey test precision was estimated to help establish the repeatability of the bioassay results. On forty-five occasions a duplicate blind sample was submitted to Sierra Foothill Laboratory to ascertain within-test variability. The results of thirty-nine of these were from four day and six were from 7 day tests (Table 5). The average percent difference in *Ceriodaphnia* survival was 3.8 and 1.7 percent, respectively. The differences were not significant (P>0.05, Mann-Whitney test) so the two data sets have been combined. The overall mean percent difference in survival was 3.6 percent with a coefficient of variation[14] of 167 percent.

No other within-test precision estimate of *Ceriodaphnia* mortality was found in the literature. Therefore, the mortality precision estimate was compared with a precision estimate of the initial electrical conductivity of the same set of duplicate blind samples (Table 5). This comparison was made as electrical conductivity is a common and well accepted water quality measurement. The average percent difference in electrical conductivity was 2.7 percent with a coefficient of variation of 151 percent. The precision of the electrical conductivity and mortality measurements were similar (T-test, P> 0.05).

---

[12] 49 surveys

[13] 18 April, 1991, and 20 January, 20 April and 6 June 1992.

[14] Standard deviation divided by the mean and multiplied by 100.

Between test variability was assessed monthly for the sixteen month study with 96-hour sodium chloride LC_{50} reference toxicant testing. U.S.EPA (1989) recommends reference toxicant testing to ascertain whether changes in animal sensitivity occurred during the test period. Of particular interest are the detection of either outlier values located beyond the 95 percent confidence limits of the long-term mean or of general trends of changing animal sensitivity. Neither were noted in the control chart (Figure 2).

In conclusion, all quality control measurements appear acceptable and suggest that the bioassay data are reliable.

SAN JOAQUIN BASIN Five hundred and fifty-nine *Ceriodaphnia* toxicity tests were conducted in the San Joaquin area between February 1991 and June 1992 (Table 6 and Appendix D). One hundred and twenty-one samples (22 percent) tested toxic. Eighteen were collected from Rivers and one hundred and three were from agriculturally dominated creeks and constructed drains. Toxicity was observed in both creeks and drains during every month of the year except August. Below, the creek-drain, tributary River and main stem San Joaquin River bioassay data have been separated and each analyzed for inter-annual, site specific and seasonal differences.

Agriculturally dominated creeks and constructed drains--Inter-annual The annual frequency of toxicity in each agriculturally dominated creek and constructed drain was calculated to ascertain whether inter-annual differences existed. No difference was detected ($P>0.05$, Chi-Squared Heterogeneity test). Therefore, the 1991 and 1992 data for each drain were combined.

Site specific Next, the frequency of toxicity among east (TID 3, 5, and 6) and westside (Orestimba, Del Puerto, Ingram-Hospital and Spanish Grant Combined Drain) agricultural inputs was compared to ascertain whether toxicity was similar in all water courses on the same side of the River. Again, no difference was observed ($P<0.05$, Chi-Squared Heterogeneity test). Therefore, the data were combined into a single set of east and westside values.

Seasonal Next, the seasonal frequency of toxicity in all inputs was calculated (Table 7). The resulting quarterly data were analyzed to ascertain whether there were seasonal differences. The frequency of toxicity was found to be greater during the first six months of the year ($P<0.001$, three dimensional contingency table with subsequent subdivision of the table; Zar, 1984).

River bank Finally, the frequency of toxicity on either side of the River was compared by quarter (Table 8). No difference was noted except for the time period of April to June when westside inputs had a higher frequency of toxicity (47.1%) than eastside ones (17.0%; chi-square P<0.001).

Tributary Rivers

The Merced, Tuolumne, and Stanislaus River data also were analyzed to ascertain whether inter-annual, site specific or seasonal differences existed in the frequency of *Ceriodaphnia* toxicity. No temporal or spatial difference was noted (P>0.05, Chi-Squared). The average frequency of toxicity in water samples collected from the three eastside Rivers during the sixteen month study was 9.5 percent.

San Joaquin River

A similar analysis was also conducted for the three San Joaquin River sites. Again, no temporal or spatial difference was detected (P>0.05, Chi-Squared). The average incidence of toxicity in the River was 4.3 percent.

PESTICIDES

Quality Control

A quality control program was conducted to assess the accuracy of the U.S Geological Survey pesticide concentration data. The program consisted of the periodic submission of blind spikes, split field samples and blind travel blanks. Spiked samples were prepared by the Department of Pesticide Regulation and were submitted to both the Sacramento Laboratory of the Department of Pesticide Regulation and to the U.S. Geological Survey (Table 9). The spiking program emphasized the organophosphate pesticides most commonly observed in field samples. Average percent organophosphate recovery by the U.S. Geological Survey and by the Department of Pesticide Regulation was 79 and 101 percent, respectively. The pesticide recovery rate reported by the Survey was significantly lower than both the nominal spiked concentrations and the values reported by the Department of Pesticide Regulation (P<0.05, sign test). Particularly noteworthy was the chlorpyrifos values which averaged 58 percent of spiked concentrations.

Thirty-four duplicate field samples were collected by the Department of Pesticide Regulation during two Lagrangian special studies and split between the Department's laboratory and the U.S. Geological Survey (Tables 10 and 11). All carbamate pesticides detected by the Department of Pesticide Regulation were below Survey reporting limits. Conversely, some organophosphate insecticides were observed by the Survey but were below Department of Pesticide Regulation reporting limits. Only on four occasions (8% of the time) was a compound (always diazinon) observed by one laboratory (always the Survey) at concentrations above the other's reporting limit but not confirmed by the second facility. Diazinon and chlorpyrifos were the only organophosphate insecticides detected by both laboratories and were observed 3 and 15 times, respectively. There did not appear to be a laboratory bias in the chlorpyrifos data for either lagrangian run or for diazinon for the 23-26 April 1991 Lagrangian survey. However, diazinon concentrations reported by the Survey averaged 46 percent lower than Department values for the 27-31 January 1991 Lagrangian survey. This difference was significant (paired T-test, $P<0.01$) but appears similar to the recovery rate reported by the U.S. Geological Survey for the method (Table 3).

Seven blind travel blanks were submitted to the U.S. Geological Survey during the San Joaquin study. No pesticides were detected.

In conclusion, both the U.S. Geological Survey and Department of Pesticide Regulation had a high rate of pesticide detection when compounds were present at concentrations above their reporting limits. However, reported U.S. Geological Survey organophosphate concentrations were somewhat lower than Department of Pesticide Regulation ones. No correction has been made to the pesticide data to reflect the fact that the U.S. Geological Survey data may have under reported actual field pesticide concentrations.

San Joaquin Basin

Five hundred and six pesticide detections were noted in four hundred and thirty-nine water samples[15] (Appendix D). Ninety-eight percent of these were organophosphate insecticides. The smaller frequency of carbamate detections was thought, at least in part, to result from the fact that the carbamate reporting limit was 50 times higher than the organophosphate one. Both the U.S. Geological Survey and the Department of Pesticide Regulation have monitoring programs in the San Joaquin Basin with lower carbamate reporting limits and both have observed a higher incidence of carbamate pesticides than this study (MacCoy *et al*., 1995; Ross, 1991; 1992a,b; 1993a,b,c).

Thirteen pesticides were detected: diazinon, chlorpyrifos, ethyl parathion, fonofos, malathion, carbaryl, methomyl, DEF, ethion, methyl parathion, isofenfos, disyston, and carbofuran (Table 12). Twelve of these are insecticides, one (DEF) an herbicide. The most common insecticides were chlorpyrifos, diazinon, parathion and fonofos. At least one of the four was present in 90 percent of all (toxic or non toxic) samples analyzed.

Below, the pesticide data have been analyzed to help ascertain the insecticides most likely responsible for causing bioassay mortality and to establish baseline concentrations in the San Joaquin River and its tributaries.

[15] 272 analysis for organophosphates and 167 for carbamates.

Probable cause of toxicity--Pesticides Water samples testing toxic were analyzed for organophosphate and carbamate pesticides to ascertain whether any chemicals were present at concentrations likely to cause mortality. Measured insecticide concentrations were divided by their reported 96 hour *Ceriodaphnia* LC_{50} value[16] (Table 13) to determine which were at biologically significant levels. The resulting value is defined as a pesticide LC_{50} unit. All values above half a unit are reported in Appendix D and Table 14. An effort was made in Table 13 to collect all reported toxicity values for each chemical. However, a high value was deliberately chosen for the pesticide LC_{50} unit determination, when multiple values were available, to be conservative about the possible cause of mortality. Finally, in samples where multiple pesticides were detected, LC_{50} units were added to provide a single estimate of the amount of available insecticide toxicity.

The addition assumes that the toxicity of organophosphate and carbamate insecticides are additive when present as mixtures. Toxicants that work on the same organ system are generally assumed to be additive (Sittig, 1981). Both classes of insecticide are acetylcholinesterase inhibitors, central nervous system toxins. Much experimental data has been collected with mammals which demonstrate additivity for mixtures of the two classes of insecticide (Hayes and Laws, 1991). However, less information is available for aquatic invertebrates. Huang *et al.,* (1994) report that the acute toxicity of mixtures of the organophosphate insecticides diazinon-chlorpyrifos-methidathion and malathion-methyl parathion-carbofuran[17] have an additive type of toxicity in tests with *Neomysis mercedis.* The acute toxicity of diazinon and chlorpyrifos is reported to be additive in *Ceriodaphnia* (personal communication, Miller). Finally, Norberg-King *et al.,* (1991) have demonstrated that the chronic toxicity of malathion and carbofuran are additive in tests with *Ceriodaphnia.* More aquatic invertebrate information is needed to verify that the toxicity of insecticide mixtures are additive, particularly at chronic levels.

One hundred and twenty-one samples tested toxic to *Ceriodaphnia*. Seven of these were not analyzed for pesticides. Seventy percent of the remaining samples contained insecticides at concentrations above half an LC_{50} unit (Table 14 and Appendix D). Pesticides of concern include chlorpyrifos, parathion, diazinon, fonofos, methomyl and carbaryl. Of these, diazinon, chlorpyrifos, and parathion account for over 90 percent of all detections exceeding half an LC_{50} unit. Obviously, the above analysis does not preclude that other unmeasured contaminants might not also have been present in some samples and have contributed to the overall toxicity.

[16]Concentration that kills 50 percent of test organisms in 96 hours in laboratory water.

[17]The latter is a carbamate insecticide

One hundred and twenty non-toxic samples were also analyzed for organophosphate insecticides (Table 15). One hundred and fifty-one insecticide detections were reported. However, only on one occasion was a chemical measured at a concentration above half an LC_{50} unit and no toxicity observed. Chlorpyrifos was reported at Laird Park on 23 April (Lagrangian study) at 0.07 ppb[18]. No *Ceriodaphnia* mortality was observed in the sample within 4 days (Table 10).

An advantage of an LC_{50} type analysis is that it can help identify bioassay samples where there appears to be an insufficient amount of contamination to explain the observed mortality. Two criteria were employed to help identify such situations. The first was when a sample tested toxic but contained less than half an LC_{50} unit of either pesticide or ammonia. The second was when complete mortality occurred within 48 hours but less than one LC_{50} unit[19] of toxicant was measured. Thirty-nine samples both this criteria (Table 16).

There are at least three possible explanations for the discrepency between the observed toxicity and the lack of contaminants. First, animal sensitivity is known to vary both between laboratories and at the same facility over time. As previously noted, this study deliberately selected a high *Ceriodaphnia* LC_{50} insecticide value (Table 13), when a range of concentrations were available, to provide a conservative estimate of the cause of death. On occasion our test organisms may have been more sensitive than the LC_{50} analysis would predict. The use of a lower LC_{50} concentration, particularily for chlorpyrifos and diazinon, could help account for some additional unexplained mortality. Second, the U.S. Geological Survey pesticide spike-recovery data (Table 3) suggested that organophosphorus insecticide concentrations may be under-reported by up to 30 percent. Errors of this magnitude appear important for chemicals like diazinon and chlorpyrifos which often appear in the data set at values close to but below the threshold known to induce toxicity. The third possibility is that the toxicity may have been caused by other unmeasured contaminant(s), including other insecticide(s). Four hundred and twenty-eight different pesticides with a combined active ingredient weight of about 28 million pounds were applied in Merced, Stanislaus and San Joaquin Counties in 1990 (California Department of Pesticide Regulation, 1990). This study only screened water samples for 20 of these compounds[20] although traces of all are possible in the samples.

---

[18]Department of Pesticide Regulation measured chlorpyrifos in a split of this sample at 0.05 ppb. The 96 hr LC_{50} was assumed to be 0.1 ppb (Table 13).

[19]Enough contaminant to kill up to half the test animals in 96 hours.

[20]By weight the twenty account for less than 4 percent of all the active ingredients applied in the three Counties.

An analysis of the location and timing of the unexplained incidents of toxicity may be useful in identifying situations when other important contaminants could be entering the watershed (Table 16). Twenty-seven such samples were collected from agricultural drains and 12 from Rivers and Salt Slough. Interestingly, all but one of the unexplained agricultural drain toxicity events fell into two time periods. The first time interval was between February and March of 1992 when there were 12 unexplained events. Half of these occurred on the East and the other half on the westside of the River. The second time period was between April and June of both 1991 and 1992 when there were 14 unexplained events. All but one of these occurred on the westside of the River. Similarly, all of the unexplained River toxicity also occurred between February and June. It is possible, therefore, that unidentified contaminant(s) present in agricultural return flow may also be causing toxicity in the River. Future monitoring and toxicity identification evaluation work should focus on this critical time period.

Ammonia

In a similar fashion to pesticides, un-ionized ammonia LC_{50} units were also calculated and are provided in Appendix D. Un-ionized ammonia concentration[21] is a function of total ammonia, pH and temperature and was estimated according to U.S. EPA procedures (1985c). Ammonia and pesticide toxicities were not assumed to be additive.

Ammonia was detected in 40 samples (Appendices B and D). Twenty-one of these detections were at concentrations above half an LC_{50} unit. Fourteen of the twenty-one samples tested toxic (Table 17). However, seven of these were also contaminated with high pesticide levels so both ammonia and pesticides are assumed to contribute to the toxicity. All but one of these samples[22] was collected from the eastside between September and April. Most were taken from TID 5. High ammonia levels have previously been observed in water samples collected from this drain in winter (Foe and Connor, 1991). The primary source of the ammonia is believed to be from the City of Turlock's publically-owned sewage treatment plant and from surrounding dairies. The City of Turlock has recently submitted a time schedule to the Regional Board for removal of toxic concentrations of ammonia from their effluent (City of Turlock letter of 1 November, 1994).

Perplexingly, seven water samples were calculated to contain more than half an LC_{50} unit of un-ionized ammonia but did not test toxic (Table 18). The discrepancy does not appear to

[21]Calculated using the highest pH recorded in the bioassay (Appendix B) and a temperature of 25°C.

[22]On 3 April 1992 elevated levels of ammonia was measured in a water sample collected from Del Puerto Creek.

result from poor ammonia analysis as all analyses were made with a calibrated probe and there was good agreement in the ammonia concentration of all duplicate blind field samples which contained measurable amounts of ammonia[23]. The disparity may have arisen because it is the concentration of un-ionized ammonia which is toxic. The fraction of the total ammonia which is in an un-ionized state in any sample is a function of water pH. Increasing pH results in an increasing proportion of un-ionized ammonia. EPA does not recommend that pH be controlled during a bioassay. In this study, pH typically varied by up to 1.0-1.5 units during the 24 hours between water changes. Hydrogen ion changes of this magnitude cause a 10-15 fold increase in un-ionized ammonia concentrations. Un-ionized ammonia concentration was calculated from the highest pH value measured during the 4 to 7 day test. Ammonia is a fairly fast acting toxicant, however, the calculated un-ionized ammonia concentration may not always have been present in the bioassay water for sufficient time to cause the predicted mortality. In the future, it is recommended that toxicity identification evaluations be conducted on samples with high ammonia concentrations to more precisely ascertain the amount of *Ceriodaphnia* mortality contributed by the un-ionized ammonia fraction.

In conclusion, ammonia may have contributed to *Ceriodaphnia* mortality on 14 occasions (12 percent of all toxic samples). However, unlike insecticides, there does not appear to be a good correlation between the presence and absence of toxic concentrations of ammonia and the presence and absence of *Ceriodaphnia* mortality.

<u>Baseline Pesticide Concentrations in San Joaquin River</u> Pesticide samples were collected weekly from the San Joaquin River at Laird Park between September 1991 and June 1992 to ascertain baseline concentrations (Table 19). Thirty-three samples were analyzed for organophosphate and carbamate pesticides over the ten month period. All but one sample had a detectable amount of pesticide. Over fifty percent of the samples were contaminated with two or more compounds. Chlorpyrifos and diazinon were most common and were present in 60 and 85 percent of the samples at mean concentrations of 0.03 and 0.01 ppb, respectively. Trace amounts of parathion, fonofos and malathion also were occasionally observed. There did not appear to be any seasonal pattern in the distribution of diazinon as the chemical was present every month sampled. In contrast, chlorpyrifos was not observed between September and December. Parathion and fonofos were most common during December-January and April-May, respectively. Ammonia was only measured once. No carbamate pesticides were ever detected.

---

[23]Three duplicate blind field samples had measurable amounts of ammonia (Table 18). All paired ammonia measurements were identical.

Baseline pesticide concentrations in tributaries

Organophosphate pesticide concentrations were measured in all San Joaquin River tributaries on eight occasions between 27 April and 22 June, 1992 (Appendix D). Eighty-one percent of the samples had detectable amounts of pesticide. The most common insecticides were diazinon and chlorpyrifos. The highest concentrations of both were measured in westside agriculturally dominated creeks and constructed drains (Table 20, $P<0.05$, Kruskall Wallis test). Fonofos was only detected there. Salt Slough had diazinon concentrations comparable to the westside but undetectable amounts of chlorpyrifos. The lowest concentrations of chlorpyrifos and diazinon were observed in the three eastside tributary Rivers ($P<0.05$, Kruskall-Wallis test). Interestingly, the Tuolumne always had measurable amounts of pesticides while the Merced and Stanislaus had only occasional traces of chlorpyrifos. Eastside constructed drains had pesticide concentrations intermediate between those of westside agricultural return water and eastside tributary Rivers.

In conclusion, diazinon and chlorpyrifos were fairly ubiquitous with the highest concentrations in westside agricultural inputs. This result is consistent with both the conclusion that pesticides are the primary cause of bioassay mortality in agricultural return water and the observation that the highest frequency of mortality in the spring occurred in samples collected from the westside (Table 8).

DISCUSSION

The principal conclusion of the study is that 21 percent of water samples[24] collected from the San Joaquin River Basin in 1991-92 tested toxic in *Ceriodaphnia dubia* bioassays (Table 6 and Appendix D). Insecticide concentrations were sufficiently elevated in 70 percent of these to, at least partially, explain the observed mortality (Table 14). Pesticide concentrations were also measured in 120 water samples[25] testing non-toxic (Table 15). One or more insecticides were detected in 83 percent of these samples. However, only on one occasion was a pesticide measured in a non-toxic sample at a concentration known to cause mortality. Staff conclude that the presence of insecticides in surface water at concentrations that cause death in bioassays is a violation of the Basin Plan narrative toxicity objective.

The primary conclusion of an earlier bioassay study was that there was a 43-mile stretch of the San Joaquin River between the confluence of the Merced and Stanislaus Rivers which tested toxic about half the time to *Ceriodaphnia* (Foe and Connor, 1991). Toxicity was ascribed to pesticides entering the River in agricultural return water from row and orchard crops. There are 76 agricultural drains discharging to the San Joaquin River between Salt Slough and Vernalis (James *et al.,* 1989). Orestimba and TID 5 were monitored as representative of west and eastside inputs. The drains tested toxic 41 and 75 percent of the time, respectively.

The present study was designed to follow up on the bioassay conclusions of the earlier work and had three major objectives. The first was to evaluate the assumption that TID 5 and Orestimba were representative of other east and westside inputs. To ascertain this, toxicity at Orestimba Creek was compared with that of three other westside inputs (Del Puerto Creek, Ingram-Hospital Creeks and the Spanish Grant Combined Drain) while bioassay mortality at TID 5 was compared with values obtained at TID 3 and 6. In an earlier critically dry year (1981), the seven water sources were estimated to provide about half of all surface agricultural return flow to the River (Kratzer *et al.*, 1986). The present study found that the frequency of toxicity in the four westside drains was similar. Likewise, the toxicity of the three eastside ones was the same. Therefore, it appears that bioassay water quality from Orestimba Creek and TID 5 can be considered representative of other discharges from their respective sides of the River.

Comparisons of mortality at Orestimba Creek demonstrate no changes in the frequency of toxicity between 1988-90 and 1991-92 (41.6 and 44.7 percent, respectively, Table 21).

[24]121 of 559 samples.

[25]24 percent of all samples analyzed with bioassays.

Similarly, no difference was noted between the two studies in the incidence of toxicity at Salt Slough or the three eastside tributary Rivers. However, frequency of mortality at TID 5 decreased from 75 to 27 percent. This decline was statistically significant ($P<0.05$, chi-square). Some of the decrease may have occurred during the first three months of the irrigation season (April to June). The cause of the decline is not known. However, it may, at least in part, result from the increasing severity of the drought. No good estimate is available of changes in the amount of water consumed in the Turlock Irrigation District as water is supplied by both private wells and diversions from the Tuolumne River. However, some idea of water scarcity can be obtained by comparing changes in the volume of agricultural return flow to the River. The discharge from all TID drains decreased by 85 percent between 1984 (the last normal water year) and 1988-90. Discharges dropped another 37 percent between 1988-90 and 1991[26] The decrease in irrigation return water must have been accomplished, at least in part, by substantial decreases in tailwater volume. As will be discussed later, tailwater is assumed to be the major mechanism responsible for transporting pesticides off fields during the irrigation season. Decreases in tailwater runoff should result in lower pesticide concentrations in surface return flow.

The second objective of the study was to determine whether the midsection of the San Joaquin River would continue to test toxic under different hydrologic conditions. The toxicity of water samples collected from the River at Laird Park was monitored weekly to evaluate this objective. This site is centrally located in the critical River section which previously tested toxic about half the time. Less toxicity was noted in the present study (5 percent) than in the 1988-90 study (42 percent). The decrease is statistically significant ($P<0.05$, Chi-Square). The cause of the decline in toxicity is not known. However, it may be related to the drop in toxicity of eastside inputs. Decreases in toxicity between years strongly suggest that changing agricultural practices, probably induced by the drought, can significantly lower pesticide concentrations in the San Joaquin River. Additional studies are needed to better understand the factors which control pesticide concentrations and toxicity in both agricultural return flow and in the main stem of the River.

The final objective of the study was to identify, if possible, the principal crops and associated water practices responsible for toxic concentrations of pesticide in agricultural return water. Analysis of the seasonal pattern of toxicity in the return water demonstrated that most of the mortality was restricted to two time periods: January-March and April-June (Table 7, $P<0.05$). A discussion follows on the crops most likely responsible for inducing toxicity during each period. It is important to note that no evidence has been obtained that any

---

[26]The sum of TID 2, 3, 5, and 6 irrigation season agricultural return flows were 75,165, 19,872, 19,428, 18,700, and 12,246 acre-feet in 1984, 1988, 1989, 1990, and 1991, respectively (personal communication, Grober).

chemical was used illegally. Rather, the data suggest that the recommended application instructions for some insecticides are inadequate to protect aquatic life.

Wet Season January to March is the rainy season in California. As previously mentioned, most water in drains during this time is from subsurface seepage and storm runoff. Little irrigation occurs. Therefore, it is assumed that stormwater runoff is the primary mechanism responsible for transporting pesticides from agricultural areas into surface water.

Half of all samples taken between January and March tested toxic with the frequency of mortality being similar on the east and westside of the River (Table 8, $P<0.05$). Toxicity is ascribed to off-target movement of insecticides from orchards, alfalfa, sugarbeets and truck farming. Cropping patterns in the San Joaquin River Basin are consistent with these conclusions as half the arable land on the east and westside of the River was planted in orchards and alfalfa during the study period (Table 2). Truck farming was primarily on the westside of the River.

Orchards The primary use of diazinon, chlorpyrifos and parathion in the San Joaquin River Basin in winter is as a dormant spray on stonefruit[27] and apple, pear and almond orchards. Three hundred and forty-seven thousand pounds of insecticide are estimated to have been applied on about 164 thousand acres of orchards in Stanislaus and Merced Counties in 1990 (Appendix E; Department of Commerce, 1987). Most of the insecticide was applied by ground rig between late December and mid-February. Dormant spray insecticides were detected 182 times in surface water between December and March of 1991 and 1992 (Appendix D). Sixty-seven of the detections were at concentrations toxic to *Ceriodaphnia*. Toxic concentrations of insecticide were observed in drains during both dry (23 December 1991, 13 January and 3 February 1992,) and wet periods (10 and 17 February 1992). Both the frequency of impairments and the concentration of the chemicals appear to increase with rain. For example, 5 of 7 sites tested toxic on 17 February after a week of rain. Elevated concentrations of dormant spray were also observed in the Merced and Tuolumne Rivers and San Joaquin River at Airport Way (Appendix D).

Off-target movement of orchard dormant spray insecticides have been confirmed by others. Foe and Sheipline (1993) conducted a study to ascertain whether the presence of dormant sprays in surface water was restricted to Stanislaus and Merced Counties or occurred wherever there are orchards in the Central Valley. As in the present study, toxic concentrations of dormant spray insecticide were found in about half of all small water courses surveyed during dry periods. All drainages became toxic after a large storm. A

[27]Apricots, cherries, nectarines, peaches, plums and prunes.

consequence of the increased concentration of insecticides in small drainages during storm events is that the concentration of insecticides also increased in rivers receiving the runoff. For example, the San Joaquin River at Vernalis was acutely toxic to *Ceriodaphnia* for eight days after the 17 February rainfall event (Foe and Sheipline, 1993). Of the four dormant sprays, diazinon appears to pose the greatest threat to aquatic organisms as it was regularly present with the greatest number of toxic units[28]. Kuivila and Foe (1995) followed up on these observations in the winter of 1993 and attempted to measure dormant spray insecticides in both the Sacramento and San Joaquin Rivers after rainstorms. Elevated concentrations of diazinon were observed in both Rivers after the two largest rainfall events of the year. During the first storm, the San Joaquin River at Vernalis contained acutely lethal concentrations of diazinon to *Ceriodaphnia* for 12 days. On the second occasion, diazinon levels in the Sacramento River were sufficiently high at Rio Vista to kill test organisms for three consecutive days. Toxic concentrations were subsequently traced as far seaward in the Estuary as Chipps Island. The Department of Pesticide Regulation confirmed the presence of diazinon in stormwater in the San Joaquin River in January 1992 and February 1993 and in the Sacramento River in February 1994 (Ross, 1992b;1993c; personal communication, Nordmark). In conclusion, the presence in Central Valley and Delta waterways of orchard dormant sprays at lethal concentrations to sensitive aquatic organisms appears to an annual occurance.

Potential mechanisms inducing off-target movement of orchard sprays in winter are reviewed in Foe and Sheipline (1992). Possible mechanisms include drift during application, runoff of contaminated rainwater from orchard surfaces, and volatization and subsequent atmospheric scavenging and redeposition of insecticides in fog and rainfall. The relative importance of the three mechanisms are, as of yet, unknown. However, ascertaining their relative importance is an essential first step to help prioritize the development of future best management practices to minimize aquatic toxicity.

Alfalfa and sugarbeets Forty-two thousand pounds of diazinon, malathion and chlorpyrifos active ingredient were applied on alfalfa in Stanislaus and Merced Counties in 1990 (Appendix E). Most was sprayed by air and ground rig in March for aphid and weevil control. An additional 2,700 pounds of chlorpyrifos was applied on sugarbeets for worm control. The three insecticides were detected 106 times in March and April of 1991 and 1992 (Appendix D). Twenty-five of these were at concentrations toxic to *Ceriodaphnia*. It is possible that some of the insecticide present in surface water in March was from earlier orchard applications. However, an unknown but larger amount is more likely from new

---

[28]Ambient chemical concentration/concentration killing 50 percent of test organisms in laboratory water in 96 hours.

applications on alfalfa and sugarbeets. This conclusion is reinforced by the observation of an increase in the frequency of toxicity from both diazinon and chlorpyrifos on 23 March 1992 after a much lower incidence of mortality for both during the previous three surveys[29] (Appendix D). As with orchards, the frequency of toxicity appeared to increase with rain. For example, twelve of thirteen samples collected during the heavy rains of March 1991 (4 and 19 March 1991, Table 1) tested toxic.[30] As previously noted, only half the samples normally collected in March are expected to do so (Table 7).

A limited number of other studies have identified pesticides from alfalfa in surface water. In 1991 the U.S. Geological Survey began daily monitoring of the San Joaquin River at Airport Way for pesticides (Crepeau *et al.,* 1991). A well defined carbofuran and diazinon peak and traces of chlorpyrifos were detected coincident with heavy rains in early March. The pesticides were believed to result from applications on alfalfa. Simultaneously, the Survey conducted a study to assess the concentration and distribution of alfalfa pesticides in the Sacramento-San Joaquin Delta Estuary (Kuivila *et al.,* 1992). Carbofuran, but not diazinon, increased westward in the Estuary to Chipps Island. The increase in carbofuran was attributed to inputs from local unmeasured alfalfa sources within the Delta while the decrease in diazinon was thought to result from dilution with uncontaminated seawater. Foe and Sheipline (1993) attempted to confirm Kuivila's results and determine whether carbofuran would reappear in the Estuary the next year. The spring of 1992 was unusually dry and little toxicity from alfalfa applications was observed. The U.S. Geological Survey also saw no diazinon, chlorpyrifos or carbofuran in surface water in the spring of 1992 (MacCoy *et al.*, 1995). Finally, the Department of Pesticide Regulation monitored insecticide concentrations in the San Joaquin River Basin in 1991 and 1992. Diazinon, malathion, and carbofuran were detected in samples collected from both drains and the San Joaquin River in March and April of both years (Ross, 1991 and 1993a). Chlorpyrifos was only measured in 1991. In conclusion, application of alfalfa insecticides probably pose a threat to sensitive aquatic invertebrates in small Central Valley water courses each year while organisms in the rivers and Delta are only at risk during wet springs.

<u>Truck Farming</u> Truck farming is an emerging industry on the west side. Principal winter and spring crops are spinach, carrots, broccoli, cauliflower and onions (Table 2). Methomyl and fonofos were detected five times in December and January at Ingram-Hospital Creek (Appendix D). Three of these were at concentrations known to be toxic to *Ceriodaphnia*. In addition, both compounds were also detected in October in the same drainage. It is

---

[29]The change in the frequency of toxicity cannot be ascribed to rain as the entire month of March, 1992 was dry.

[30]TID 6 was not toxic on 4 March 1991.

difficult, because of the limited number of detections, to be completely certain of the responsible crops. However, broccoli and cauliflower are planted between late August and mid-October and harvested between November and January (University of California, 1981). The principal winter use of methomyl is on cauliflower[31]. The only reported winter use of fonofos is on broccoli.[32] More monitoring needs to be conducted to verify that winter truck farming is the source of these two chemicals.

Irrigation Season April is the beginning of the irrigation season. In both years the last precipitation fell by mid-April (Table 1). Therefore, most of the water present in agriculturally dominated creeks and constructed drains after the end of March is from irrigation return flow. It is assumed, therefore, that tailwater runoff from row and orchard crops is the primary vehicle responsible for transporting pesticides into surface water during the irrigation season.

Slightly less than half of the water samples collected from the westside of the Valley between April and June tested toxic (Table 8). This is in contrast to the eastside where the frequency of toxicity was only 17%. The difference was significant (Chi-Squared, $P<0.05$). As described below, the difference in toxicity between the two sides of the River is primarily believed to result from differences in cropping patterns.

Four insecticides--chlorpyrifos, diazinon, fonofos and carbaryl--appear responsible for most of the toxicity. Outlined below are the primary seasonal uses of each chemical and the crops from which they most likely came.

Chlorpyrifos is a wide spectrum insecticide used extensively in agriculture on a variety of crops. The chemical was detected 85 times between April and June 1991-92 (Appendix D). Eighteen of these were at concentrations toxic to *Ceriodaphnia*. All samples collected between 27 April and 22 June 1992 were analyzed for organophosphorus insecticides. Chlorpyrifos was detected in 82 % of the drain samples[33] from both the east and westside of the River. Unlike the other pesticides discussed below, the frequency of chlorpyrifos detections were the same on both sides of the River (Chi-Square, $P>0.05$). Some detections in early April, such as at Salt Slough on 13 April 1992, are likely to have resulted from late applications on alfalfa and sugarbeets. However, the continued presence of chlorpyrifos in

---

[31]In 1990, 2,442 and 318 pounds of methomyl active ingredient were applied on cauliflower and onions in Stanislaus County (Appendix E).

[32]In 1990, 110 pounds of fonofos active ingredient was applied on broccoli in Stanislaus County (Appendix E).

[33]43 of 53 samples.

drains throughout the season suggests additional applications. The precise crops responsible are not known. However, the principal uses in Stanislaus County are on walnuts and almonds for coddling moth and twig borers control (Appendix E; Sheipline, in press; personal communication Walt Heimgartner). Two minor uses are on apples and corn. Most of the almonds and corn are grown on the eastside while walnuts and apples are evenly distributed on both sides of the River (Table 2). Therefore, the distribution pattern of chlorpyrifos detections is consistent with the distribution of crops upon which it is applied.

Diazinon is another commonly used agricultural insecticide. It was detected 81 times between April and June of 1991 and 1992. Four of these were at concentrations toxic to *Ceriodaphnia*. Diazinon runoff appears to be predominately a westside problem. All toxic concentrations of the chemical were observed there. In addition, 97 percent of all westside samples collected between 27 April and 22 June 1992 contained diazinon as compared with only 23 percent on the Eastside. The difference was significant (Chi-Square, $P<0.05$).

Off-target movement of diazinon is likely to result from multiple agricultural uses. The principal seasonal use of diazinon in Stanislaus County is on almonds (Appendix E, Sheipline in press; personal communication Walt Heimgartner). Secondary uses are on melons, tomatoes, peaches, apricots, and walnuts. Almonds and peaches are mostly grown on the eastside while melons, tomatoes and apricots are westside crops (Table 2). Walnut stands occur on both sides of the River. Therefore, melons, tomatoes, and apricots appear to be the crops most likely responsible for the diazinon runoff.

Fonofos is an organophosphorus insecticide which is broadcast and then incorporated into the soil profile by tillage prior to planting. The chemical was only observed in water samples collected from the westside of the River. Fonofos was detected 24 times between April and June of 1991-92. Four of these were at concentrations toxic to *Ceriodaphnia*. The principal seasonal use of fonofos in Stanislaus County is on beans and tomatoes to control wireworms (Appendix E, Sheipline in press; personal communication Walt Heimgartner). Both commodities are almost exclusively grown on the westside. Therefore, the geographic pattern of fonofos detections is also consistent with its principal agricultural use.

Carbaryl is the last of the four insecticides. It is a commonly used foliar spray. Carbaryl was detected five times in May. All detections were in water samples collected from the westside. One of these was at a concentration known to be toxic to *Ceriodaphnia*. However, caution must be exercised in evaluating both the frequency and spatial pattern of the distribution as the detection limit for the carbamate analysis was fifty times higher than for the organophosphorus one. As a result, water samples were only analyzed for carbamate insecticides when toxicity was observed. Therefore, both the frequency of carbaryl detections and their spatial distribution may be larger than is suggested by this data.

Common uses during the early irrigation season in Stanislaus County are on almonds, beans, corn, grapes, peaches and tomatoes. Of these only beans and tomatoes are commonly grown on the westside.

As previously mentioned, the Department of Pesticide Regulation monitored insecticide concentrations in April of 1991 and 1992 in the San Joaquin River Basin. No monitoring was conducted during May or June of either year. Diazinon, chlorpyrifos, and carbaryl were detected in April of one or both years (Ross, 1991 and 1993a). Fonofos was not observed in the summer by the Department.

The U.S. Geological Survey collected water daily from the San Joaquin River at Vernalis between November 1991 and April 1994 and combined them into two day composites for dissolved pesticide analysis (MacCoy *et al.*, 1995). Diazinon, carbaryl and chlorpyrifos were observed 43, 31, and 2 times, respectively, between the months of April and June. Fonofos was not measured. The higher frequency of carbaryl detections by the U.S. Geological Survey than in the present study (Table 19) is thought to result from the Survey's approximate tenfold lower reporting limit. Conversely, the present study observed a higher incidence of diazinon and chloryprifos. Again, the bias is thought to result from the approximate threefold lower organophosphate reporting limits employed here.

Factors influencing the concentration of pesticides in tailwater have not been extensively evaluated. In the only comprehensive study known, Spencer *et al.* (1985) investigated factors influencing pesticide levels in runoff from irrigated fields in the Imperial Valley. The authors found that there was a strong positive relationship between the amount of insecticide present in the top one cm of furrow soil and the subsequent concentration in tailwater. For chlorpyrifos and diazinon, the tailwater usually contained about 1 to 1.5 percent of the amount of chemical present in the soil. Two factors influenced soil insecticide concentrations. The most important of these was the amount of time elapsed since the application as soil and tailwater pesticide concentrations were observed to decrease exponentially with time. Chlorpyrifos and diazinon soil half-lives were determined to be 3-11 and 13-15 days, respectively. The second factor influencing the amount of pesticide bound to the soil was the proportion of wettable furrow covered by crop canopy at the time of application. In general, crop leaf surfaces are not wetted during irrigation. Therefore, pesticides attached to them are unlikely to be remobilized with irrigation tailwater. This finding is consistent with observations obtained in the present study as most westside bioassay mortality occurred early in the irrigation season (April-June) when crops were young and of a relatively small stature (Table 8). Similar amounts of the same insecticides are reported to be applied later in the irrigation season on (presumably) larger plants. Less mortality was observed in bioassays then.

Two factors which did not affect the amount of insecticide in tailwater were the concentration of suspended sediment and the method of pesticide application. Spencer *et al.* (1985) found that about 15 percent of the chlorpyrifos carried in tailwater was bound to sediment while 85 percent was in the dissolved phase. Diazinon was even more hydrophilic. As a result, there was no relationship between the amount of total suspended sediment and the insecticide concentration. These observations are toxicologically important as it is the dissolved insecticide fraction which is believed to be biologically available and responsible for the observed mortality. Finally, Spencer *et al.* found no difference in tailwater insecticide concentrations when the chemical was applied by ground or air rig.

Spencer *et al.* (1985) suggest three possible best management practices to help reduce transport of pesticides from irrigated fields in the Imperial Valley. The first was to insure that the pesticide application and the irrigation event never co-occurred. The second was to delay irrigation for as long as possible after applying pesticides to insure that the greatest amount of chemical degradation possible had occurred. Finally, the authors recommend that minimal amounts of tailwater be released after pesticide applications.

DiGiorgio *et al.* (1995) has completed the second of a three-year bioassay study of agricultural return water in the Imperial Valley. Forty-one percent of the water samples collected from the Alamo River and its principal agricultural tributaries tested toxic to *Ceriodaphnia*. Modified phase I toxicity identification evaluations (U.S.EPA, 1988; Bailey *et al.*, 1995) were conducted on twenty toxic samples. Non polar organics were implicated in nineteen of the toxicity identification evaluations. Chemical analysis supported these conclusions and revealed that the samples contained diazinon, chlorpyrifos, malathion, carbaryl, and carbofuran at concentrations near or above the *Ceriodaphnia* LC_{50} value. The study assumed that the insecticides were transported to the River in tailwater from row and field crops.

A similar bioassay study is presently being conducted in the Sacramento-San Joaquin Delta Estuary (Deanovic *et al.*, in prep). *Ceriodaphnia* mortality has been observed in water samples collected from upland agriculturally dominated creeks and constructed drains and from the back sloughs to which they drain. Diazinon, chlorpyrifos and carbofuran were measured in the samples at concentrations reported toxic to *Ceriodaphnia* and other sensitive local aquatic organisms. Again, the primary source of the chemicals is believed to be tailwater runoff from upland row and orchard crops.

In conclusion, the aquatic threat posed by insecticides in tailwater does not appear to be restricted to the San Joaquin River Basin. More work needs to be undertaken to better understand the primary factors controlling pesticide concentrations in tailwater from all areas of the State. This information is essential, as with dormant sprays, to help direct the development of best management practices to minimize the threat of insecticides to the aquatic community.

Ecological impacts

The ecological impact of elevated pesticide levels in the San Joaquin River Basin is not known. However, indirect evidence suggests that impacts may be occurring to sensitive aquatic organisms in both the Central Valley and the Sacramento-San Joaquin Delta Estuary.

Direct evidence of ecological impacts on aquatic communities is difficult to measure (Clements and Kiffney, 1994; DeVlaming, 1995). The U.S. EPA developed the three species bioassay approach (U.S.EPA, 1985a;1989) as an early warning system of potential pollutant impacts. The Agency attempted to validate the approach by conducting eight freshwater studies to ascertain whether there was a correlation between toxicity in receiving water as measured by their tests and instream impacts (reviewed in U.S. EPA, 1991b). The bioassay results predicted receiving water impacts at seven sites. At each location differences were measured in the abundance and distribution of aquatic organisms below the site as compared to above it. At one location no difference was predicted by the bioassay testing and none was detected in the receiving water. Subsequent field work by Eagleston *et al.*, (1990), Birge *et al* (1990) and Dickson *et al.* (1989) provide further support for the hypothesis that bioassays can be an indirect method of assessing whether pollutants are impacting freshwater organisms. These results have lead the U.S. EPA to recommend bioassay testing as an acceptable surrogate to the measurement of the abundance and distribution of organisms at sites where impacts from pollutants are suspected. However, the method has been criticized by Marcus and McDonald (1992) and Parkhurst (1995). Recently, DeVlaming (1995) has reviewed all critiques conducted to date and concluded that there is a good qualitative relationship between bioassay results and aquatic ecosystem response. Predictions about ecological impacts are particularly strong if acute toxicity is observed in bioassays conducted on ambient water samples.

Sheipline (in press) reviewed the sensitivity of different classes of aquatic organisms to the pesticides reported in water samples from the San Joaquin Basin. Surprisingly little information was available for many insecticides. However, in general, cladocerans appeared to be the most sensitive aquatic forms and exhibited pesticide tolerances similar to *Ceriodaphnia*. Support for this conclusion was obtained from a large mesocosm study sponsored by Ciba-Geigy, the manufacturer of diazinon (Giddings, 1992). In the study, replicate ponds were dosed with increasing concentrations of diazinon and the abundance of different classes of organisms compared with the undosed control. The study found reduced numbers of cladocerans and caddisflies in the lowest treatment (about 2.4 ppb). However, both classes of organisms returned to normal about 10 weeks after pesticide dosing stopped. While interesting, the latter observation may not be applicable to water bodies in the San

Joaquin River Basin which are subjected to repeated episodes of acute invertebrate toxicity from pesticide exposure.

An analysis of fifteen years of Department of Fish and Game zooplankton tow net data has recently been completed (Obrebski *et al.*, 1992). The analysis is particularly valuable as it eliminates the impact of salinity (flow) and seasonality, two variables that have confounded previous analysis. The study demonstrates a decline in abundance of zooplankton species (copepods, rotifers and cladocerans) in the freshwater portion of the Estuary. In contrast, population levels of species inhabiting intermediate and marine salinities have largely remained stable. The cause of the decline of freshwater forms is not known. However, historically, it seems likely that a portion of the freshwater zooplankton community in the Delta was the result of a continuous repopulation with individuals from slow moving, warm, eutrophic back waters in the Central Valley. The repopulation is probably most important for the Rivers and upper Delta with their strong seaward flow. The primary nursery areas in the Central Valley are likely to have included the agriculturally dominated creeks and constructed drains which now contain pesticides at toxic concentrations to many zooplankton species.

Zooplankton are important in aquatic systems, in part, as food for larval and juvenile fish. Zooplankton densities in the freshwater portion of the Estuary are now reported to be one to two orders of magnitude lower than in the early seventies (Obrebski *et al.*, 1992). The population of many freshwater fish in the Estuary are also in decline, including species like splittail, delta smelt and striped bass whose larvae feed almost exclusively on small zooplankton. Laboratory evidence suggests that food levels in the Estuary are limiting, at least for striped bass larvae (reviewed in Herbold *et al.*, 1992). However, no evidence of field starvation (death from lack of food) has been found for bass although increased larval predation rates are hypothesized because of suppression in growth from both toxins and lack of food (Bennett *et al.*, 1995).

Regulatory significance of insecticide findings

Thirteen pesticides were detected in this study (Table 12). The Water Quality Control Plan for the San Joaquin River Basin (Basin Plan) contains a conditional prohibition of discharge[34] for irrigation return flows containing carbofuran, malation and methyl

[34]The prohibition of discharge is lifted if the discharge is following management practices approved by the Regional Board. To receive approval, the management practices must be expected to meet performance goals set by the Board.

parathion[35]. Carbofuran and malathion performance goals were exceeded in 1 and 6 samples, respectively. No exceedance was observed for methyl parathion. Use of a fourth compound, ethyl parathion, is now banned because of human health concerns. Performance goals are not available for any of the other compounds. Therefore, water quality criteria have been assembled for the remaining nine chemicals (Table 12) to help evaluate their aquatic threat. Also included is the lowest reported concentration of each insecticide known to cause *Ceriodaphnia* toxicity.

The analysis suggests that of the thirteen compounds, diazinon and chlorpyrifos pose the greatest threat to aquatic life in the Basin. The two were detected a total of 328 times in the year and a half study. Over half of these measurements were at concentrations greater than the draft California Department of Fish and Game Hazard Assessment criteria to protect freshwater aquatic life (Menconi and Cox, 1994; Menconi and Paul, 1994). Ninety measurements were at concentrations reported in the literature to be toxic to *Ceriodaphnia*. Finally, almost half of all water samples analyzed for pesticides were contaminated with both chemicals and the toxicity of the two is additive, at least for *Ceriodaphnia* (personal communication, Dr Miller). This suggests that water quality objectives for both insecticides should consider additivity.

[35]Performance goals for methyl parathion, malathion and carbofuran are 0.01, 0.1 and 0.4 ppb, respectively, Central Valley Basin Plan (1990).

Acknowledgements *Ceriodaphnia* bioassays were conducted under the direction of Sandy Nurse at Sierra Foothill Laboratory. Dr Joseph Domagalski was the contract manager for pesticide analysis at the U.S. Geological Survey. Jerry Bruns, Val Connor, Rudy Schnagl and Dennis Westcot reviewed an earlier draft of the manuscript. The help of all the above individuals is gratefully acknowledged.

Literature cited

Amato, J.R., D.I Mount, E.J. Durham, M.T. Lukasewycz, G.T. Ankley and E.D. Roberts. 1992. An Example of the identification of diazinon as a primary toxicant in an effluent. Env. Tox. and Chem. 11:209-216

Bailey, H.C., C.L. DiGiorgio, K. Kroll, G. Starrett, M. Miller and D.E. Hinton. 1995. Development of procedures for identifying pesticide toxicity in effluent and ambient waters:carbofuran, diazinon, and chlorpyrifos.Final report to the State Water Resources Control Board, Sacramento Ca.

Bailey, R., J. McClung, D. Faulkner. 1989. Non point source pollution and planning for water quality improvements in Western Stanislaus County. U.S. Department of Agriculture, Soil Conservation Service, Special Report. 68pp.

Bennett, W. A., D.J. Ostrach and D.E. Hinton. 1995. Larval striped bass condition in a drought stricken estuary: Evaluating pelagic food web limitations. Accepted Ecological Applications.

Birge,W.J., J.A. Black, T.M. Shortand A.G. Waterman. 1989. A comparative Ecological and toxicological investigation of a secondary wastewater treatment plant effluent and its receiving water. Envi. Toxicol. and Chem. 8:437-450.

Clements, W.H. and P.M. Kiffney. 1994. Assessing contaminant effects at higher levels of Biological organization. Environ. Toxi and Chem. 13:357-359.

Crepeau, K.L., K.M. Kuivila and J.L. Domagalski. 1991. Riverine inputs of pesticides to the Sacramento-San Joaquin Delta Estuary, Ca. Abstract presented at the 11th International Estuarine Research Conference, San Francisco. Ca. Nov 10-14, 1991.

Central Valley Regional Water Quality Control Board, 1990. The Water Quality Control Plan (Basin Plan) for the Central Valley Regional Water Quality Control Board (Region 5). Second Edition. Central Valley Regional Water Quality Control Board publication, Sacramento, Ca.

Department of Commerce, 1987. Census of Agriculture. Volume I Geographic Area Series. Bureau of Census, Washington D.C.

Department of Pesticide Regulation. 1990. Monthly Pesticide Use Report by County. Staff report, Department of Pesticide Regulation, Sacramento Ca.

DeVlaming, V. 1995. Are the results of single species toxicity tests reliable predictors of aquatic ecosystem community response? A Review. Draft report State Water Resources Control Board, Sacramento, Ca.

Dickson,K.L., W.T. Waller, J.H. Kennedy, W.R. Arnold, W.P. Desmond, S.D. Dyer, J.F. Hall, J.T. Knight, D. Malas, M.L. Martinez, S.L. Matzner. 1989. A water quality and ecological survey of the Trinity River, Volume I. Report conducted by Institute of applied Sciences, University of N. Texas and Graduate Program in Enviromental Sciences, University of Texas at Dallas.

DiGiorgio, C., H.C. Bailey, and D.E. Hinton. 1995. Colorado River Basin toxicity report. U.C. Davis, Ca. 100pp

Eagleson, K.W., D.L. Lenat, L. Ausley and F. Winborne. 1990. Comparison of measured instream biological responses with responses predicted by *Ceriodaphnia* chronic toxicity tests. Env. Toxicol. and Chem. 9:1019-28

Foe, C. G. 1988. Results of the 1986-87 Lower Sacramento River toxicity survey. Staff memorandum. Central Valley Regional Water Quality Control Board, Sacramento, Ca.

Foe, C.G. and V. Connor. 1991. San Joaquin watershed bioassay resutls, 1988-90. Staff memorandum. Central Valley Regional Water Quality Control Board, Sacramento, Ca.

Foe, C.G. and R. Sheipline. 1993. Pesticides in surface water from applications on orchards and alfalfa during the winter and spring of 1991-92. Staff memorandum. Central Valley Regional Water Quality Control Board, Sacramento, Ca.

Giddings, J.M. 1992. Aquatic mesocosm test for environmental fate and ecological effects of diazinon. Springborn Report Number 92-3-4155. Springborn Laboratories, Inc. Wareham, Mass. 0257. 320 pp.

Hansen, S. R. and Associates. 1994. Identification and control of toxicity in storm water discharges to urban creeks. Prepared for Alameda County Urban Runoff Clean water program. 4085 Nelson Ave, Suite I Concord CA 94520.

Hayes, W.J. and E.R. Laws. 1991. Handbook of Pesticide Toxicology. Volume II. Classes of Pesticides. Academic Press San Diego. Ca 1991.

Herbold, B., A.D. Jassbay and P.B. Moyle. 1992. Status and Trends Report on aquatic resources in the San Francisco Estuary. San Francisco Estuary Project. P.O. Box 2050 Oakland Ca 94604-2050 257 pp

Huang, Z.C., R.W. Fujimura, B.J. Finlayson. 1994. Evaluation of toxicity in pesticide mixtures. Abstract presented at the 15th annual Society of Env. Toxicology and Chemistry. Denver, Co. 30 Oct-3 Nov 1994.

Issac, G. and P. Phillips. 1994. Toxicity of Agricultural chemicals to waterfleas and young mysid shrimp. California Department of Fish and Game. Env. Services Division Administration Report 94-2. 28pp

James, E.W. , D.W. Westcot and J.L. Gonzales. 1989. Water diversions and discharge points along the San Joaquin River. Mendota Pool Dam to Mossdale Bridge. Staff Report. Central Valley Regional Water Quality Control Board, Sacramento Ca.

Kratzer, C. R., P.J. Pickett, E.A. Rashmawi, C.L. Cross, K.D. Bergeron. 1987. An input-output model of the San Joaquin River from the Landers Avenue Bridge to the Airport Way Bridge. Appendix C to Regulation of Agricultural drainage to the San Joaquin River. State Water Resources Control Board, Order No. Water Quality 85-1. Technical Committee Report.

Kuivila, K.M., K.L. Crepeau and J.L. Domagalski. 1992. Input and transport of selected alfalfa pesticides to the San Francisco Bay Ca. Abstract presented at the 13th Annual Society of Env. Tox. and Chemistry, Cincinnati, OH. Nov 9-13, 1992.

Kuivila, K.M. and C.G. Foe 1995. Concentration, transport and biological impact of dormant spray pesticides in the San Francisco Estuary, California. Env. Toxicol. and Chem. 14:1141-1150.

MacCoy, D., K.L. Crepeau, and K. M. Kuivila. 1995. Dissolved pesticide data for the San Joaquin River at Vernalis and the Sacramento River at Sacramento Ca.. 1991-94. U.S. Geological Survey open file report 95-10. Sacramento Ca. 1995. pg 27.

Marcus, M.P. and L.L. McDonald. 1992. Evaluating the statistical bases for relating receiving water impacts to effluent and ambient toxicities. Environ. Toxicol. and Chem. 11:1389-1403.

Menconi, M. and S. Gray. 1992. Hazard assessment report of the insecticide carbofuran to aquatic organisms in the Sacramento-San Joaquin River System. California Department of Fish and Game. Environmental Services Division Admininstration Report 92-3. 56 pp.

Menconi, M. and A. Paul. 1994. Hazard assessment report of the insecticide chlorpyrifos to aquatic organisms in the Sacramento-San Joaquin River System. California Department of Fish and Game. Environmental Services Division Admininstration Report 94-1. 73 pp.

Menconi, M. and C. Cox. 1994. Hazard assessment report of the insecticide diazinon to aquatic organisms in the Sacramento-San Joaquin River System. California Department of Fish and Game. Environmental Services Division Admininstration Report 94-2. 58 pp.

National Academy of Sciences and National Academy of Engineering, 1973. Water quality criteria, 1972: U.S. Environmental Protection Agency Report R3-73-033 Washington D.C.

Norberg-King, T.J., E.J. Durham, G.T. Ankley, and G. Robert 1991. Application of toxicity identification evaluation procedures to the ambient waters of the Colusa Basin Drain, California. Environ. Toxi. and Chem. 10:891-900.

Obrebski, S., J.J. Orsi and W. Kimmerer. 1992. Long-term trends in zooplankton distributions and abundance in the Sacramento-San Joaquin Estuary. Technical Report 32. Interagency Ecological Studies Program for the Sacramento-San Joaquin Delta Estuary.

Oris, J.T., R.W. Winner and M.V. Moore (1991). A four day survival and reproduction toxicity test for *Ceriodaphnia dubia*. Environ. Toxicol. and Chem. 10(2):217-224.

Parkhurst, B.R. 1995. Are single species toxicity test results valid indicators of effects to aquatic communities? pg 105-121 In Ecological Toxicity Tests. (eds J. Cairns, Jr. and D. Neiderlehner). Louis Publishers, Boca Raton, FL.

Ross, Lisa. 1991. Preliminary findings from the March-April 1991 sampling season. Staff memorandum. California Department of Pesticide Regulation, Sacramento. Ca.

Ross, Lisa. 1992a. Preliminary results of the San Joaquin River study, summer 1991. Staff memorandum. California Department of Pesticide Regulation, Sacramento. Ca.

Ross, Lisa. 1992b. Preliminary results of the San Joaquin River study, winter 1991-92. Staff memorandum. California Department of Pesticide Regulation, Sacramento. Ca.

Ross, Lisa. 1993a. Spring 1992 San Joaquin River Data. Staff memorandum. California Department of Pesticide Regulation, Sacramento. Ca.

Ross, Lisa. 1993b. Preliminary results of the San Joaquin River study, summer 1992. Staff memorandum. California Department of Pesticide Regulation, Sacramento. Ca.

Ross, Lisa. 1993c. Preliminary results of the San Joaquin River study, winter 1992-93. Staff memorandum. California Department of Pesticide Regulation, Sacramento. Ca.

Sheipline (in press). Background information on nine selected pesticides. Central Valley Regional Water Quality Control Board staff report. Sacramento Ca. 150 pp

Sittig, M. 1981. Handbook of toxic and hazardous chemicals. Noyes Publications. Park Ridge New Jersey. USA.

Spencer, W.F., M.M. Cliath J.W. Blair and R.A. LeMert. 1985. Transport of Pesticides from irrigated fields in surface water runoff and tile drain waters. U.S. Department of Agriculture. Conservation Research Report. No. 31. 71 pp

Straalen, N.M, Van der Hoeven, J.de Bruijn and M. Hof. 1994. How to measure no effect:Towards a new measurement of chronic toxicity in ecotoxicology. Workshop report the Hague, the Netherlands, September 9th 1994. 44p.

University of California, 1981. Vegetable crops, planting and harvesting periods for California. Division of Agricultural Sciences, Cooperative Extension Berkeley, Ca.

U.S. Army Corp of Engineers. 1984 a. San Joaquin River: Stockton to the Merced River. Sacramento District Water Resources Planning Branch Investigations Section C. Plates A1-A64.

U.S. Army Corp of Engineers. 1984 b. San Joaquin River: Merced River to Mendota Pool. Sacramento District Water Resources Planning Branch Investigations Section C. Plates B1-B45.

U.S. EPA 1985a. Methods for measuring the acute toxicity of effluents to freshwater and marine organisms (third edition). Environmental monitoring and support Laboratory, Cincinnati, O.H. 45268 EPA/600/4-85/013.

U.S. EPA 1985b. Short term methods for estimating the chronic toxicity of effluents and receiving water to freshwater organisms. Env. Monitoring and Support Laboratory. Cincinnatti, OH. EPA/600/4-85/014.

U.S. EPA, 1985c. Ambient water quality control for ammonia--1984. Office of water regulation and Standards. Criteria and Standards Division, Washington D.C. 20460. EPA/5-85/001.

U.S. EPA, 1986a. Water Quality Criteria for Malathion. Office of Water Regulation and Standards. Criteria and Standards Division, Washington, D.C. 20460. EPA 440/5-86/001

U.S. EPA, 1986b Ambient water quality criteria for Chlorpyrifos. Office of Water Regulations and Standards, Criteria and Standards Division, Washington DC 20460 pp 64

U.S. EPA, 1986c Ambient water quality criteria for Parathion. Office of Water Regulations and Standards, Criteria and Standards Division, Washington DC 20460 pp 64

U.S. EPA, 1988. Methods for aquatic toxicity identification evaluation. Phase I. Toxicity characterization procedures. Environmental Research Laboratory. Duluth. MN. 55804. EPA/600/3-88/034.

U.S. EPA, 1989. Short-term methods for estimating the chronic toxicity of effluents and receiving water to freshwater organisms (second edition). Environmental Monitoring and Support Laboratory. Cincinnati, OH. EPA/600/4-89/001

U. S. EPA, 1991a. Methods for measuring the acute toxicity of effluents and receiving water to freshwater and marine organisms. Office of Research and Development. Washington D.C. EPA/600/4-90/027.

U. S. EPA, 1991b. Technical Support Document for water quality based toxics control. Office of Water. EPA/505/2-90/001.

U. S. EPA, 1994. Test methods for evaluating solid waste physical/chemical methods. (Third Edition, revision 2). SW 846. Washington D.C.

Wershaw, R.L. M.J. Fishman, R.R. Grabbe, and L.E. Lowe. 1987. Techniques of water resources investigations of the United States Geological Survey. Chapter A3. methods for the determination of organic substances in water and fluvial sediments. Denver Co. 80225 80 pp.

Table 1. Daily precipitation in inches at the City of Stockton. Shading indicates sampling dates. "T" denotes trace amounts of precipitation.

	1991											1992					
Date	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
1		.70		T									.10	.06			
2	.50	.11												.06			
3		.78												T			
4	.73	.42										.03					
5	.17											.69	T	.71			
6											.01	.11	.33	.03			
7											.34	.22	.09				
8																	
9													.26				
10		.13											.45				
11													.80				
12		.10											.80		.72		
13		.26		.12			.05						.03		T		
14		T					.02						1.19	.24			
15		.07											.27	.05			.08
16													.64	.04			
17		.32		T						.34	.01	T		T			
18		.03									T		.03				
19		.10				.02							.14				
20		.50	.41										.23				
21			.04										.01				
22													T	.11			
23		.36															
24		1.13							.10								
25		.01						T	.44								
26		.33							1.44								
27	.62				T						.21						
28	.30				.11						.02	.34					
29											.17						.04
30																	
sum	2.32	5.35	0.45	0.12	0.11	0.02	0.07	t	1.98	0.34	0.76	1.39	5.37	1.30	0.72	0	0.12

Table 2. Cropping patterns (%) for representative irrigation districts located on the east and west side of the San Joaquin River. Percentages sum to more than 100% because of double cropping.

	EASTSIDE		WESTSIDE			
	Turlock Irrigation District		Patterson Irrigation District		W. Stanislaus Irrigation District	
CROP	1991	1992	1991	1992	1991	1992
ORCHARDS						
Almonds	29.6	28.4	0.5	0.6	4.1	4.3
Apples	0.5	0.7	0.1	0.1	0.3	0.3
Apricots		0.1	20.2	16.1	7.8	8.6
Cherries	0.1	0.1	1.6	1.4	0.5	0.5
Peaches	5.0	5.1				
Walnuts	3.7	3.7	4.5	4.5	3.9	4.5
TOTALS	39.1	38.4	27.5	23.2	16.6	18.3
FIELD						
Alfalfa	15.1	17.7	21.6	23.9	7.0	5.2
Corn	27.2	28.0		1.7		
Grain	5.6	2.3				
Clover	0.4	0.8				
Oats	20.9	21.7	4.0	0.6	0.4	
Pasture	10.0	9.5	2.1	2.3		
Sudan	0.6	0.8	0.6			0.2
Barley					0.5	
Wheat				1.1	0.6	2.1
Beans	1.7	1.7	15.9	19.3	30.9	28.7
Cotton						
Sugarbeets			0.4	1.6		0.4
Turf			1.6	2.8	0.8	0.3
TOTALS	81.5	82.5	46.2	53.3	40.2	36.9

Table 2 . (Continued)

	EASTSIDE		WESTSIDE			
	Turlock Irrigation District		Patterson Irrigation District		W. Stanislaus Irrigation District	
CROP	1991	1992	1991	1992	1991	1992
VEGETABLE						
Melons	0.6	0.9		0.9	11.8	12.7
Tomatoes			12.8	11.6	13.6	16.5
Onions					1.7	1.7
Peas			2.7		3.8	3.3
Pumpkins	0.2	0.4	0.1			
Celery			0.5	1.3	0.5	
Spinach			1.2	0.4	0.3	
Carrots				0.8		
Broccoli				2.1	1.7	2.0
Cauliflower					2.3	1.5
Peppers			0.2		2.2	3.0
TOTALS	0.8	1.3	23.4	19.2	37.9	40.7
OTHER						
Vines	4.9	4.0				
Duck Clubs						
Fallow			2.2	2.1	2.5	1.6
Seed crops			0.8	0.9		
TOTALS	4.9	4.0	3.0	3.0	2.5	1.6
Irrigated Acreage	146,371	148,887	13,716	13,585	26,586	25,347
Acreage double cropped	43,038	43,834	1,023	915	1,821	2,921

Table 3. Organophosphate pesticides and associated reporting limits (ug/l) for U.S. Geological Survey total recoverable organophosphate scan 1319. Also included are reported accuracy and precision estimates obtained by spiking seven replicates of each insecticide into laboratory water (Wershaw *et al.* 1987)

Compound	Reporting Limits (ug/l)	Concentration Spiked (ug/l)	Mean Concentration Recovered	Mean (%) Recovery	Relative Standard Deviation
Chlorpyrifos	0.01				
DEF	0.01				
Diazinon	0.01	0.230	0.150	65.0	20.0
Disulfoton	0.01				
Ethion	0.01	0.15	0.120	80.0	7.4
Fonfos	0.01				
Malathion	0.01	0.260	0.180	69.0	32.0
Methyl Paration	0.01	0.220	0.160	73.0	9.2
Parathion	0.01	0.150	0.120	80.0	6.3
Phorate	0.01				
Trithion	0.01	0.250	0.180	73.0	7.6

Table 4. Carbamate pesticides and associated reporting limits (ug/l) for U.S. Geological Survey total recoverable Carbamate scan 1359. Also included are reported accuracy and precision estimates obtained by spiking four replicates of each insecticide into surface water (Wershaw *et al.* 1987).

Compound	Reporting Limits (ug/l)	Concentration Spiked (ug/l)	Mean concentration Recovered	Mean (%) Recovery	Relative Standard Deviation
Methiocarb	0.50				
Propoxur	0.50				
Methomyl	0.50	2.52	2.13	84.9	20.0
Propham	0.50	7.05	5.68	80.6	5.7
Sevin	0.50	2.36	2.33	97.0	5.7
1-Naphthol	0.50				
3-hydroxy carbofuran	0.50				
Aldicarb sulfoxide	0.50				
Aldicarb sulfone	0.50				
Oxyamyl	0.50				
Carbofuran	0.50				
Aldicarb	0.50				

Table 5. Comparison of *Ceriodaphnia* survival and electrical conductivity (umho/cm) in duplicate blind field samples submitted to Sierra Foothill Laboratory for analysis. Bioassay survival is for a four day test unless noted otherwise. Electrical conductivity measurements were made before the addition of *Ceriodaphnia* food.

Location	Date	Survival			Electrical Conductivity		
		Sample	Duplicate	Difference (%)	Sample	Duplicate	Difference (%)
TID 5[1]	2-25-91	100	90	10	2050	2060	0.5
SJR[2] @ Airport Wy	3-4-91	80	100	20	1082	1076	0.6
Orestimba Ck	3-19-91	0	0	0	904	910	0.7
SJR @ Hills Ferry	4-4-91	90	100	10	2300	2440	6.1
TID 5	4-18-91	100	100	0	899	900	0.1
TID 5	5-3-91	100	100	0	525	525	0.0
TID 6	5-15-91	100	100	0	1028	1020	0.7
TID 3	6-12-91	100	90	10	838	916	9.3
Spanish Grant	6-26-91	100	90	10	1736	1771	2.0
SJR @ Airport	7-2-91	100	100	0	904	909	0.6
TID 3	7-15-91	100	100	0	748	757	1.2
Spanish Grant	7-30-91	90	100	10	1353	1337	1.2
Spanish Grant	8-6-91	890	100	20	1035	1029	0.6
Spanish Grant	9-6-91	100	100	0	1535	1589	3.5
Orestimba Creek	9-18-91	100	100	0	1042	1020	2.1
Ingram-Hospital	9-26-91	90	100	10	1647	1676	1.8
TID 3	10-9-91	90	90	0	1010	1004	0.6
TID 5	10-24-91	100	100	0	500	506	1.2
Spanish Grant	10-30-91	100	100	0	788	779	1.0
TID 5	11-13-91	100	100	0	1148	1140	0.7
Orestimba Creek	11-25-91	100	100	0	878	882	0.5
Ingram-Hospital	12-4-91	0	0	0	1472	1477	0.2
Spanish Grant	12-11-91	100	100	0	1386	1358	2.0
TID 3	12-18-91	100	100	0	1023	1041	1.8
Merced R[3].	1-5-92	100	100	0	188	225	19.7
Center Rd Drain	1-13-92	100	100	0	1879	1805	3.9
TID 6	1-20-92	0	0	0	850	850	0.0
Ingram-Hospital	2-3-92	100	100	0	1671	1693	1.3
Merced R[3].	2-10-92	100	100	0	141	146	3.5
SJR @ Airport	2-17-92	0	0	0	467	467	0.0

[1]Turlock Irrigation District [2]San Joaquin River [3]Seven day test

Table 5. Continued

Location	Date	Survival: Sample	Survival: Duplicate	Survival: Difference (%)	Electrical Conductivity: Sample	Electrical Conductivity: Duplicate	Electrical Conductivity: Difference (%)
Del Puerto Ck	2-24-92	100	100	0	1065	1149	7.9
TID 6	3-2-92	100	100	0	1172	1170	0.2
Tuolumne R[3].	3-9-92	100	100	0	187	174	7.0
TID 5	3-16-92	100	90	10	1435	1402	2.2
Salt Slough[3]	3-30-92	100	100	0	2260	2330	3.1
Ingram-Hospital	4-6-92	100	100	0	1990	1968	1.1
TID 6	4-13-92	80	100	20	468	486	3.8
Ingram-Hospital	4-20-92	90	80	10	1626	1618	0.5
Ingram-Hospital	5-4-92	0	0	0	1733	1748	0.9
Tuolumne R[3]	5-11-92	90	100	10	81.6	95	16.4
Tuolumne R[3]	5-18-92	100	100	0	286	297	3.9
Ingram-Hospital	5-25-92	0	0	0	1530	1517	0.8
Ingram-Hospital	6-1-92	100	100	0	1548	1557	0.5
Ingram-Hospital	6-15-92	100	100	0	1642	1653	0.7
Ingram-Hospital	6-22-92	80	90	10	1394	1431	2.6

[1]Turlock Irrigation District [2]San Joaquin River [3]Seven day test

Table 6. Summary of percent <u>Ceriodaphnia</u> survival in water samples collected from the San Joaquin in 1991-92. Toxicity was defined as any sample with statistically ($P<0.05$) more death than the laboratory control. These events are indicated by shading. Results are for four day tests unless noted otherwise. Blanks indicate no sample taken.

	1991																		
	2-25	3-4	3-19	4/4	4/18	5-3	5-15	5-28	6-12	6-26	7-2	7-15	7-30	8-16	9-6	9-18	9-26	10-9	10-24
Salt Slough[1]											80	90	100	90	100	100	80		
SJR[2] @ Hills Ferry[1]		100	90	90	70	100	100	90	**0**	100	100	90	100	100	100	100	100	100	90
SJR @ Laird Park[1]	100	100	80	100	100	100	100	80	**0**	100	90	90	100	100	100	90	90	100	100
SJR @ Airport Way[1]	100	80	90	90	90	90	80	80	90	100	100	100	100	100	100	100	100	100	100
Merced R[1].	100	100	100	100	100	100	100	90	100	90								**20**	100
Tuolumne R[1].	100	100	100	100	80	80	100	90	100	100								100	100
Stanislaus R[1].	90		100	100	**50**	100	100	100	**60**	90								80	100
TID[3] 6	100			70			100	**0**		90		**60**		90	90	100		100	
TID 5	100	**0**	**0**	**10**	100	100		100	100	100			100	100	100	100	90		100
TID 3	100	**0**	**0**	**0**	100	100	100		100	100	100	100	90	100	100			90	
Orestimba Ck	**20**	**0**	**0**		**0**	100	**0**	100	90	100	100	90	**0**			100	100	100	90
Del Puerto Ck	100	**0**	**0**	100	80	90	**0**	**0**	100		100	100	100	100	90	100	90	100	100
Ingram-Hospital Cks	100	**0**	**0**	90	100	100	**0**	**0**	**10**	100	100	100		100	**0**	100	90	100	**0**
Spanish Grant Drain	100	**0**	**0**		**50**	90	**0**	**0**	**10**	100	100	90	90	80	100	90	100	100	100
Laboratory Control	100	100	100	90	100	100	100	100	100	100	100	100	90	100	100	100	100	100	100

[1]Results are for a seven day test after 25 November 1991. [2]San Joaquin River. [3]Turlock Irrigation District

Table 6. (Continued).

	1991							1992											
	10-30	11-13	11-25	12-4	12-11	12-18	12-23	1-5	1-13	2-3	2-10	2-17	2-24	3-2	3-9	3-16	3-23	3-30	4-6
Salt Slough[1]														100	90	0	100		100
SJR[2] @ Hills Ferry[1]	100	100	100	100	90	90	90	90	100	90	100	100	100	100	100	20	100	100	100
SJR @ Laird Park[1]	100	100	100	100	100	100	90	100	100	100	90		80		0	100	90	100	70
SJR @ Airport Way[1]	100	100	100	70	90	90	90	100	80	100	100	0	80	90	0	80	100	90	100
Merced R[1]	100	100	100	60	80	90	100	100	100	100	100	0	100	100	40	80	90	90	100
Tuolumne R[1].	100	90	100	90	100	90	100		100	100	80	0	100	100	100	90	100	100	100
Stanislaus R[1]	100	90	100	80	90	90	90	100	80	100		90	90	100		100	80	70	90
TID[3] 6			0		80		90	100	0	0	0	0	100	100	90	100	100	100	0
TID 5	100	100	100	100	90	0	100	40	0	0	0	0	0		0	100	100	100	100
TID 3		100			100	100		0			0	0	0	0	0	0	0	100	
Orestimba Ck		100	100	100	50			100		90	0	0			0		0	100	100
Del Puerto Ck	100	100	100	100		0	0	0	0	0	0	100	100	100	100	70	0	100	10
Ingram-Hospital Cks		100	100	0	90		0	0		100	0	100	0	100	0	0	0	100	100
Spanish Grant Drain	100	100		100	100	70	70	0			10	0	80	100	90	100	0	100	100
Laboratory Control	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100	90

[1]Results are for a seven day test after 25 November 1991. [2]San Joaquin River. [3]Turlock Irrigation District

Table 6. (Continued).

	1992									
	4-13	4-20	4-27	5-4	5-11	5-18	5-25	6-1	6-15	6-22
Salt Slough[1]	0	90	100	70	100	90	100	100	90	90
SJR[2] @ Hills Ferry[1]	100	90	100	100	80	100	100	100	100	100
SJR @ Laird Park[1]	100	100	90	100	90	100	80	100	100	90
SJR @ Airport Way[1]	100	100	70	80	90	90	80	100	100	100
Merced R[1].	0	100	100	90	100		100	100	80	50
Tuolumne R[1].	80	90	90	70	90	100	100	100	90	40
Stanislaus R[1].	90	100	90	60		90	70	100	100	40
TID[3] 6	80	100	90	100	50	100		0	100	100
TID 5		100	100	100	100	100		100	100	100
TID 3	90		80	100	90	100				0
Orestimba Ck	100	20	0	0	0	90	0	100	100	0
Del Puerto Ck	100	100	100	0	0	100	0	100	100	100
Ingram-Hospital Cks	100	90	70	0	0	0	0	100	100	80
Spanish Grant Drain	40	0	0	0	0	0		0	100	0
Laboratory Control	100	100	90	100	100	100	100	100	100	100

[1]Results are for a seven day test after 25 November 1991. [2]San Joaquin River. [3]Turlock Irrigation District

Table 7. Percent frequency of acute *Ceriodaphnia* toxicity in water samples collected from agricultural return flow in the San Joaquin Basin in 1991-92. Values with the same letter are not statistically different (P<0.05).

Season	Frequency of toxicity (%)
January-March	58.9 a
April-June	35.8 a
July-September	7.7 b
October-December	17.8 b

Table 8. Percent frequency of acute *Ceriodaphnia* toxicity in water samples collected from east and westside agricultural return flows during 1991-92. Eastside inputs were Turlock Irrigation District Lateral No. 3, 5 and 6. Westside ones were Orestimba, Del Puerto, and Ingram-Hospital Creeks and the Spanish Grant Combined Drain. Values with the same letter are not statistically different (P>0.05).

	Frequency of toxicity (%)	
Season	Eastside	Westside
January-March	62.2 a	55.1 a
April-June	17.0 b	47.1 a
July-September	7.1 b	8.0 b
October-December	12.5 b	20.6 b

Table 9. Results of spiked organophosphate and carbamate samples prepared by the California Department of Pesticide Regulation and submitted to their Sacramento Laboratory and to the U.S. Geological Survey. U.S. Geological Survey reporting limits for organophosphate and carbamate pesticides were 0.01 and 0.5 ppb, respectively. Department of Pesticide Regulation reporting limits were 0.05 ppb.

Date	Chemical	Nominal Concentration (ppb)	U.S.Geological Survey (ppb)[1]	Department of Pesticide Regulation (ppb)[1]
23 April 1991	diazinon	0.250	0.200 (80%)	0.22 (88%)
	ethyl parathion	0.05	0.04 (80%)	0.05 (100%)
	carbaryl	0.10	<0.50	no analysis
	diazinon	0.10	0.08 (80%)	no analysis
	carbofuran	0.450	<0.5	0.40 (89%)
20 January 1992	chlorpyrifos	0.05	0.04 (80%)	0.05 (100%)
	ethyl parathion	0.05	0.04 (80%)	0.05 (100%)
	diazinon	0.05	0.05 (100%)	0.05 (100%)
	methidathion	0.05	[2]	0.05 (100%)
24 February 1992	chlorpyrifos	0.05	0.03 (60%)	0.05 (100%)
	ethyl parathion	0.05	0.04 (80%)	0.06 (120%)
	diazinon	0.05	0.05 (100%)	0.06 (120%)
	methidathion	0.05	[2]	0.05 (100%)
23 March 1992	carbofuran	0.50	<0.05	0.05 (100%)
	diazinon	0.06	0.04 (67%)	0.06 (100%)
	malathion	0.06	<0.01	0.06 (100%)
	chlorpyrifos	0.06	0.02 (33%)	0.05 (83%)
18 May 1992	diazinon	0.05	0.06 (120%)	no analysis
	fonofos	0.05	0.04 (80%)	no analysis
	chlorpyrifos	0.05	0.03 (60%)	no analysis
	carbaryl	1.0	<0.50	no analysis

[1]Measured concentration (percent recovery) [2]Not in the U.S. Geological Survey organophosphate scan.

Table 10. Data from lagrangian study conducted in cooperation with the California Department of Pesticide Regulation. Bioassays were conducted by Sierra Foothill Laboratory. All samples were analyzed for both organophosphate and carbamate pesticides. U.S. Geological Survey reporting limits for organophosphate and carbamate pesticides were 0.01 and 0.5 ppb, respectively. Department of Pesticide Regulation reporting limits were 0.05 ppb. Blanks indicate no detections.

Dates: 23 to 26 April 1991							
Station	Ceriodaphnia Survival (%) by day				U.S. Geological Survey (ppb)	Department of Pesticide Regulation (ppb)	Difference between laboratories[1]
Salt Slough @ HWY 165[2]	100	100	100	100	diazinon=0.02	diazinon=0.07 oxamyl=0.140	diazinon=-0.05
Mud Slough[2]	100	100	90	90	diazinon=0.02 chlorpyrifos=0.01		
SJR[3] @ HWY 165[2]	80	80	80	80	diazinon=0.05		
Los Banos Creek[2]	100	100	100	100	chlorpyrifos=0.01 diazinon=0.01		
SJR @ Fremont Ford[2]	100	100	100	100	chlorpyrifos=0.01 diazinon=0.21 malathion=0.01	diazinon=0.08 oxamyl=0.120	diazinon=0.13
Newman Wasteway[2]	100	100	100	100	chlorpyrifos=0.01 diazinon=0.01 fonofos=0.01 parathion=0.01		
Merced River[2]	100	100	100	100	chlorpyrifos=0.01		
SJR @ Hills Ferry[2]	90	90	80	80	diazinon=0.09	diazinon=0.08 oxamyl=0.120	diazinon=0.01
Orestimba Creek[4]	100	100	100	100	chlorpyrifos=0.01		
TID[5] 5[4]	0	0	0	0	chlorpyrifos=0.19 diazinon=0.02	chloropyrifos=0.230	chlorpyrifos=-0.04
SJR @ West Main[4]	100	90	70	60	chlorpyrifos=0.09 diazinon=0.06[7]	chloropyrifos=0.08	chlorpyrifos=0.01
Del Puerto Creek[4]	100	100	100	100	chlorpyrifos=0.04 diazinon=0.05[7]		
Tuolumne River[4]	100	100	80[6]	80			
SJR @ Laird Park[4]	100	100	100	100	diazinon=0.06[7] chlorpyrifos=0.07	chloropyrifos=0.05	chlorpyrifos=0.02
Stanislaus River[4]	100	100	100	100	chlorpyrifos=0.01 diazinon=0.01		
Ingram Hospital Creek[4]	100	100	90	90	chlorpyrifos=0.03 parathion=0.02 diazinon=0.04	carbofuran=0.05	
SJR @ Maze Blvd.[4]	100	100	100	100	chlorpyrifos=0.02 diazinon=0.02		
SJR @ Airport Road[4]	100	100	100	100			
Laboratory Control #1	100	100	100	100			
Laboratory Control #2	100	100	100	100			
Dilution Control #1	100	90	90	90			

[1] Dfferences only calculated for insecticides detected by both laboratories. Difference=USGS-DPR. [2]Bioassay laboratory control #1 applies. [3]San Joaquin River. [4]Bioassay laboratory control #2 applies. [5]Turlock Irrigation District. [6] One animal accidentally killed by laboratory personnel. [7] U.S. Geological Survey reported diazinon at concentrations above Department reporting limit. The Department of Pesticide Regulation did not detect the diazinon.

Table 11. Data from lagrangian study conducted in cooperation with the California Department of Pesticide Regulation. Bioassay data was invalidated because of high laboratory control mortality. Organophosphate and carbamate pesticide analysis were conducted by the Department of Pesticide Regulation. Only organophosphate analysis was conducted by the U.S. Geological Survey. U.S. Geological Survey and Department of Pesticide Regulation reporting limits are 0.01 and 0.05 ppb, respectively.

Dates: 27 to 31 January 1992			
Station	California Department of Pesticide Regulation (ppb)	U.S. Geological Survey (ppb)	Difference between laboratories[1]
Salt Slough	organophosphates=nd	diazinon=0.01	
Mud Slough	organophosphates=nd	organophosphates=nd	
SJR[3] @ HWY 165	diazinon=0.150	diazinon=0.03	diazinon=-0.12
Los Banos Creek	organophosphates=nd	diazinon=0.02	
SJR @ Fremont Ford Park	organophosphates=nd	chlorpyrifos=0.01	
Newman Wasteway	diazinon=0.09	diazinon=0.03	diazinon=-0.06
Merced River	diazinon=0.1	chlorpyrifos=0.02 diazinon=0.08	diazinon=-0.02
SJR @ Hills Ferry Road	diazinon=0.09	chlorpyrifos=0.02 diazinon=0.03	diazinon=-0.06
Orestimba Creek	no flow		
TID[4] 5	diazinon=0.45	chlorpyrifos=0.01 diazinon=0.54	diazinon=0.09
SJR @ West Main	diazinon=0.08	chlorpyrifos=0.01 diazinon=0.05	diazinon=-0.03
Del Puerto Creek	no flow		
Tuolumne River	diazinon=0.09	chlorpyrifos=0.01 diazinon=0.04	diazinon=-0.05
SJR @ Laird Park	diazinon=0.09	chlorpyrifos=0.02 diazinon=0.04	diazinon=-0.05
Stanislaus River	diazinon=0.1	chlorpyrifos=0.01 parathion=0.01 diazinon=0.04	diazinon=-0.06
Ingram Hospital Creek	diazinon=0.06	chlorpyrifos=0.01 diazinon=0.09	diazinon=0.03
SJR @ Maze Blvd.	diazinon=0.11	chlorpyrifos=0.01 diazinon=0.07	diazinon=-0.04
SJR @ Airport Road	diazinon=0.09	chlorpyrifos=0.03 diazinon=0.05	diazinon=-0.04

[1] Difference only calculated for insecticides detected by both laboratories. Difference=USGS-DPR. [3]San Joaquin River. [4]Turlock Irrigation District.

Table 12. Summary statistics for pesticide detections in the San Joaquin study 1991-92. The data includes pesticide detections in samples testing both toxic and non toxic in bioassays but does not include information obtained from the two Lagrangian special studies done in cooperation with the Department of Pesticide Regulation.

Pesticides	frequency of detection	number of detections	mean concentration (ppb)	median concentration (ppb)	range	number of samples exceeding NAS[1]	F&G[2]	EPA[3]	Basin Plan[4]	number of samples exceeding lowest *Ceriodaphnia* LOEC[4]
Diazinon	65.4	178	0.14	0.04	0.01-2.60	178	84			52
Chlorpyrifos	55.2	150	0.07	0.02	0.01-1.60		82	45		38
Parathion, ethyl	18.0	49	0.16	0.03	0.01-2.10			31		20
Fonofos	15.4	42	0.07	0.03	0.01-0.54					3
Malathion	5.1	14	0.10	0.01	0.01-0.42			6	6	
Carbaryl	3.6	6	2.9	1.9	0.06-8.4					0
Methomyl	1.8	3	3.7	3.2	2.6-5.4					0
DEF	1.1	2	0.01	0.01	0.01					
Ethion	0.7	2	0.03	0.03	0.01-0.05					
Parathion, methyl	0.4	1	0.02	0.02					0	
Isofenfos	0.4	1	0.07	0.07						
Disyston	0.4	1	0.06	0.06						
Carbofuran	0.6	1	0.8	0.8			1		1	0

[1]National Academy of Sciences Criteria (1973) of 0.009 ppb. [2] California Department of Fish and Game Draft Hazard Assessment Criteria for diazinon, chlorpyrifos and carbofuran of 0.04, 0.015 and 0.4 ppb, respectively (1993a,b;1994a,b). [3]U.S. EPA recommended freshwater criteria to protect aquatic life for chlorpyifos, ethyl parathion and malathion of 0.041, 0.013, and 0.1 ppb, respectively (U.S. EPA 1986b;c;a). [4]Table 13. [4]Basin Plan performance goals for malathion, methyl parathion, and carbofuran of 0.1, 0.13, and 0.4 ppb, respectively (Central Valley Regional Water Quality Control Board, 1990)

Table 13. Reported toxicity to *Ceriodaphnia* of contaminants (ppb) detected in this study. Un-ionized ammonia concentration is reported as mg/l ammonia.

	Toxicity					
Contaminant	96 Hr LC_{50}[1]	48 Hr LC_{50}	24 HR LC_{50}	Pesticide LC_{50} value[8]	OTHER	SOURCE
Ammonia	2.47, 1.35			1.91	4 da NOEC[2]=0.95 4 da LOEC[3]=1.88	Bailey *et al.*, 1995
		3.99			7 da LC_{50}=2.50	per. comm. Tom Willingham
Chlorpyrifos	0.08, 0.13			0.10		per. comm. Robert Fujimura
	0.06				4 da NOEC=0.03, 0.05	Bailey *et al.*, 1995
Diazinon	0.51, 0.47			0.50		per. comm. Robert Fujimura
	0.47, 0.41				4 da NOEC=0.29, 0.33	Bailey *et al.*, in prep
		0.35				Amato *et al.* (1992)
					7 da LOEC<0.08	Hansen *et al.* (1994)
Malathion	1.4			1.4		Norberg-King *et al* (1991)
Oxamyl	103.65			103.65	4 da NOEC[7]=75.0	Issac and Phillips, 1994
Methomyl	5.56			5.56	4 da NOEC[7]=4.0	Issac and Phillips, 1994
Fonofos	0.27			0.27	4 da NOEC[7]=0.19	Issac and Phillips, 1994
Parathion (ethyl)	0.07			0.07	4 da NOEC[7]=0.04	Issac and Phillips, 1994
Carbaryl		11.6		11.6	7 da NOEC[6]=7.2 7 da LOEC[3]=10.6	Oris *et al* (1991)
Methyl Parathion		2.6	5.5		7 da NOEC[2]=1.0	Norberg-King *et al* (1991)
Carbofuran		2.4		2.4	7 da NOEC[2]=1.3 7 da LOEC[3]=2.6	Norberg-King *et al* (1991)

[1]Concentration causing 50 percent mortality in 96 hours. [2]Highest concentration not causing significant mortality in 7 days. [3]Lowest concentration causing significant mortality in 7 days. [6]Lowest concentration causing a significant decrease in reproduction. [7]Highest concentration not causing significant mortality in 4 days. [8]Value used to calculate pesticide or ammonia LC_{50} unit concentration.

Table 14. Water samples collected in the study which tested toxic to *Ceriodaphnia* and contained toxic amounts of insecticide. Insecticide concentration is reported both in ppb and in Ceriodaphnia LC_{50} units (pesticide concentration/96 hr LC_{50} value). The number of LC_{50} units of ammonia in each toxic sample is also reported.

Date	Location	Survival (day^{-1})				Pesticides[1]	Pesticide[3] LC_{50} units	Ammonia LC_{50} unit
25 Feb 91	Orestimba	90	90	40	20	Parathion=0.24(3.4)	3.4	
14 Mar 91	TID[2] 3	0	0	0	0	Chlorpyrifos=0.12(1.2) Parathion=0.37(5.3)	6.5	
	Orestimba	0	0	0	0	Parathion=0.31(4.4)	4.4	
	Del Puerto	30	0	0	0	Parathion=0.13(1.9)	1.9	
	Ingram-Hospital	60	0	0	0	Parthion=0.12(1.7)	1.7	
	Spanish Grant	40	0	0	0	Parthion=0.09(1.3)	1.3	
19 Mar 91	TID 5	0	0	0	0	Chloropyrifos=0.05(0.5) NH_3=13.75(7.2)	0.5	7.2
	TID 3	0	0	0	0	Chloropyrifos=0.23(2.3)	2.3	
	Orestimba	60	0	0	0	Diazinon=0.3(0.6) Chlorpyrifos=0.05(0.5)	1.1	
	Del Puerto	40	0	0	0	Chlorpyrifos=0.12(1.2)	1.2	
	Ingram-Hospital	0	0	0	0	Chlorpyrifos=0.57(5.7)	5.7	
	Spanish-Grant	0	0	0	0	Chlorpyrifos=0.47(4.7) Parathion=0.04(0.6)	5.3	
4 Apr 91	TID 3	100	50	10	0	Chlorpyrifos=0.06(0.6) NH_3=2.25(1.2)	0.6	1.2
18 Apr 91	Orestimba	50	0	0	0	Chlorpyrifos=0.15(1.5)	1.5	
	Spanish Grant	100	90	80	60	Chlorpyrifos=0.11(1.1)	1.1	
18 May 91	Orestimba	0	0	0	0	Chloryprifos=0.12(1.2)	1.2	
	Ingram-Hospital	100	20	0	0	Carbaryl=8.4(0.7)	0.7	
	Spanish Grant	0	0	0	0	Chlorpyrifos=0.22(2.2)	2.2	
28 May 91	TID 6	100	50	0	0	Chlorpyrifos=0.15(1.5)	1.5	
	Del Puerto	0	0	0	0	Diazinon=0.42(0.8) Parathion=0.72(10.3)	11.1	
	Ingram-Hospital	0	0	0	0	Parathion=0.91(9.1)	9.1	
	Spanish-Grant	0	0	0	0	Chlorpyrifos=0.21(2.1) Fonofos=0.20(0.7)	2.8	
12 Jun 91	Spanish Grant	100	100	70	10	Chlorpyrifos=0.08(0.8)	0.8	
30 Jul 91	Orestimba	0	0	0	0	Chlorpyrifos=0.72(7.2)	7.2	
6 Sept 91	Ingram-Hospital	0	0	0	0	Chlorpyrifos=0.33(3.3)	3.3	

[1]ug/l(LC_{50} units) [2]Turlock Irrigation District. [3]Sum of all pesticide LC_{50} units greater than half a unit.

Table 14. (Continued).

Date	Location	Survival (day^{-1})							Pesticides[1]	Pesticide[3] LC_{50} unit	Ammonia LC_{50} unit
24 Oct 91	Ingram-Hospital	0	0	0	0				Methomyl=3.2(0.6)	0.6	
4 Dec 91	Ingram-Hospital	0	0	0	0				Methomyl=2.6(0.5) Diazinon=0.31(0.6) Fonofos=0.28(1.0)	2.1	
18 Dec 91	Del Puerto	0	0	0	0				Parathion=2.1(30)	30.0	
23 Dec 91	Del Puerto	40	40	0	0				Parathion=0.24(3.4)	3.4	
	Ingram-Hospital	100	100	0	0				Parathion=0.16(2.3)	2.3	
5 Jan 92	TID 3	20	0	0	0				Parathion=0.1(1.4)	1.4	
	Del Puerto	0	0	0	0				Parathion=0.51(7.3)	7.3	
	Ingram-Hospital	0	0	0	0				Parathion=0.12(1.7) Methomyl=5.4(0.6)	2.3	
	Spanish Grant	0	0	0	0				Parathion=0.29(4.1)	4.1	
13 Jan 92	TID 6	0	0	0	0				NH_3=1.66(0.9) Chlorpyrifos=0.24(2.4) Parathion=0.05(0.7)	3.1	0.9
	Del Puerto	0	0	0	0				Parathion=0.46(6.6)	6.6	
3 Feb 92	TID 6	100	30	0	0				Chloryprifos=0.05(0.5)	0.5	
	TID 5	100	20	0	0				Diazinon=0.26(0.5) NH_3=2.66(1.4)	0.5	1.4
	Del Puerto	0	0	0	0				NH_3=3.99(2.1) Diazinon=2.6(5.0) Parathion=0.22(3.1)	8.1	2.1
10 Feb 92	TID 6	0	0	0	0				Chlorpyrifos=0.1291.2) Diazinon=0.91(1.8) NH_3=10.64(5.6)	3.0	5.6
	TID 5	0	0	0	0				Diazinon=0.29(0.6) NH_3=9.31(4.9)	0.6	4.9
	TID 3	0	0	0	0				Chlorpyrifos=0.73(7.3) Diazinon=2.6(5.2)	12.5	
	Orestimba	60	0	0	0				Diazinon=0.26(0.5)	0.5	
	Del Puerto	0	0	0	0				Diazinon=1.3(2.6) Parathion=0.07(1.0)	3.6	
	Ingram-Hospital	80	0	0	0				Diazinon=0.24(0.5)	0.5	
	Spanish Grant	100	90	30	10				Chlorpyrifos=0.08(0.8) Parathion=0.12(1.7)	2.5	
17 Feb 92	SJR Airport Way	20	0	0	0	0	0	0	Diazinon=0.28(0.6)	0.6	
	Merced R.	30	0	0	0	0	0	0	Chlorpyrifos=0.05(0.5) Diazinon=0.32(0.6)	1.1	
	Tuolumne R.	100	100	100	50	10	0	0	Diazinon=0.35(0.7)	0.7	
	TID 6	0	0	0	0				Diazinon=0.35(0.7)	0.7	
	TID 5	0	0	0	0				Chlorpyrifos=0.08(0.8) Diazinon=0.5(1.0)	1.8	

Table 14. (Continued).

Date	Location	Survival (day^{-1})	Pesticides[1]	Pesticide LC_{50} units	Ammonia LC_{50} units
17 Feb 92	TID 3	0 0 0 0	Chlorpyrifos=0.83(1.6) Diazinon=0.82(1.6)	3.3	
	Orestimba	20 0 0 0	Parathion=0.04(0.6) Diazinon=0.38(0.8)	1.4	
24 Feb 92	TID 5	0 0 0 0	Diazinon=0.45(0.9) NH_3=2.66(1.4)	0.9	1.4
2 Mar 92	TID 3	80 0 0 0	Diazinon=0.33(0.7)	0.7	
9 Mar 92	TID 5	0 0 0 0	Chlorpyrifos=0.08(0.8)	0.8	
	TID 3	0 0 0 0	Diazinon=0.27(0.5) Chlorpyrifos=0.12(1.2)	1.7	
16 Mar 92	Salt Sl	30 0 0 0	Diazinon=0.33(0.7)	0.7	
	SJR Hills Ferry	100 100 100 20	Diazinon=0.38(0.8)	0.8	
	Ingram Hospital	90 10 0 0	Chlorpyrifos=0.06(0.6)	0.6	
24 Mar 92	Orestimba	0 0 0 0	Chlorpyrifos=0.29(2.9)	2.9	
	Del Puerto	0 0 0 0	Fonofos=0.54(2.0)	2.0	
	Ingram-Hospital	0 0 0 0	Parathion=0.04(0.6) Chlorpyrifos=0.05(0.5) Diazinon=0.29(0.6)	1.7	
	Spanish Grant	0 0 0 0	Chlorpyrifos=0.06(0.6) Parathion=0.11(1.1)	1.7	
6 Apr 92	TID 6	40 0 0 0	Chlorpyrifos=0.14(1.4) NH_3=19.5(10.2)	1.4	
	Del Puerto	100 100 70 10	Fonofos=0.52(1.9)	1.9	
13 Apr 92	Salt Slough	100 90 90 90 90 90 0	Chlorpyrifos=0.12(1.2)	1.2	
	Merced R.	100 100 100 100 100 100 0	Chlorpyrifos=0.13(1.3)	1.3	
20 Apr 92	Orestimba	100 100 90 70	Fonofos=0.21(0.8)	0.8	
27 Apr 92	Orestimba	100 10 0 0	Chlorpyrifos=0.09(0.9)	0.9	
	Spanish Grant	0 0 0 0	Chlorpyrifos=0.19(1.9)	1.9	
4 May 92	Orestimba	0 0 0 0	Chlorpyrifos=0.08(0.8)	0.8	
	Spanish Grant	0 0 0 0	Chlorpyrifos=0.07(0.7)	0.7	
11 May 92	TID 6	100 70 50 50	Chlorpyrifos=0.07(0.7)	0.7	
	Spanish Grant	0 0 0 0	Diazinon=1.2(2.4)	2.4	

Table 14. (Continued).

Date	Location	Survival (day^{-1})				Pesticides[1]	Pesticide[3] LC_{50} units	Ammonia LC_{50} units
18 May 92	Spanish Grant	100	70	0	0	Chlorpyrifos=0.05(0.5)	0.5	
25 May 92	Orestimba	0	0	0	0	Diazinon=0.88(1.8)	1.8	
	Ingram-Hospital	0	0	0	0	Diazinon=1.8(3.6)	3.6	
1 Jun 92	TID 6	0	0	0	0	Chlorpyrifos=0.25(2.5)	2.5	

[1]ug/l(LC_{50} units) [2]Turlock Irrigation District. [3]Sum of all pesticide LC_{50} units greater than half a unit.

Table 15. Pesticide concentrations in water samples testing non toxic to *Ceriodaphnia*. Samples were only submitted for organophosphate pesticide analysis unless noted otherwise. Also included is the sum of the pesticide 96 hour LC_{50} units (pesticide concentration/LC_{50} concentration) for all instances when insecticide concentration was above half a unit. Only one such value was noted (San Joaquin River at Laird Park on 4-23-91). Blanks indicate no pesticide detection.

			Insecticide (ppb)					
Date	(days)	Location	Diazinon	Malathion	Parathion	Chlorpyrifos	Fonofos	sum of LC_{50} units
5-18-91	4	SJR[1] @ Laird Park	0.01			0.01	0.01	
5-18-91	4	SJR @ Airport Way	0.01			0.01		
5-28-91	4	SJR @ Laird Park	0.06		0.03	0.02	0.02	
6-12-91	4	SJR @ Airport Way[2]	0.01					
9-6-91	4	SJR @ Laird Park	0.01					
9-26-91	4	Del Puerto Ck	0.01					
9-26-91	4	SJR @ Laird Park	0.01					
10-9-91	4	Stanislaus River						
10-24-91	4	SJR @ Laird Park	0.01					
10-30-91	4	SJR @ Laird Park	0.01					
11-13-91	4	SJR @ Laird Park	0.01					
12-18-91	4	SJR @ Laird Park			0.01			
12-23-91	4	SJR @ Laird Park			0.01			
1-5-92	7	SJR @ Laird Park	0.02	0.02				
1-13-92	7	SJR @ Laird Park	0.01					
2-3-92	7	SJR @ Laird Park	0.06			0.01		
2-10-92	7	SJR @ Laird Park	0.07					
2-17-92	7	Stanislaus R.	0.06					
2-24-92	7	SJR @ Laird Park	0.08			0.01		
2-24-92	4	TID 6	0.02			0.01		
3-16-92	7	SJR @ Laird Park	0.07	0.08		0.01		
3-24-92	7	SJR @ Laird Park	0.14	0.01		0.01		
3-30-92	7	SJR @ Laird Park	0.03			0.01		
4-13-92	7	SJR @ Laird Park	0.02			0.02		
4-20-92	7	SJR @ Laird Park	0.02			0.03		
4-27-92	7	Salt Slough	0.17					
4-27-92	7	SJR @ Hills Ferry	0.07			0.01		
4-27-92	7	SJR @ Laird Park	0.03			0.02		
4-27-92	7	SJR @ Airport Way				0.01		
4-27-92	7	Merced River					0.01	

San Joaquin River 2/ Isofenfos = 0.074 3/ Turlock Irrigation District

Table 15. (Continued)

Date	(days)	Location	Insecticide (ppb) Diazinon	Malathion	Parathion	Chlorpyrifos	Fonofos	sum of LC_{50} units
4-27-92	7	Tuolumne River				0.01		
4-27-92	4	TID 6				0.01		
4-27-92	4	TID 5	0.01			0.02		
4-27-92	4	TID 3						
4-27-92	4	Del Puerto Ck	0.02			0.03		
4-27-92	4	Ingram Hospital Cks	0.02			0.01		
5-4-92	7	Salt Slough	0.06					
5-4-92	7	SJR @ Hills Ferry	0.06					
5-4-92	7	SJR @ Laird Park	0.02			0.02		
5-4-92	7	SJR @ Airport Way				0.01		
5-4-92	7	Merced River				0.01		
5-4-92	7	Tuolumne River				0.01		
5-4-92	4	TID 6				0.01		
5-4-92	4	TID 5	0.01			0.01		
5-4-92	4	TID 3						
5-11-92	7	Salt Slough	0.02			0.02		
5-11-92	7	SJR @ Hills Ferry	0.02			0.02		
5-11-92	7	SJR @ Laird Park[4]				0.02		
5-11-92	7	SJR @ Airport Way						
5-11-92	7	Merced River						
5-11-92	7	Tuolumne River				0.01		
5-11-92	4	TID 5	0.01			0.05		
5-11-92	4	TID 3	0.01			0.01		
5-18-92	7	Salt Slough	0.03					
5-18-92	7	SJR @ Hills Ferry	0.02					
5-18-92	7	SJR @ Laird Park	0.04			0.01		
5-18-92	7	SJR @ Airport Way	0.05					
5-18-92	7	Merced River	0.01			0.01		
5-18-92	7	Tuolumne River	0.02					
5-18-92	7	Stanislaus River						
5-18-92	4	TID 6						
5-18-92	4	TID 3				0.01		
5-18-92	4	Orestimba Ck	0.07			0.01		

[1] San Joaquin River [2] Isofenfos = 0.074 [3] Turlock Irrigation District [4] disyston=0.06

Table 15. (Continued)

Date	(days)	Location	Insecticide (ppb) Diazinon	Malathion	Parathion	Chlorpyrifos	Fonofos	sum of LC_{50} units
5-18-92	4	Del Puerto Ck	0.01			0.01		
5-25-92	7	Salt Slough	0.04					
5-25-92	7	SJR @ Hills Ferry	0.03					
5-25-92	7	SJR @ Laird Park	0.02					
5-25-92	7	SJR @ Airport Way	0.06					
5-25-92	7	Tuolumne River	0.03			0.01		
5-25-92	7	Merced River						
5-25-92	4	TID 3						
5-25-92	4	TID 5				0.01		
5-25-92	4	Spanish Grant	0.07			0.03	0.02	
6-1-92	7	Salt Slough	0.02					
6-1-92	7	SJR @ Hills Ferry	0.02					
6-1-92	7	SJR @ Laird Park	0.02			0.01		
6-1-92	7	SJR @ Airport Way	0.01					
6-1-92	7	Merced River						
6-1-92	7	Stanislaus River						
6-1-92	7	Tuolumne River	0.01					
6-1-92	4	TID 5				0.01		
6-1-92	4	Orestimba Ck	0.02				0.02	
6-1-92	4	Del Puerto Ck	0.02			0.02	0.01	
6-1-92	4	Ingram-Hospital Cks	0.07					
6-15-92	7	Salt Slough						
6-15-92	7	JR @ Hills Ferry Rd						
6-15-92	7	SJR @ Airport Way						
6-15-92	7	Merced River						
6-15-92	7	Stanislaus River						
6-15-92	4	TID 6						
6-15-92	7	SJR @ Laird Park				0.01		
6-15-92	7	Tuolumne River				0.01		
6-15-92	4	Orestimba				0.01		
6-15-92	4	Del Puerto	0.01			0.01	0.03	
6-15-92	4	Ingram-Hospital	0.01			0.01		
6-15-92	4	Spanish Grant	0.01			0.01		
6-22-92	7	Salt Slough	0.01					

Table 15. (Continued)

Date	(days)	Location	Insecticide (ppb) Diazinon	Malathion	Parathion	Chlorpyrifos	Fonofos	sum of LC_{50} units
6-22-92	7	SJR @ Hills Ferry	0.01					
6-22-92	7	SJR @ Laird Park	0.02			0.01		
6-22-92	7	SJR @ Airport Way						
6-22-92	4	TID 6				0.01		
6-22-92	4	TID 5				0.01		
6-22-92	4	Del Puerto Ck	0.02			0.04		
6-22-92	4	Ingram-Hospital	0.01			0.01		
--Lagrangian cooperative study with the California Department of Pesticide Regulation--								
4-23-91	4	Salt Slough	0.02					
4-23-91	4	Mud Slough	0.02			0.01		
4-23-91	4	SJR @ HWY 165	0.05					
4-23-91	4	Los Banos	0.01			0.01		
4-23-91	4	SJR @ Fremont Ford	0.21	0.01		0.01		
4-23-91	4	Newman Wasteway	0.01		0.01	0.01	0.01	
4-23-91	4	Merced River				0.01		
4-23-91	4	SJR @ Hills Ferry	0.09					
4-23-91	4	Orestimba Ck				0.01		
4-23-91	4	SJR @ Laird Park	0.06			0.07(0.7)		0.7
4-23-91	4	Tuolumne River						
4-23-91	4	Del Puerto Ck	0.05			0.04		
4-23-91	4	Stanislaus River	0.01			0.01		
4-23-91	4	Ingram-Hospital Ck	0.04		0.02	0.03		
4-23-91	4	SJR @ Maze Blvd	0.02			0.02		
4-23-91	4	SJR @ Airport Way						

Table 16. Water samples which tested toxic in biossays but did not appear to contain sufficient toxic material to explain the observed bioassay results. See text for selection criteria.

Date	Location	Survival (day^{-1})							Contaminants[1] (ppb)
18 April 91	Stanislaus R.	100	90	50	50				
18 May 91	Ingram-Hospital	0	0	0	0				Chloropyrifos=0.01 Fonofos=0.06 Diazinon=0.03 Carbaryl=8.4(0.7)
12 June 91	SJR @ Hills Ferry	0	0	0	0				Chlorpyrifos=0.01 Diazinon=0.01
9 Oct 91	Merced R.	90	80	80	70				
24 Oct 91	Ingram-Hospital	0	0	0	0				Methomyl=3.2(0.6) Fonofos=0.05 Diazinon=0.19
10 Feb 92	Orestimba	60	0	0	0				Chloropyrifos=0.02 Parathion=0.01 Diazinon=0.26(0.5)
10 Feb 92	Ingram-Hospital	80	0	0	0				Chlorpyrifos=0.01 Fonofos=0.02 Diazinon=0.24(0.5) Parathion=0.02
17 Feb 92	SJR @ Airport	20	0	0	0				Chlorpyrifos=0.02 Parathion=0.01 Diazinon=0.28(0.6)
17 Feb 92	TID 6	0	0	0	0				Chlorpyrifos=0.04 Malathion=0.01 Diazinon=0.35(0.7) Parathion=0.01
17 Feb 92	Spanish Grant	40	0	0	0				Diazinon=0.06 Parathion=0.01
24 Feb 92	TID 3	0	0	0	0				Chlorpyrifos=0.03 Diazinon=0.23
24 Feb 92	Ingram-Hospital	100	0	0	0				Chlorpyrifos=0.01 Parathion=0.01 Diazinon=0.2
2 Mar 92	TID 3	80	0	0	0				Chlorpyrifos=0.04 Diazinon=0.33(0.7)
9 Mar 92	SJR @ Laird Park	100	90	90	40	0	0	0	Chlorpyrifos=0.04 Diazinon=0.04
9 Mar 92	SJR @ Airport Way	100	100	100	90	40	0	0	Chlorpyrifos=0.03 Diazinon=0.04
9 Mar 92	Merced R.	100	100	100	100	100	80	40	Chlorpyrifos=0.01 Parathion=0.01 Diazinon=0.04
9 Mar 92	TID 5	0	0	0	0				Chlorpyrifos=0.08(0.8) Diazinon=0.08

[1]Value in brackets is the number of pesticide LC_{50} units.

Table 16. (Continued).

Date	Location	Survival (day^{-1})							Contaminants[1] (ppb)
9 Mar 92	Ingram-Hospital	0	0	0	0				Chlorpyrifos=0.01 Fonofos=0.01 Diazinon=0.06
16 Mar 92	Salt Slough	30	0	0	0				Chlorpyrifos=0.01 Malathion=0.16 Diazinon=0.33(0.7)
16 Mar 92	TID 3	100	100	0	0				Chlorpyrifos=0.04 Diazinon=0.18
23 Mar 92	TID 3	90	0	0	0				
13 Apr 92	Spanish Grant	100	100	80	40				Diazinon=0.03
20 Apr 92	Spanish Grant	50	0	0	0				
4 May 92	Stanislaus R.	100	90	80	80	60	60	60	
4 May 92	Orestimba	0	0	0	0				Chlorpyrifos=0.08(0.8) Fonofos=0.03
4 May 92	Del Puerto	100	100	0	0				Chlorpyrifos=0.02 Diazinon=0.01
4 May 92	Ingram-Hospital	0	0	0	0				Carbaryl=2.0 Chlorpyrifos=0.02 Diazinon=0.01
4 May 92	Spanish Grant	0	0	0	0				Chlorpyrifos=0.07(0.7) Fonofos=0.07 Diazinon=0.01
11 May 92	Orestimba	70	0	0	0				Ethion=0.01 Diazinon=0.18 Chlorpyrifos=0.02 Fonofos=0.02
11 May 92	Del Puerto	100	100	20	0				Chlorpyrifos=0.02 Fonofos=0.03
11 May 92	Ingram-Hospital	0	0	0	0				Carbaryl=2.8 Chlorpyrifos=0.01 Diazinon=0.06
18 May 92	Ingram-Hospital	0	0	0	0				Chlorpyrifos=0.01 Diazinon=0.05 Carbaryl=0.6
25 May 92	Stanislaus R.	100	100	100	100	100	100	70	
25 May 92	Del Puerto	100	100	30	0				Chlorpyrifos=0.01 Diazinon=0.2
22 June 92	Merced R.	100	100	100	80	80	60	50	
22 June 92	Tuolumne R.	100	100	90	70	70	50	40	Diazinon=0.01
22 June 92	TID 3	100	100	100	0				NH_3=1.2
22 June 92	Orestimba	100	0	0	0				Chlorpyrifos=0.02 Fonofos=0.01 Diazinon=0.03
22 June 92	Spanish Grant	0	0	0	0				Chlorpyrifos=0.01 Fonofos=0.01 Diazinon=0.22 Ethion=0.05(?) Diazinon=0.01

[1]Value in brackets is the number of pesticide LC_{50} units.

Table 17. Water samples collected in the study which tested toxic to *Ceriodaphnia* and contained toxic amounts of un-ionized ammonia. Ammonia is reported in terms of *Ceriodaphnia* LC_{50} units. The number of LC_{50} units of insecticide in each sample is also reported.

Date	Location	Survival (day^{-1})				Ammonia (LC_{50} units)	Pesticide (LC_{50} units)
4 Mar 91	TID 5	0	0	0	0	1.9	
19 Mar 91	TID 5	0	0	0	0	7.2	0.5
4 Apr 91	TID 5	80	10	10	10	1.4	
4 Apr 91	TID 3	100	50	10	0	1.2	0.6
25 Nov 91	TID 6	50	0	0	0	1.0	
18 Dec 91	TID 5	30	20	0	0	1.6	
5 Jan 92	TID 5	80	60	40	40	7.2	
13 Jan 92	TID 6	0	0	0	0	0.9	
13 Jan 92	TID 5	100	90	30	0	2.8	
3 Feb 92	TID 5	100	20	0	0	1.4	0.5
3 Feb 92	Del Puerto	0	0	0	0	2.1	4.4
10 Feb 92	TID 6	0	0	0	0	5.6	3.0
10 Feb 92	TID 5	0	0	0	0	4.9	0.6
24 Feb 92	TID 5	0	0	0	0	1.4	0.9

Table 18. Water samples collected in the study which contained toxic concentrations of un-ionized ammonia but did not test toxic in bioassays. Ammonia concentrations are reported in terms of *Ceriodaphnia* LC_{50} units.

Date	Location	Ammonia (LC_{50} units)
6 Sept 91	TID 5	0.6
9 Oct 91	TID 5	0.9[1]
13 Nov 91	TID 5	0.9[2]
25 Nov 91	TID 5	0.7
11 Dec 91	TID 5	0.6
23 Dec 91	TID 5	0.6
2 Mar 92	TID 6	1.2[3]

[1]Total ammonia in both duplicate samples was 6.0 mg/l.
[2]Total ammonia in both duplicate samples was 7.0 mg/l.
[3]Total ammonia in both duplicate samples was 8.0 mg/l.

Table 19. Pesticide and ammonia concentration in water samples collected from the San Joaquin River at Laird Park. All samples were analyzed for carbamate and organophosphorus pesticides and for ammonia. Samples tested non toxic in bioassays unless noted otherwise. No carbamate insecticides were detected.

Date	Diazinon	Chlorpyrifos	Parathion	Fonofos	Malathion	Ammonia
	Insecticides (ppb)					
4-24-91[1]	0.06	0.07				
5-15-91[2]	0.01	0.01		0.01		
5-28-91	0.06	0.02	0.03	0.02		
6-12-91[3,4]						
9-6-91	0.01					
9-26-91	0.01					
10-24-91	0.01					
10-30-91	0.01					
11-13-91	0.01					
12-18-91			0.01			
12-23-91			0.01			
1-15-92	0.02		0.02			
1-13-92	0.01					
1-20-92	0.01	0.01				0.53
1-28-92[1]	0.04	0.02				
2-3-92	0.06	0.01				
2-10-92	0.07					
2-19-92	0.10	0.02	0.01			
2-24-92	0.08	0.01				
3-9-92[3]	0.04	0.04				
3-16-92	0.07	0.01			0.08	
3-23-92	0.14	0.01			0.01	
3-30-92	0.03	0.01				
4-6-92[3]	0.02			0.01		
4-13-92	0.02	0.02				
4-20-92	0.02	0.03				
4-27-92	0.03	0.02				
5-4-92	0.02	0.02				
5-11-92[6]		0.02				
5-18-92	0.04	0.01				
5-25-92	0.02					
6-1-92	0.02	0.01				
6-15-92		0.01				
6-22-92	0.02	0.01				

[1]Lagrangian Survey. [2]Extraction not done for two months, chemical concentrations may be low. [3]Sample tested toxic to <u>Ceriodaphnia</u>. Chemical cause of toxicity not known. [4]Carbamate bottle broken, organophosphates=nd. [5]Organophosphate bottle broken, carbamates=nd. [6]Disyston = 0.06 ppb.

Table 20. Mean baseline pesticide concentrations (ppb) between 27 April and 22 June, 1992, in water bodies tributary to the San Joaquin River[1]. Values with the same letter are not statistically different (P>0.05, Kruskall-Wallis and Dunn mean separation test).

Site	Diazinon	Chlorpyrifos	Fonofos
Merced	[2] (7) a	0.006 a	[2] a
Tuolumne	0.011 (8) c	0.008 b	[2] a
Stanislaus	[2] (7) a	0.006 a	[2] a
TID 6	[2] (7) a	0.058 c d	[2] a
TID 5	0.008 (8) b	0.015 c	[2] a
TID 3	0.011 (6) b c	0.008 b	[2] a
Orestimba	0.150 (8) d	0.034 c	0.020 b
Del Puerto	0.064 (8) d	0.020 c	0.011 b
Ingram-Hospital	0.254 (8) d	0.011 c	[2] a
Spanish Grant	0.179 (8) d	0.071 d	0.030 b
Salt Slough	0.044 (8) d	[2] a	[2] a

[1]Non-detections were assigned, for computational purposes, a value of one half the reporting limit (0.005). [2]Site with no pesticide detection. [3]Mean (sample size).

Table 21. Comparisons of the precent frequency of toxicity of water samples collected in the San Joaquin River watershed during 1988-90 and 1991-92. The 1988-90 data are from Foe and Connor (1991) while the 1991-92 values are from the present study.

	Percent frequency of toxicity		
Site	1988-90	1991-92	
Salt Slough	8.3	10.0	
SJR[1] @ Hills Ferry	25.0	4.3	NS[3]
SJR @ Laird Park	41.7	4.3	P<0.05
SJR @ Airport Way	8.3	4.2	
TID[2] 5	75.0	26.8	P<0.05
Orestimba Ck	41.6	44.7	
Merced R.	16.7	15.0	
Tuolumne R.	8.3	5.0	
Stanislaus R.	0.0	10.8	NS

[1]San Joaquin River
[2]Turlock Irrigation District
[3]Chi-sqaure test

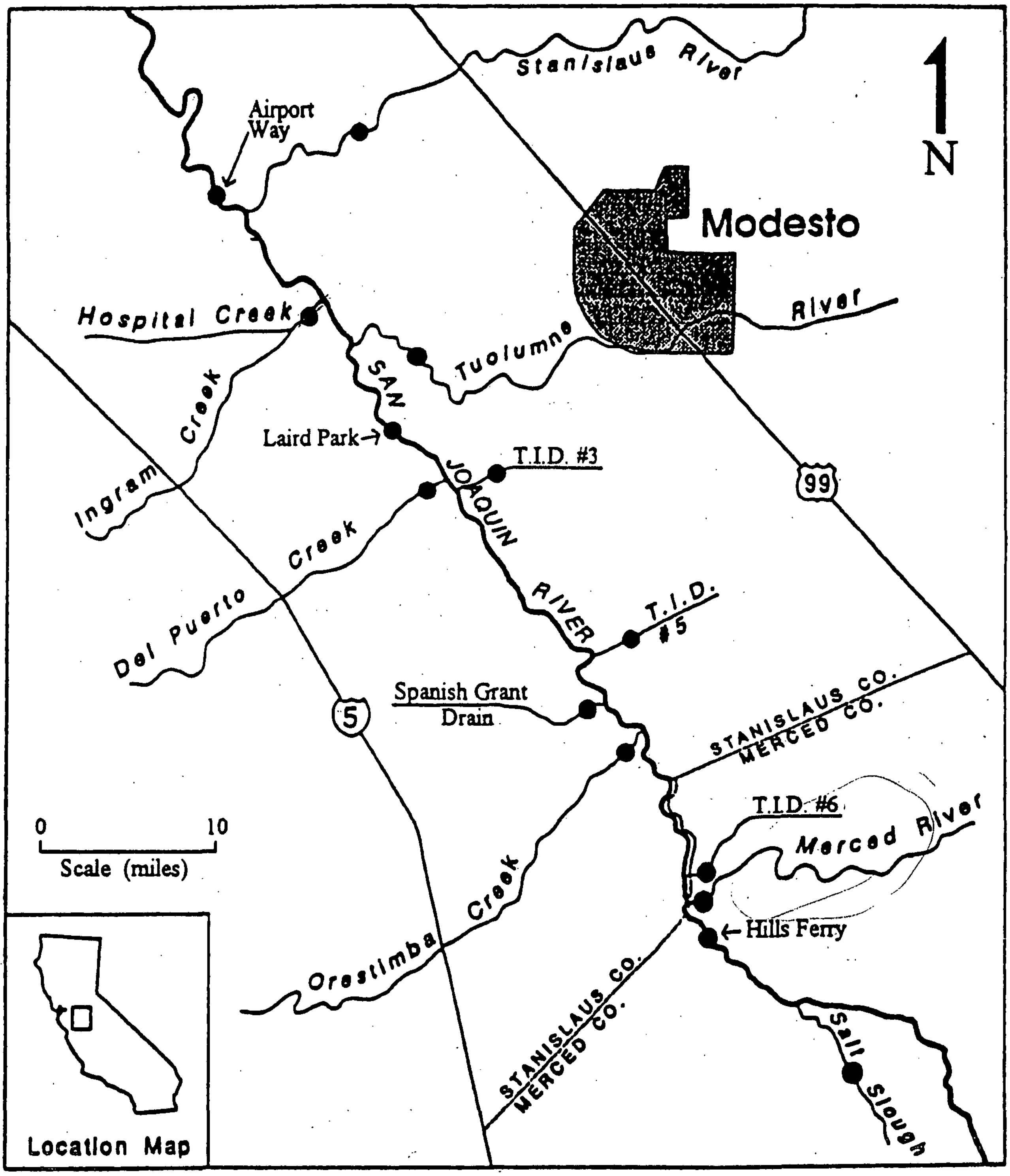


Figure 1. Map of San Joaquin Basin study sites.

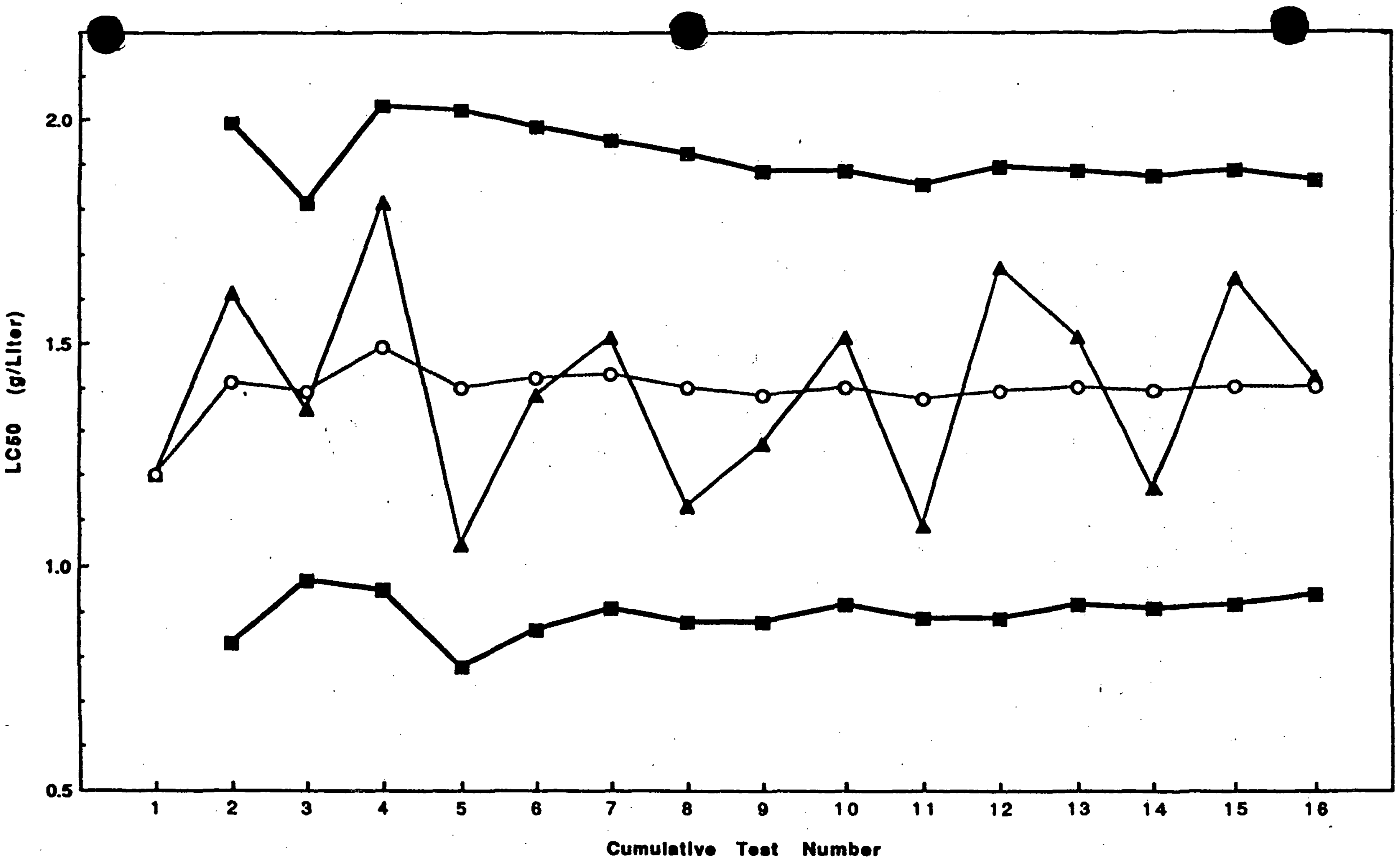


Figure 2. Control chart for the 96 hour *Ceriodaphnia* sodium chloride reference toxicant testing. Individual monthly LC_{50} values are plotted as triangles, the long-term LC_{50} mean as open circles, and the upper and lower 95 percent confidence limits of the long-term mean as solid squares. No individual LC_{50}value ever exceeded either the upper or lower control value.

APPENDIX A

ESTIMATED UNIMPAIRED FLOWS FOR SAN JOAQUIN BASIN

Table 1. Comparison of seasonal and annual unimpaired flows (acre-feet) for the San Joaquin River for water years 1983[1]-1985 and 1991-92. Data is from the San Joaquin River input-output model described in Kratzer *et al.* (1987). 1983 was classified as wet, 1984 as normal, 1985 as dry, and both 1991-92 as critically dry water year types.

Irrigation Season (March-September)					
	1983[2]	1984	1985	1991	1992
East-side tribs	10,032,810(94.9)	1,060,020(64.6)	685,286(57.5)	264,957(51)	280,670(49.3)
Salt Slough	164,971(1.6)	108,798(6.6)	124,007(10.4)	58,176(11.2)	45,393(8.0)
Mud Slough	31,420(0.3)	23,524(1.4)	50,856(4.3)	10,409(2.0)	8,361(1.5)
Groundwater	68,220(0.6)	81,408(5.0)	42,021(3.5)	18,139(3.5)	46,066(8.1)
Surface return flows[3]	266,959(2.5)	358,907(21.9)	281,207(23.6)	162,237(31)	181,299(31.8)
Subsurface return flows	8,152(0.1)	9,308(0.6)	7,561(0.6)	5,983(1.2)	7,532(1.3)
Total for Basin	10,572,590(100)	1,641,965(100)	1,190,938(100)	519,901(100)	569,321(100)

Non-irrigation season (September-March)					
	1983	1984	1985	1991	1992
East-side Tributaries	4,597,785(95.8)	4,584,949(95.3)	984,716(86.6)	158,421(75.5)	253,346(74.2)
Salt Slough	61,923(1.3)	52,332(1.1)	34,588(3.0)	28,426(13.5)	29,359(8.6)
Mud Slough	87,640(1.8)	70,195(1.5)	45,107(4.0)	922(0.9)	7,989(2.3)
Groundwater	12,720(0.3)	34,214(0.7)	27,122(2.4)	6,202(3.0)	30,690(9.0)
Surface return flows	37,294(0.8)	64,659(1.3)	43,053(3.8)	13,144(6.3)	17,337(5.1)
Subsurface return flows	2,052(0.0)	2,826(0.)	2,843(0)	1,823(0.9)	2,811(0.8)
Total for Basin	4,799,414(100)	4,809,176(100)	1,137,430(100)	209,938(100)	341,533(100)

[1]The 1987 water year is defined as the time interval from 1 October 1987 to 30 September 1988
[2]Flow in acre-feet water(%)
[3]Surface return flows from agriculturally dominated natural creeks and constructed drains.

Table 1. (Continued)

	Full year				
	1983	1984	1985	1991	1992
East-side Tributaries	14,630,650(95.2)	5,644,969(87.5)	1,670,002(71.7)	423,378(58)	534,016(58.6)
Salt Slough	226,894(1.5)	161,130(2.5)	158,596(6.8)	86,602(11.9)	74,752(8.2)
Mud Slough	119,060(0.8)	93,719(1.5)	95,964(4.1)	12,331(1.7)	16,350(1.8)
Groundwater	80,940(0.5)	115,622(1.8)	69,143(3.0)	24,341(3.3)	76,756(8.4)
Surface return flows	304,253(2.0)	423,566(6.6)	324,259(13.9)	175,381(24.0)	198,635(21.8)
Subsurface return flows	10,203(0.1)	12,135(0.2)	10,405(0.4)	7,806(1.1)	10,343(1.1)
Total for Basin	15,372,000(100)	6,451,140(100)	2,328,368(100)	729,839(100)	910,853(100)

[1]The 1987 water year is defined as the time interval from 1 October 1987 to 30 September 1988
[2]Flow in acre-feet water(%)
[3]Surface return flows from agriculturally dominated natural creeks and man constructed drains.

APPENDIX B

BIOASSAY WATER QUALITY DATA

Table 1. Bioassay water quality measurement

Date: 25 February 1991								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
Salt Sl	7.9	8.1	2580/2000	2020	7.2	7.0	<2.0	27
SJR[6] @ Laird Park	8.0	8.3	2160/1876	1925	7.6	7.0	<2.0	17
SJR @ Airport Way	8.1	8.3	1136	1180	8.1	6.0	<2.0	
Merced R	7.8	8.2	374	420	7.7	7.2	<2.0	
Tuolumne R	7.9	8.2	300	337	7.6	7.0	<2.0	
Stanislaus R.	7.9	8.1	157	181	8.2	7.0	<2.0	
TID[7] 6	8.2	8.3	1251	1271	9.6	7.1	<2.0	
TID 5	8.7	8.7	2050	2100	8.8	7.4	<2.0	
TID 5 - chemical duplicate	8.7	8.7	2060	2110	8.8	7.0	<2.0	
TID 3	8.0	8.6	1046	1080	7.9	7.9	<2.0	
Orestimba Ck	8.4	8.6	1366	1360	8.3	7.2	<2.0	
Del Puerto Ck	used for water chemistry duplicate							
Ingram-Hospital Cks	8.6	8.6	2050	2070	8.8	7.0	<2.0	
Spanish Grant Combined Drain	8.4	8.4	2160/1925	1930	8.2	6.8	<2.0	17
Laboratory control	8.4	8.3	217	239	8.6	7.2	<2.0	
Dilution control								

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District.

Table 1. (Continued).

Date: 4 March 1991								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
SJR[6] @ Hills Ferry	8.1	8.6	2010	1996	8.8	8.2	<2.0	
SJR @ Laird Park	8.0	8.4	1427	1454	8.8	7.9	<2.0	
SJR @ Airport Way	8.0	8.3	1082	1090	8.4	8.2	<2.0	
SJR @ Airport Way - chemical duplicate	8.2	8.7	1076	1089	8.4	7.8	<2.0	
Merced R.	7.6	8.0	120	133	8.6	8.0	<2.0	
Tuolumne R.	7.8	8.3	262	269	8.5	8.0	<2.0	
Stanislaus R.	used for water chemistry duplicate							
TID[7] 6	7.9	8.3	167	184	8.8	8.1	<2.0	
TID 5	8.1	8.7	1740	1702	6.8	7.4	15.0	
TID 3	7.8	8.2	387	402	7.4	7.6	2.5	
Orestimba Ck	8.1	8.2	799	803	8.6	8.1	<2.0	
Del Puerto Ck	8.4	8.5	909	938	8.8	7.8	3.5	
Ingram-Hospital Cks	8.2	8.4	1309	1298	8.8	8.1	<2.0	
Spanish Grant Combined Drain	7.9	8.2	795	827	9.0	8.0	<2.0	
Laboratory control	7.4	8.2	167	227	8.6	8.0	<2.0	
Dilution control								

[1] Electrical conductivity (μmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}}$ X 100 [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 19 March 1991								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
SJR[6] @ Hills Ferry	8.2	8.5	2110	2180	8.3	7.2	<2.0	
SJR @ Laird Park	8.2	8.5	1559	1629	8.1	7.4	<2.0	
SJR @ Airport Way	8.2	8.5	1265	1284	8.0	7.4	<2.0	
Merced R.	7.9	8.1	139	151	8.0	7.4	<2.0	
Tuolumne R.	8.1	8.2	260	276	8.0	7.4	<2.0	
Stanislaus R.	8.1	8.0	131	153	8.0	7.2	<2.0	
TID[7] 6	used for water chemistry duplicate							
TID 5	8.1	8.7	1630	1552	6.2	7.5	58.0	
TID 3	8.4	8.4	591	620	6.8	7.8	<2.0	
Orestimba Ck	8.3	8.3	904	944	8.0		<2.0	
Orestimba Ck - chemistry duplicate	8.2	8.2	910	918	8.4		<2.0	
Del Puerto Ck	8.7	8.7	978	982	8.4		<2.0	
Ingram-Hospital Cks	8.5	8.7	1875	1962	8.4	7.8	<2.0	
Spanish Grant Combined Drain	8.3	8.6	1916	1947	7.8	7.9	<2.0	
Laboratory control	7.9	8.0	197	247	8.2	7.4	<2.0	
Dilution control								

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{(\text{volume dilution water + volume sample})}$ X 100 [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 4 April 1991								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
SJR[6] @ Hills Ferry	8.2	8.4	2300/2060	2070	9.8	8.1	<2.0	14
SJR @ Hills Ferry - chemistry duplicate	8.5	8.8	2440/2080	2030	9.8	8.0	<2.0	21
SJR @ Laird Park	8.0	8.6	1615	1608	9.4	8.0	<2.0	
SJR @ Airport Way	8.0	8.5	1274	1260	9.4	8.0	<2.0	
Merced R.	7.7	8.1	169	217	9.6	8.1	<2.0	
Tuolumne R.	7.9	8.1	277	288	9.4	8.0	<2.0	
Stanislaus R.	7.9	8.2	180	194	9.8	8.1	<2.0	
TID[7] 6	8.4	8.7	1069	1043	8.9	8.1	<2.0	
TID 5	7.9	8.7	1032	1035	8.9	7.8	11.4	
TID 3	8.0	8.9	1136	1072	8.5	7.9	7.0	
Orestimba Ck	No flow							
Del Puerto Ck	8.0	8.9	1505	1458	8.7	8.2	<2.0	
Ingram-Hospital Cks	8.2	8.7	1994	1934	9.7	8.2	<2.0	
Spanish Grant Combined Drain	used for water chemistry duplicate							
Laboratory control	7.9	8.5	267	266	8.6	7.6	<2.0	
Dilution control	8.1	8.4	187	196	8.6	8.3	<2.0	

[1] Electrical conductivity (μmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 18 April 1991								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5]
	start	end	start[4]	end	start	end		(%)
SJR[6] @ Hills Ferry	8.1	8.5	2870/2100	2100	8.4	8.0	<2.0	30
SJR @ Laird Park	8.1	8.8	2010	2010	8.4	8.1	<2.0	
SJR @ Airport Way	8.5	8.7	1500	1529	8.8	8.2	<2.0	
Merced R.	8.0	8.5	308	296	8.4	8.1	<2.0	
Tuolumne R.	8.0	8.3	290	278	8.3	7.9	<2.0	
Stanislaus R.	8.0	8.2	170	188	8.5	8.0	<2.0	
TID[7] 6	used for water chemistry duplicate							
TID 5	7.9	8.7	899	916	8.0	7.8	<2.0	
TID 5 - chemistry duplicate	7.9	8.7	900	915	7.9	8.0	<2.0	
TID 3	8.0	8.8	670	684	8.3	8.0	<2.0	
Orestimba Ck	8.1	8.5	1084	1108	8.0	7.8	<2.0	
Del Puerto Ck	8.6	8.8	1806	1848	8.6	8.0	<2.0	
Ingram-Hospital Cks	8.7	8.7	2000	2000	8.5	7.9	<2.0	
Spanish Grant Combined Drain	8.3	8.8	1452	1460	8.3	8.0	<2.0	
Laboratory control	8.1	8.4	177	182	8.6	8.1	<2.0	
Dilution control	7.9	8.4	148	156	8.6	7.9	<2.0	

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 3 May 1991								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
SJR[6] @ Hills Ferry	8.0	8.4	2980/2000	2050	10.6	8.4	<2.0	38
SJR @ Laird Park	8.1	8.6	1890	1859	9.8	8.4	<2.0	
SJR @ Airport Way	8.0	9.4	400	457	12.0	8.4	<2.0	
Merced R.	7.8	8.2	231	278	1.06	8.2	<2.0	
Tuolumne R.	7.7	7.8	60	78	10.8	8.2	<2.0	
Stanislaus R.	7.6	7.9	102	138	11.6	8.2	<2.0	
TID[7] 6	used for water chemistry duplicate							
TID 5	7.8	8.4	525	547	10.6	8.0	<2.0	
TID 5 - chemistry duplicate	7.9	8.4	525	577	11.2	8.2	<2.0	
TID 3	7.9	8.5	700	720	10.8	8.2	<2.0	
Orestimba Ck	8.3	8.6	1000	1017	11.2	8.0	<2.0	
Del Puerto Ck	8.3	8.6	1510	1534	11.2	8.2	<2.0	
Ingram-Hospital Ck	8.1	8.6	1618	1610	10.6	8.0	<2.0	
Spanish Grant Combined Drain	8.1	8.6	1443	1447	10.4	8.0	<2.0	
Laboratory control	8.1	8.4	300	303	8.6	8.2	<2.0	
Dilution control	7.9	8.3	188	180	8.6	8.0	<2.0	

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 15 May 1991								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
SJR[6] @ Hills Ferry	8.3	8.4	2900/2050	2070	9.3	8.6	<2.0	35
SJR @ Laird Park	8.4	8.6	1743	1749	10.4	8.7	<2.0	
SJR @ Airport Way	8.7	8.5	899	924	10.6	8.7	<2.0	
Merced R.	8.1	8.2	203	228	8.8	8.6	<2.0	
Tuolumne R.	7.9	8.3	220	227	8.8	8.6	<2.0	
Stanislaus R.	7.9	8.2	128	151	9.2	8.7	<2.0	
TID[7] 6	7.8	8.6	1028	1005	8.1	8.4	<2.0	
TID 6 - chemical duplicate	7.8	8.6	1020	1010	8.1	8.3	<2.0	
TID 5	used for water chemistry duplicate							
TID 3	7.9	8.7	684	716	8.7	8.6	<2.0	
Orestimba Ck	8.2	8.3	929	891	9.2	7.9	<2.0	
Del Puerto Ck	8.5	8.4	1496	1505	9.4	7.8	<2.0	
Ingram-Hospital Cks	8.4	8.4	1641	1605	8.9	7.8	<2.0	
Spanish Grant Combined Drain	8.1	8.1	1600	1595	8.7	7.7	<2.0	
Laboratory control	8.1	8.5	287	288	8.7	8.6	<2.0	
Dilution control	7.9	8.3	198	203	8.7	8.5	<2.0	

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 28 May 1991								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
SJR[6] @ Hills Ferry	8.0	8.4	2400/2099	2100	8.2	8.0	<2.0	17
SJR @ Laird Park	8.3	8.6	1799	1795	9.0	8.0	<2.0	
SJR @ Airport Way	8.6	8.5	819	865	9.7	7.9	<2.0	
Merced R.	7.9	8.3	335	373	8.7	8.2	<2.0	
Tuolumne R.	7.7	8.2	219	241	8.5	8.0	<2.0	
Stanislaus R.	7.7	8.1	151	172	8.4	8.1	<2.0	
TID 6	7.4	8.5	627	642	10.8	7.8	<2.0	
TID 5	7.8	8.5	781	787	8.2	7.8	<2.0	
TID 3	7.9	8.8	898	836	8.2	7.6	<2.0	
Orestimba Ck	8.4	8.7	1120	1150	8.6	8.0	<2.0	
Del Puerto Ck	8.5	8.7	1707	1709	8.4	7.4	<2.0	
Ingram-Hospital Cks	8.2	8.7	1657	1635	8.5	7.8	<2.0	
Spanish Grant Combined Drain	8.2	8.7	1504	1486	8.8	7.7	<2.0	
Laboratory control	8.1	8.3	223	250	8.7	8.1	<2.0	
Dilution control	7.9	8.3	187	193	8.7	8.0	<2.0	

[1] Electrical conductivity (μmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] Volume dilution water / (volume dilution water + volume sample) X 100 [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Site	pH start	pH end	EC[1] start[4]	EC[1] end	DO[2] start	DO[2] end	NH_3-N[3]	dilution[5] (%)
Date: 12 June 1991								
SJR[6] @ Hills Ferry	7.9	8.3	2620/2030	1999	8.1	8.2	<2.0	29
SJR @ Laird Park	8.8	8.6	2010	1999	10.6	8.3	<2.0	
SJR @ Airport Way	9.5	8.5	1149	1175	10.8	7.6	<2.0	
Merced R.	8.0	8.7	815	832	8.5	7.7	<2.0	
Tuolumne R.	8.1	8.4	403	438	9.0	7.4	<2.0	
Stanislaus R.	8.1	8.1	142	173	8.4	7.5	<2.0	
TID[7] 6	used for water chemistry duplicate							
TID 5	7.7	8.5	773	788	7.8	7.5	3.0	
TID 3	7.8	8.7	838	849	7.9	7.4	<2.0	
TID 3 - chemistry duplicate	7.6	8.4	916	902	6.4	7.2	<2.0	
Orestimba Ck	8.2	8.6	1076	1085	8.0	7.4	<2.0	
Del Puerto Ck	8.5	8.6	1484	1496	8.6	7.4	<2.0	
Ingram-Hospital Cks	8.9	8.6	1994	1990	8.7	7.4	<2.0	
Spanish Grant Combined Drain	8.0	8.6	1621	1641	7.5	7.4	<2.0	
Laboratory control	8.1	8.4	287	288	8.6	7.4	<2.0	
Dilution control	7.9	8.3	157	169	8.7	7.5	<2.0	

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 26 June 1991								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
SJR[6] @ Hills Ferry	8.2	8.4	2050	2060	8.1	7.4	<2.0	
SJR @ Laird Park	8.6	8.6	1830	1887	10.4	7.6	<2.0	
SJR @ Airport Way	8.3	8.4	935	1015	10.5	7.7	<2.0	
Merced R.	8.3	8.4	415	458	8.9	7.4	<2.0	
Tuolumne R.	8.5	8.5	477	515	9.5	7.4	<2.0	
Stanislaus R.	8.2	8.2	126	176	8.7	7.2	<2.0	
TID[7] 6	7.5	8.7	1044	1054	7.6	7.2	<2.0	
TID 5	7.8	8.6	1110	1140	8.3	7.1	3.0	
TID 3	8.2	8.5	555	619	8.8	7.2	<2.0	
Orestimba Ck	8.3	8.6	1200	1232	8.7	7.2	<2.0	
Del Puerto Ck	used for water chemistry duplicate							
Ingram-Hospital Cks	8.8	8.6	1770	1804	8.6	7.2	<2.0	
Spanish Grant Combined Drain	8.1	8.6	1736	1785	8.4	7.0	<2.0	
Spanish Grant Combined Drain -chemistry duplicate	8.5	8.6	1771	1804	8.9	7.2	<2.0	
Laboratory control	7.9	8.3	241	301	8.6	7.2	<2.0	

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 2 July 1991								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
Salt Sl @ HWY 165	8.1	8.4	1336	1318	8.1	7.8	<2.0	
SJR[6] @ Hills Ferry	8.3	8.5	1794	1785	8.1	7.8	<2.0	
SJR @ Laird Park	8.5	8.6	1628	1634	8.9	7.8	<2.0	
SJR @ Airport Way	8.1	8.5	904	952	10.8	7.9	<2.0	
SJR @ Airport Way -chemistry duplicate	8.1	8.6	909	933	8.2	7.9	<2.0	
TID[7] 6	no flow							
TID 5	used for water chemistry duplicate							
TID 3	8.3	8.7	693	715	8.2	7.7	<2.0	
Orestimba Ck	8.3	8.7	1059	1077	8.3	7.8	<2.0	
Del Puerto Ck	8.4	8.6	1513	1523	8.2	7.8	<2.0	
Ingram-Hospital Cks	8.5	8.7	1592	1601	8.0	7.8	<2.0	
Spanish Grant Combined Drain	8.1	8.6	1694	1691	8.4	7.8	<2.0	
Laboratory control	7.4	8.3	249	296	8.6	7.8	<2.0	

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}}$ X 100 [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 15 July 1991								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
Salt Sl	8.1	8.5	1680	1741	8.4	7.8	<2.0	
SJR[6] @ Hills Ferry	8.8	8.6	2170	2100	9.4	7.6	<2.0	
SJR @ Laird Park	8.7	8.5	1640	1714	9.8	7.6	<2.0	
SJR @ Airport Way	9.0	8.5	820	944	9.8	7.6	<2.0	
TID[7] 6	7.6	8.4	730	801	6.6	7.4	<2.0	
TID 5	used for water chemistry duplicate							
TID 3	7.7	8.6	748	754	6.6	7.6	<2.0	
TID 3 - chemistry duplicate	8.0	8.6	757	797	8.0	7.8	<2.0	
Orestimba Ck	8.2	8.3	968	1014	8.3	7.8	<2.0	
Del Puerto Ck	8.3	8.5	1065	1098	8.3	8.0	<2.0	
Ingram-Hospital Cks	8.4	8.6	1350	1392	7.8	7.8	<2.0	
Spanish Grant Combined Drain	8.2	8.4	1169	1250	8.1	7.6	<2.0	
Laboratory control	7.8	8.2	331	326	8.6	8.0	<2.0	

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 30 July 1991								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
Salt S1	7.9	8.2	1184	1190	7.8	8.2	<2.0	
SJR[6] @ Hills Ferry	8.1	8.4	1723	1748	7.9	8.1	<2.0	
SJR @ Laird Park	8.4	8.5	1514	1532	8.1	8.3	<2.0	
SJR @ Airport Way	8.6	8.4	883	924	8.6	8.1	<2.0	
TID[7] 6	no flow							
TID 5	8.0	8.4	868	889	7.8	8.0	<2.0	
TID 3	8.1	8.4	503	530	7.8	8.0	<2.0	
Orestimba Ck	8.3	8.4	1283	1284	7.8	7.7	<2.0	
Del Puerto Ck	8.3	8.5	1213	1235	8.1	8.0	<2.0	
Ingram-Hospital Cks	used for water chemistry duplicate							
Spanish Grant Combined Drain	8.1	8.5	1353	1373	7.8	8.2	<2.0	
Spanish Grant Combined Drain -chemistry duplicate	8.1	8.4	1337	1351	7.6	8.0	<2.0	
Laboratory control	8.1	8.3	198	268	8.4	8.0	<2.0	

[1] Electrical conductivity (μmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 16 August 1991								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
Salt Sl	7.6	8.2	1151	1245	8.6	7.9	<2.0	
SJR[6] @ Hills Ferry	8.1	8.2	1495	1492	8.6	7.6	2.0	
SJR @ Laird Park	8.2	8.5	1384	1396	8.6	7.6	<2.0	
SJR @ Airport Way	8.6	8.3	949	978	9.8	7.7	<2.0	
TID[7] 6	7.9	8.4	522	544	8.3	8.0	<2.0	
TID 5	7.9	8.4	757	766	8.5	7.5	<2.0	
TID 3	7.9	8.6	662	667	8.4	7.4	<2.0	
Orestimba Ck	used for water chemistry duplicate							
Del Puerto Ck	8.1	8.5	993	1002	8.6	7.3	<2.0	
Ingram-Hospital Cks	8.2	8.3	1311	1325	8.0	7.4	<2.0	
Spanish Grant Combined Drain	8.0	8.5	1035	1144	8.4	7.5	<2.0	
Spanish Grant Combined Drain - chemistry duplicate	8.2	8.5	1029	1068	8.7	7.6	<2.0	
Laboratory control	8.2	8.3	191	220	8.4	7.4	<2.0	

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 6 September 1991								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
Salt S1	8.2	8.7	1581	1621	9.1	7.9	<2.0	
SJR[6] @ Hills Ferry	8.4	8.6	2380/2090	2070	8.4	8.5	<2.0	17
SJR @ Laird Park	8.7	8.8	1581	1648	8.2	7.9	<2.0	
SJR @ Airport Way	9.3	8.5	944	996	10.2	8.1	<2.0	
TID[7] 6	7.5	8.7	2040	681[9]	6.3	8.3	2.5	
TID 5	7.9	8.7	878	905	8.4	8.0	5.0	
TID 3	7.8	8.8	818	839	7.6	8.0	<2.0	
Orestimba Ck	used for water chemistry duplicate							
Del Puerto Ck	8.2	8.6	1616	1678	8.2	8.5	4.0	
Ingram-Hospital Cks	8.2	8.4	942	960	8.1	8.1	<2.0	
Spanish Grant Combined Drain	8.6	8.6	1535	1447	8.5	8.3	<2.0	
Spanish Grant Combined Drain - chemistry duplicate	8.4	8.6	1589	1617	8.6	8.0	<2.0	
Laboratory control	7.9	8.5	213	226	8.4	8.2	<2.0	
Dilution control	8.0	8.4	185	185	8.4	8.6		

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

[9] Sample discarded before EC could be rerun

Table 1. (Continued).

Date: 18 September 1991								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
Salt Sl @ HWY 165	8.3	8.7	1290	1561	8.7	8.1	<2.0	
SJR[6] @ Hills Ferry	8.3	8.7	2020	2440	8.4	7.9	<2.0	
SJR @ Laird Park	8.4	8.8	1431	1691	9.1	8.0	<2.0	
SJR @ Airport Way	9.0	8.7	1008	1305	9.6	7.9	<2.0	
TID[7] 6	7.4	8.8	567	714	7.1	8.0	<2.0	
TID 5	8.1	8.9	926	1143	8.1	8.0	<2.0	
TID 3	no flow							
Orestimba Ck	8.3	8.8	1042	1227	8.1	8.1	<2.0	
Orestimba Ck - chemistry duplicate	8.2	8.8	1020	1219	8.0	8.1	<2.0	
Del Puerto Ck	7.9	8.8	1532	1791	7.9	7.8	<2.0	
Ingram-Hospital Cks	8.1	8.8	1495	1763	8.0	8.1	<2.0	
Spanish Grant Combined Drain	7.9	8.8	1223	1513	8.0	8.1	<2.0	
Laboratory control	8.1	8.6	199	293	8.4	7.9	<2.0	

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}}$ X 100 [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 26 September 1991								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
Salt S1	7.7	[9]	1998	[9]	8.6	8.6	<2.0	
SJR[6] @ Hills Ferry	8.2	8.1	2090	2060	8.7	8.6	<2.0	
SJR @ Laird Park	8.6	8.6	1533	1564	9.8	8.5	<2.0	
SJR @ Airport Way	8.9	8.6	1099	1128	10.2	8.5	<2.0	
TID[7] 6	no flow							
TID 5	8.3	8.5	528	602	8.4	8.4	<2.0	
TID 3	used for water chemistry duplicate							
Orestimba Ck	8.0	8.6	1155	1173	8.5	8.5	<2.0	
Del Puerto Ck	8.0	8.6	1528	1522	8.5	8.2	<2.0	
Ingram-Hospital Cks	8.0	8.7	1647	1679	8.4	8.4	<2.0	
Ingram-Hospital Cks - chemistry duplicate	8.0	8.7	1676	1661	8.4	8.4	<2.0	
Spanish Grant Combined Drain	7.9	8.5	1414	1585	8.5	8.4	<2.0	
Laboratory control	7.9	8.3	201	228	8.5	8.3	<2.0	

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

[9] Spilled before could take water quality readings

Table 1. (Continued).

Date: 9 October 1991								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
SJR[6] @ Hills Ferry	7.5	8.7	2200/1999	2020	9.1	7.9	3.0	17
SJR @ Laird Park	8.1	8.8	1560	1679	9.7	8.0	<2.0	
SJR @ Airport Way	8.5	8.8	1100	1170	10.2	8.0	<2.0	
Merced R.	7.9	8.5	321	334	8.9	7.9	<2.0	
Tuolumne R.	7.9	8.7	443	447	9.2	8.0	<2.0	
Stanislaus R.	8.0	8.3	103	117	9.1	7.8	<2.0	
TID[7] 6	7.5	8.9	724	721	8.6	7.9	<2.0	
TID 5	used for water chemistry duplicate							
TID 3	7.7	8.8	1010	1027	8.8	7.0	6.0	
TID 3 - chemistry duplicate	7.7	8.8	1004	966	8.8	7.7	6.0	
Orestimba Ck	8.1	8.8	1010	1034	9.1	7.8	<2.0	
Del Puerto Ck	7.9	8.7	1224	1254	9.0	7.8	<2.0	
Ingram-Hospital Cks	8.2	8.8	1560	1587	9.1	7.8	<2.0	
Spanish Grant Combined Drain	8.0	8.7	1201	1237	8.8	7.8	<2.0	
Laboratory control	8.0	8.5	194	210	8.6	7.9		
Dilution control	8.1	8.5	194	231	8.7	7.6		

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 24 October 1991								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
SJR[6] @ Hills Ferry	8.0	8.5	2670/2040	2090	9.0	8.4	<2.0	25
SJR @ Laird Park	7.9	8.7	1577	1623	8.9	8.1	<2.0	
SJR @ Airport Way	7.9	8.5	8.6	848	9.0	8.2	<2.0	
Merced R.	7.6	8.2	211	238	9.0	8.3	<2.0	
Tuolumne R.	7.5	8.2	180	195	8.7	8.2	<2.0	
Stanislaus R.	7.6	8.0	8.2	999	8.9	8.1	<2.0	
TID[7] 6	used for water chemistry duplicate							
TID 5	7.7	8.4	500	535	8.9	8.4	<2.0	
TID 5 - chemistry duplicate	7.8	8.4	506	526	8.7	8.3	<2.0	
TID 3	no flow							
Orestimba Ck	8.1	8.7	971	1021	8.5	8.5	<2.0	
Del Puerto Ck	8.1	8.5	744	783	8.9	8.4	<2.0	
Ingram-Hospital Cks	8.2	8.4	1540	1520	8.9	8.0	<2.0	
Spanish Grant Combined Drain	8.6	8.7	1038	1085	9.2	8.4	<2.0	
Laboratory control	8.3	8.4	188	214	8.6	8.4		
Dilution control	8.1	8.3	153	161	8.6	8.4		

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 30 October 1991								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5]
	start	end	start[4]	end	start	end		(%)
SJR[6] @ Hills Ferry	8.0	8.5	1671	1664	9.6	8.4	3.0	
SJR @ Laird Park	7.8	8.4	1041	1157	9.5	8.4	<2.0	
SJR @ Airport Way	7.7	8.3	660	750	9.5	8.4	<2.0	
Merced R.	7.6	7.8	128	185	9.2	8.2	<2.0	
Tuolumne R.	7.5	8.0	180	201	9.2	8.4	<2.0	
Stanislaus R.	7.4	7.8	80	112	9.3	8.4	<2.0	
TID[7] 6	no flow							
TID 5	7.6	8.4	500	500	9.6	8.4	<2.0	
TID 3	no flow							
Orestimba Ck	used for water chemistry duplicate							
Del Puerto Ck	8.1	8.5	1734	1601	9.8	8.4	<2.0	
Ingram-Hospital Cks	no flow							
Spanish Grant Combined Drain	8.0	8.2	788	806	9.5	8.4	<2.0	
Spanish Grant Combined Drain - chemistry duplicate	7.9	8.1	779	803	9.4	8.4	<2.0	
Laboratory control	7.9	7.8	181	245	8.4	8.4		

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 13 November 1991								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
SJR[6] @ Hills Ferry	8.0	8.5	2010	2090	8.0		<2.0	
SJR @ Laird Park	7.8	8.4	1104	1161	7.8		<2.0	
SJR @ Airport Way	7.8	8.3	773	816	7.8		<2.0	
Merced R.	7.4	7.7	100	118	7.6		<2.0	
Tuolumne R.	7.7	8.1	203	226	7.9		<2.0	
Stanislaus R.	7.7	7.9	89	106	7.7		<2.0	
TID[7] 6	used for water chemistry duplicate							
TID 5	7.9	8.7	1148	1217	7.6		7.0	
TID 5 -chemistry duplicate	7.9	8.7	1140	1204	7.5		7.0	
TID 3	8.6	8.8	806	850	8.8		<2.0	
Orestimba Ck	8.1	8.3	637	678	7.7		<2.0	
Del Puerto Ck	8.2	8.7	1470	1483	7.7		<2.0	
Ingram-Hospital Cks	8.2	8.5	1088	1137	7.6		<2.0	
Spanish Grant Combined Drain	8.3	8.4	950	982	7.7		<2.0	
Laboratory control	7.6	8.2	209	199	8.4			

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}}$ X 100 [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 25 November 1991								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5]
	start	end	start[4]	end	start	end		(%)
SJR[6] @ Hills Ferry	8.0	8.4	2070	2120	8.4	6.8	<2.0	
SJR @ Laird Park	7.7	8.4	1262	1404	8.3	6.6	<2.0	
SJR @ Airport Way	7.8	8.3	861	906	8.5	6.8	<2.0	
Merced R.	7.5	7.9	84	158	8.4	6.6	<2.0	
Tuolumne R.	7.8	7.9	221	243	8.2	6.8	<2.0	
Stanislaus R.	7.7	7.8	95	119	8.4	6.8	<2.0	
TID[7] 6	8.2	8.5	1493	1499	8.2	5.8	12.0	
TID 5	7.9	8.4	1293	1184	7.7	6.4	10	
TID 3	no flow							
Orestimba Ck	8.0	8.4	878	930	8.2	6.4	<2.0	
Orestimba Ck - chemistry duplicate	8.0	8.4	882	949	8.0	6.6	<2.0	
Del Puerto Ck	8.0	8.3	961	987	8.2	6.6	<2.0	
Ingram-Hospital Cks	8.2	8.4	1671	1677	8.1	6.6	<2.0	
Spanish Grant Combined Drain	used for water chemistry duplicate							
Laboratory control	7.9	8.2	191	237	8.4	6.6	<2.0	

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}}$ X 100 [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 4 December 1991								
Site	pH start	pH end	EC[1] start[4]	EC[1] end	DO[2] start	DO[2] end	NH_3-N[3]	dilution[5] (%)
SJR[6] @ Hills Ferry	7.9	8.5	1980	2050	8.3	8.0	<2.0	
SJR @ Laird Park	7.7	8.4	1154	1209	8.4	8.0	<2.0	
SJR @ Airport Way	7.7	8.4	838	894	8.7	7.9	3.0	
Merced R.	7.7	7.8	117	137	8.6	8.0	<2.0	
Tuolumne R.	7.7	8.2	238	264	8.6	8.0	<2.0	
Stanislaus R.	7.7	8.1	141	163	8.5	8.0	<2.0	
TID[7] 6	used for water chemistry duplicate							
TID 5	7.8	8.4	1047	1100	8.1	7.6	3.0	
TID 3	no flow							
Orestimba Ck	8.1	8.2	814	922	8.5	7.6	<2.0	
Del Puerto Ck	8.1	8.4	1520	1551	8.2	7.2	4.0	
Ingram-Hospital Cks	8.2	8.5	1472	1481	8.5	8.1	<2.0	
Ingram-Hospital Cks - chemistry duplicate	8.1	8.1	1477	1471	8.6	8.0	<2.0	
Spanish Grant Combined Drain	8.2	8.3	912	1014	8.8	8.2	<2.0	
Laboratory control	7.9	8.3	187	208	8.4	8.1		

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 11 December 1991								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
SJR[6] @ Hills Ferry	8.0	8.3	2280/1887	1898	9.4	8.8	<2.0	25
SJR @ Laird Park	7.7	8.3	1208	1244	9.5	8.9	<2.0	
SJR @ Airport Way	7.8	8.3	866	910	9.7	8.8	<2.0	
Merced R.	7.4	7.9	116	135	9.5	8.9	<2.0	
Tuolumne R.	7.9	8.1	249	278	9.8	8.9	<2.0	
Stanislaus R.	7.8	8.0	142	169	10.0	8.9	<2.0	
TID[7] 6	8.5	8.7	894	923	10.8	7.6	<2.0	
TID 5	7.8	8.3	1011	1026	8.7	7.3	10	
TID 3	8.3	8.4	772	789	9.5	7.4	<2.0	
Orestimba Ck	8.7	8.3	1072	1070	9.8	7.5	<2.0	
Del Puerto Ck	used for water chemistry duplicate							
Ingram-Hospital Cks	8.2	8.6	1398	1526	9.9	7.6	<2.0	
Spanish Grant Combined Drain	8.2	8.4	1386	1324	9.8	7.6	<2.0	
Spanish Grant Combined Drain -chemistry duplicate	8.2	8.6	1358	1408	10.1	7.6	<2.0	
Laboratory control	7.9	8.2	188	157	8.2	8.7		
Dilution control	7.8	8.1	133	149	8.2	8.7		

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 18 December 1991								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
SJR[6] @ Hills Ferry	7.7	8.2	2670/2090	2110	7.9	8.0	<2.0	25
SJR @ Laird Park	7.6	8.3	1363	1350	7.9	7.8	<2.0	
SJR @ Airport Way	7.6	8.3	932	938	8.1	7.9	<2.0	
Merced R.	7.4	7.6	89	116	8.1	8.0	<2.0	
Tuolumne R.	7.8	8.0	242	288	8.0	7.8	<2.0	
Stanislaus R.	7.6	8.0	171	180	8.1	7.9	<2.0	
TID[7] 6	used for water chemistry duplicate							
TID 5	7.7	8.5	972	982	7.5	7.3	20	
TID 3	7.8	8.5	1023	1020	7.7		<2.0	
TID 3 - chemistry duplicate	8.0	8.7	1041	975	8.2		<2.0	
Orestimba Ck	no flow							
Del Puerto Ck	8.1	8.3	1254	1324	7.8	7.6	<2.0	
Ingram-Hospital Cks	no flow							
Spanish Grant Combined Drain	8.2	8.4	1561	1553	8.1		<2.0	
Laboratory control	8.1	8.3	204	211	8.4	8.1		
Dilution control	7.8	8.0	127	156	8.4	7.9		

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 23 December 1991								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
SJR[6] @ Hills Ferry	8.1	8.4	2700/2090	2070	9.6	7.8	<2.0	25
SJR @ Laird Park	8.0	8.4	1390	1432	9.4	7.8	<2.0	
SJR @ Airport Way	8.0	8.4	984	1031	9.7	7.6	<2.0	
Merced R.	7.6	7.6	86	105	9.6	7.9	<2.0	
Tuolumne R.	8.0	8.2	240	267	10.1	7.8	<2.0	
Stanislaus R.	7.9	8.0	141	163	9.8	7.7	<2.0	
TID[7] 6	8.4	8.7	831	848	9.7	7.0	<2.0	
TID 5	7.8	8.6	835	855	8.5	7.2	6.0	
TID 3	no flow							
Orestimba Ck	no flow							
Del Puerto Ck	8.2	8.3	1475	1533	9.2	7.7	<2.0	
Ingram-Hospital Cks	8.2	8.3	1526	1566	9.2	7.8	<2.0	
Spanish Grant Combined Drain	8.2	8.5	1622	1633	8.7	7.0	<2.0	
Laboratory control	7.9	8.2	218	228	8.2	7.6		
Dilution control	7.9	8.1	157	161	8.3	7.6		

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 5 January 1992								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
SJR[6] @ Hills Ferry	7.9	8.4	3000/2010	2100	8.5	7.9	<2.0	33
SJR @ Laird Park	7.7	8.4	1230	1340	8.4	7.8	<2.0	
SJR @ Airport Way	7.9	8.4	980	1020	8.6	7.8	<2.0	
Merced R.	7.4	7.8	188	195	8.6	7.9	<2.0	
Merced R. - chemistry duplicate	7.8	8.2	225	253	8.5	7.9	<2.0	
Tuolumne R.	used for water chemistry duplicate							
Stanislaus R.	7.7	8.0	124	158	8.6	7.8	<2.0	
TID[7] 6	8.2	8.5	760	801	8.3	7.3	<2.0	
TID 5	7.8	8.6	920	956	7.8	6.9	70.2	
TID 3	7.9	8.0	161	180	8.5	8.0	<2.0	
Orestimba Ck	8.0	7.9	285	341	8.8	7.8	<2.0	
Del Puerto Ck	7.7	7.8	354	427	8.5	7.9	<2.0	
Ingram-Hospital Cks	7.8	8.0	618	659	8.2	7.9	<2.0	
Spanish Grant Combined Drain	8.3	8.2	1034	1091	8.6	7.8	<2.0	
Laboratory control	8.1	8.3	167	188	8.2	7.6		
Dilution control	8.0	8.2	124	139	8.2	7.7		

[1] Electrical conductivity (μmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}}$ X 100 [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 13 January 1992								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
SJR[6] @ Hills Ferry	7.9	8.4	2650/2010	2040	9.6	8.3	3.0	25
SJR @ Laird Park	7.8	8.5	1399	1442	9.4	8.5	<2.0	
SJR @ Airport Way	7.7	8.4	1065	1056	9.2	8.2	<2.0	
Merced R.	7.2	7.6	262	195	9.5	8.5	<2.0	
Tuolumne R.	7.7	8.1	259	282	9.7	8.3	<2.0	
Stanislaus R.	7.6	8.0	165	157	9.4	8.2	<2.0	
TID[7] 6	8.0	8.7	1146	1159	8.6	7.5	7.0	
TID 5	7.7	8.4	867	879	9.0	9.6	40	
TID 3	no flow							
Orestimba Ck	no flow							
Del Puerto Ck	7.6	8.2	535	584	9.0	7.4	<2.0	
Ingram-Hospital Cks	used for water chemistry duplicate							
Spanish Grant Combined Drain	no flow							
Laboratory control	8.0	8.3	164	184	8.4	8.6		
Dilution control	8.0	8.2	164	162	8.3	8.2		

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 20 January 1992								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
SJR[6] @ Hills Ferry	7.9	8.3	2930/2070	2040	9.3	7.8	<2.0	35
SJR @ Laird Park	7.8	8.4	1505	1657	9.1	7.4	3.0	
SJR @ Airport Way	7.8	8.3	1117	1352	9.3	7.6	<2.0	
Merced R.	7.3	7.8	113	196	9.5	7.4	<2.0	
Tuolumne R.	7.6	8.1	245	288	9.5	7.8	<2.0	
Stanislaus R.	7.7	8.1	148	205	9.7	7.4	<2.0	
TID[7] 6	8.1	8.6	850	804	8.9	8.7	<2.0	
TID 6 -chemistry duplicate	8.0	8.6	850	803	8.8	8.5	<2.0	
TID 5	7.8	8.6	1378	1301	5.7	7.4	60	
TID 3	8.2	8.6	885	892	10.3	8.5	<2.0	
Orestimba Ck	no flow							
Del Puerto Ck	used for water chemistry duplicate							
Ingram-Hospital Cks	8.0	8.6	1612	1672	9.6	7.1	<2.0	
Spanish Grant Combined Drain	no flow							
Laboratory control	7.9	8.1	194	360	8.2	7.4		
Dilution control	7.9	8.1	129	216	8.3	7.4		

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 3 February 1992								
Site	pH start	pH end	EC[1] start[4]	EC[1] end	DO[2] start	DO[2] end	NH_3-N[3]	dilution[5] (%)
SJR[6] @ Hills Ferry	8.0	8.2	3220/1960	1983	9.8	7.9	<2.0	46
SJR @ Laird Park	7.8	8.5	1520	1594	9.4	8.2	<2.0	
SJR @ Airport Way	7.8	8.4	1091	1134	9.6	8.1	<2.0	
Merced R.	7.7	7.9	104	127	10.0	8.1	<2.0	
Tuolumne R.	7.9	8.0	230	262	10.2	7.6	<2.0	
Stanislaus R.	7.8	7.9	145	166	10.1	8.0	<2.0	
TID[7] 6	8.4	8.6	1289	1230	10.4	8.0	<2.0	
TID 5	7.9	8.4	910	1030	9.4	7.6	20.0	
TID 3	no flow							
Orestimba Ck	8.2	8.5	1033	1194	9.6		<2.0	
Del Puerto Ck	8.3	8.4	1020	1054	8.1		30.0	
Ingram-Hospital Cks	8.6	8.7	1671	1850	10.2		<2.0	
Ingram-Hospital Cks - chemistry duplicate	8.6	8.6	1693	1867	9.8		<2.0	
Spanish Grant Combined Drain	used for water chemistry duplicate							
Laboratory control	8.4	8.3	260	209		7.8		
Dilution control	8.2	8.0	139	118		7.8		

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 10 February 1992								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
SJR[6] @ Hills Ferry	8.0	8.0	2910/1896	1919	9.0	8.9	4.0	42
SJR @ Laird Park	7.8	8.2	1475	1503	9.0	9.4	<2.0	
SJR @ Airport Way	7.8	8.2	1063	1118	9.4	9.2	<2.0	
Merced R.	7.8	7.9	141	140	9.5	8.9	<2.0	
Merced R. - chemistry duplicate	7.7	7.9	146	174	9.3	9.1	<2.0	
Tuolumne R.	7.7	7.8	208	241	9.3	8.8	<2.0	
Stanislaus R.	used for water chemistry duplicate							
TID[7] 6	7.9	8.4	1327	1324	4.6	7.2	80	
TID 5	7.8	8.4	1111	1119	7.1	7.7	70	
TID 3	9.1	8.0	144	180	9.6	8.3	<2.0	
Orestimba Ck	8.0	7.8	193	316	9.2	8.0	<2.0	
Del Puerto Ck	7.8	8.1	494	560	9.3	8.3	<2.0	
Ingram-Hospital Cks	8.0	8.1	768	801	8.7	7.8	<2.0	
Spanish Grant Combined Drain	8.1	8.5	1536	1960	8.8	8.4	<2.0	
Laboratory control	8.2	8.2	241	211	8.4	9.1		
Dilution control	8.1	8.0	148	150	8.4	8.9		

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}}$ X 100 [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 17 February 1992								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
SJR[6] @ Hills Ferry	6.7	8.1	490	524	10.2	9.2	<2.0	
SJR @ Laird Park	no sample							
SJR @ Airport Way	7.1	8.0	467	513	10.2	9.8	<2.0	
SJR @ Airport Way - chemistry duplicate	7.7	8.1	467	494	8.0	9.6	<2.0	
Merced R.	7.2	7.7	104	128	10.4	9.2	<2.0	
Tuolumne R.	7.2	8.0	150	200	10.2	10.4	<2.0	
Stanislaus R.	7.3	7.9	117	148	10.4	9.1	<2.0	
TID[7] 6	7.5	8.4	731	748	8.6	9.4	<2.0	
TID 5	7.5	8.2	447	473	10.0	9.8	3.0	
TID 3	7.8	7.9	146	174	10.6	9.8	<2.0	
Orestimba Ck	7.8	8.3	294	327	10.8	9.4	<2.0	
Del Puerto Ck	8.6	8.6	700	814	10.8	10.4	<2.0	
Ingram-Hospital Cks	8.2	8.4	1126	1335	10.6	10.8	<2.0	
Spanish Grant Combined Drain	7.8	8.5	1607	1733	10.5	9.2	<2.0	
Laboratory control	8.0	8.3	197	214	8.6	9.4		
Dilution control	7.9	8.1	164	150	8.6	10.6		

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 24 February 1992								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5]
	start	end	start[4]	end	start	end		(%)
SJR[6] @ Hills Ferry	7.7	8.4	1763	1838	10.6	8.4	<2.0	
SJR @ Laird Park	7.8	8.4	1137	1202	10.8	8.5	<2.0	
SJR @ Airport Way	7.7	8.3	835	888	10.4	8.5	<2.0	
Merced R.	7.7	7.9	126	154	10.6	8.6	<2.0	
Tuolumne R.	7.5	8.1	229	260	10.4	8.5	<2.0	
Stanislaus R.	7.5	8.1	171	199	10.6	8.5	<2.0	
TID[7] 6	8.3	8.8	1138	1169	10.2	7.8	<2.0	
TID 5	7.8	8.4	1301	1289	10.0	10.0	20	
TID 3	7.7	8.7	1186	1154	7.1	10.6	<2.0	
Orestimba Ck	used for water chemistry duplicate							
Del Puerto Ck	8.7	8.9	1065	1189	10.8	7.9	<2.0	
Del Puerto Ck - chemistry duplicate	8.3	8.8	1149	1217	10.2	7.8	<2.0	
Ingram-Hospital Cks	8.1	8.4	1222	1261	10.6	9.9	<2.0	
Spanish Grant Combined Drain	8.1	8.6	2810/2010	2140	10.8	7.8	<2.0	35
Laboratory control	7.9	8.2	248	212	8.4	8.4		
Dilution control	7.9	8.0	143	177	8.4	8.0		

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 2 March 1992								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5]
	start	end	start[4]	end	start	end		(%)
Salt Slough	7.8	8.3	2780/1985	1925	10.0	6.9	<2.0	35
SJR[6] @ Hills Ferry	7.9	8.3	2500/1935	1835	10.5	7.1	<2.0	29
SJR @ Laird Park	no sample collected							
SJR @ Airport Way	7.9	8.4	1205	1206	10.2	6.6	<2.0	
Merced R.	7.7	7.9	133	142	10.4	5.8	<2.0	
Tuolumne R.	7.7	7.9	249	276	10.5	6.4	<2.0	
Stanislaus R.	7.7	7.9	160	174	10.4	8.5	<2.0	
TID[7] 6	8.2	8.8	1172	1181	9.1	8.4	8.0	
TID 6 - chemistry duplicate	7.8	8.7	1170	1168	9.2	8.5	8.0	
TID 5	used for water chemistry duplicate							
TID 3	8.5	8.6	768	786	10.8	8.4	<2.0	
Orestimba Ck	no flow							
Del Puerto Ck	9.0	8.9	1154	1326	10.8	9.0	<2.0	
Ingram-Hospital Cks	8.4	8.5	2100/1864	1910	10.7	8.8	<2.0	17
Spanish Grant Combined Drain	8.2	8.4	2940/2000	2040	10.8	8.8	<2.0	
Laboratory control	8.1	8.2	197	200	8.6	8.2		
Dilution control	8.1	8.2	129	133	8.6	8.2		

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 9 March 1992								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5]
	start	end	start[4]	end	start	end		(%)
SJR[6] @ Hills Ferry	7.7	8.5	2440/1704	1698	14.0	7.6	<2.0	35
SJR @ Laird Park	7.9	8.5	2060/1575	1599	14.0	7.8	<2.0	29
SJR @ Airport Way	7.6	8.4	1010	1048	12.3	8.8	<2.0	
Merced R.	7.4	8.1	133	174	10.6	7.7	<2.0	
Tuolumne R.	7.4	7.9	187	199	10.6	7.0	<2.0	
Tuolumne R. - chemistry duplicate	7.5	8.1	174	189	10.4	7.7	<2.0	
Stanislaus R.	used for water chemistry duplicate							
TID[7] 6	8.1	8.9	1041	1134	12.0	8.5	<2.0	
TID 5	7.7	8.6	1142	1102	12.1	7.2	5.0	
TID 3	9.6	7.9	286	318	12.8	7.3	<2.0	
Orestimba Ck	7.9	8.5	706	1033	12.7	8.7	<2.0	
Del Puerto Ck	8.9	9.0	1026	1097	12.7	8.8	<2.0	
Ingram-Hospital Cks	8.3	8.2	2050/1544	1501	18.8	7.3	<2.0	
Spanish Grant Combined Drain	8.2	8.7	2360/1746	1921	18.4	8.7	<2.0	
Laboratory control	8.1	8.4	188	199	8.4	7.7		
Dilution control	8.0	8.2	163	132	8.4	7.9		

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 16 March 1992								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
Salt Slough	7.7	8.4	2430/2020	1940	8.6	8.2		25
SJR[6] @ Hills Ferry	7.9	8.3	2630/2000	2130	8.7	7.4		29
SJR @ Laird Park	8.0	8.4	1618	1727	8.8	7.3		
SJR @ Airport Way	8.0	8.4	1239	1317	8.9	7.4		
Merced R.	7.8	7.8	126	173	8.9	7.3		
Tuolumne R.	7.8	8.0	258	322	8.9	7.4		
Stanislaus R.	7.8	7.9	175	215	8.9	7.4		
TID[7] 6	7.8	8.6	1418	1508	6.4	7.1		
TID 5	7.8	8.6	1435	1497	5.9	7.0		
TID 5 - chemistry duplicate	8.5	8.5	1402	1417	9.8	7.4		
TID 3	8.3	8.5	934	938	10.4	7.0		
Orestimba Ck	used for water chemistry duplicate							
Del Puerto Ck	8.9	8.8	1195	1271	8.6	7.3		
Ingram-Hospital Cks	8.4	8.6	2000	2010	8.8	7.7		
Spanish Grant Combined Drain	8.3	8.2	2150/1980	1915	9.8	7.4		12
Laboratory control	7.7	7.8	230	228	8.6	7.4		
Dilution control	7.6	7.4	190	130	8.6	7.6		

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 23 March 1992								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5]
	start	end	start[4]	end	start	end		(%)
Salt Slough	7.7	8.5	1880	2160	8.9	8.0		
SJR[6] @ Hills Ferry	8.0	8.6	2170/1730	1670	9.2	8.0		
SJR @ Laird Park	8.1	8.7	1568	1630	9.5	7.7		
SJR @ Airport Way	8.0	8.5	1217	1268	9.4	8.1		
Merced R.	7.8	8.1	123	143	9.6	8.0		
Tuolumne R.	7.8	8.3	219	245	9.6	7.9		
Stanislaus R.	7.8	8.0	95	117	9.8	7.2		
TID[7] 6	8.2	8.9	944	960	9.2	8.5		
TID 5	7.9	8.7	1020	1134	8.4	8.3		
TID 3	8.4	8.6	557	587	10.2	7.1		
Orestimba Ck	8.3	8.2	922	940	9.8	7.4		
Del Puerto Ck	8.6	8.6	780	804	10.2	7.4		
Ingram-Hospital Cks	8.1	8.1	276	305	9.4	7.3		
Spanish Grant Combined Drain	7.9	8.3	1284	1286	9.2	7.2		
Laboratory control	8.4	8.2	210	208	8.4	7.8		
Dilution control	8.3	8.1	152	153	8.4	7.8		

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 30 March 1992								
Site	pH start	pH end	EC[1] start[4]	EC[1] end	DO[2] start	DO[2] end	NH_3-N[3]	dilution[5] (%)
Salt Slough	used for water chemistry duplicate							
SJR[6] @ Hills Ferry	8.1	8.5	2260/1846	1853	9.9	8.7		25
SJR @ Hills Ferry - chemistry duplicate	7.7	8.4	2330/1812	1842	9.6	8.7		29
SJR @ Laird Park	8.1	8.6	1656	1700	10.	8.5		
SJR @ Airport Way	8.1	8.5	1103	1192	10.	8.4		
Merced R.	7.8	8.1	124	153	10.2	8.6		
Tuolumne R.	8.0	8.3	252	281	10.2	8.2		
Stanislaus R.	7.8	8.1	94	118	10.4	8.5		
TID[7] 6	8.4	8.8	898	941	10.2	8.6		
TID 5	7.9	8.7	1070	1080	9.6	8.7		
TID 3	7.6	8.9	957	970	6.9	7.8		
Orestimba Ck	7.8	8.4	1052	1142	8.0	8.0		
Del Puerto Ck	8.5	8.5	784	849	10.4	8.5		
Ingram-Hospital Cks	8.3	8.7	1615	1751	10.1	8.6		
Spanish Grant Combined Drain	8.3	8.6	1218	1239	10.6	8.9		
Laboratory control	8.1	8.4	197	207	8.6	8.4		
Dilution control	8.0	8.2	149	167	8.6	8.4		

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Site	pH start	pH end	EC[1] start[4]	EC[1] end	DO[2] start	DO[2] end	NH_3-N[3]	dilution[5] (%)
Date: 6 April 1992								
Salt Slough	7.8	8.4	2800/1960	2020	9.2	8.5		35
SJR[6] @ Hills Ferry	8.1	8.4	2720/1999	1985	9.1	8.5		32
SJR @ Laird Park	8.2	8.7	1790	1831	9.5	8.3		
SJR @ Airport Way	8.3	8.5	1002	1044	10.4	8.5		
Merced R.	7.7	8.1	150	172	9.8	8.3		
Tuolumne R.	8.0	8.2	242	271	9.7	8.0		
Stanislaus R.	7.9	8.0	96	123	9.8	8.2		
TID[7] 6	8.8	8.6	562	601	10.0	7.4		
TID 5	7.9	8.5	816	887	10.1	8.0		
TID 3	used for water chemistry duplicate							
Orestimba Ck	8.2	8.3	986	834	8.9	8.1		
Del Puerto Ck	8.5	8.5	1178	1202	10.0	7.6		
Ingram-Hospital Cks	8.3	8.2	1999	1970	9.9	8.2		
Ingram-Hospital Cks - chemistry duplicate	8.3	8.5	1968	2030	9.6	8.2		
Spanish Grant Combined Drain	8.4	8.5	1338	1389	10.1	8.2		
Laboratory control	8.0	8.4	187	212	8.4	8.6		
Dilution control	7.9	8.2	164	141	8.4	7.9		

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.
[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 13 April 1992								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
Salt Slough	7.9	8.5	2540/1778	1820	10.2	9.2	<2.0	35
SJR[6] @ Hills Ferry	8.1	8.6	2740/1922	1971	10.3	9.3	<2.0	35
SJR @ Laird Park	8.1	8.8	1950	1965	10.2	9.2	<2.0	
SJR @ Airport Way	8.1	8.6	827	890	10.7	9.1	<2.0	
Merced R.	7.7	9.0	156	184	10.4	8.6	<2.0	
Tuolumne R.	7.9	8.2	252	271	10.3	8.7	<2.0	
Stanislaus R.	7.8	8.4	96	114	10.5	8.5	<2.0	
TID[7] 6	7.8	8.5	468	462	10.4	8.5	<2.0	
TID 6 - chemistry duplicate	7.9	8.4	486	491	10.2	8.7	<2.0	
TID 5	used for water chemistry duplicate							
TID 3	8.7	8.3	195	203	10.7	8.6	<2.0	
Orestimba Ck	8.3	8.6	888	860	10.0	8.6	<2.0	
Del Puerto Ck	8.4	8.6	1276	1297	10.4	8.3	<2.0	
Ingram-Hospital Cks	8.2	8.7	1925	1900	10.0	8.7	<2.0	
Spanish Grant Combined Drain	8.3	7.3	718	763	10.3	8.0	<2.0	
Laboratory control	8.0	8.4	198	213	8.6	8.9		
Dilution control	8.2	8.2	134	142	8.6	8.9		

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 20 April 1992								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5]
	start	end	start[4]	end	start	end		(%)
Salt Slough	8.0	8.5	2080	2140	9.6	9.0	<2.0	
SJR[6] @ Hills Ferry	8.2	8.5	2540/1856	1867	10.2	8.9	<2.0	35
SJR @ Laird Park	8.1	8.7	1738	1758	10.1	8.7	<2.0	
SJR @ Airport Way	8.3	8.4	755	810	10.4	8.9	<2.0	
Merced R.	7.9	8.2	170	195	10.0	8.6	<2.0	
Tuolumne R.	8.1	8.0	234	260	10.2	8.6	<2.0	
Stanislaus R.	7.8	7.9	88	110	10.2	8.9	<2.0	
TID[7] 6	8.2	8.5	711	796	10.4	7.8	<2.0	
TID 5	7.9	8.5	378	453	10.0	7.7	<2.0	
TID 3	used for water chemistry duplicate							
Orestimba Ck	8.3	8.7	1200	1310	10.3	7.8	<2.0	
Del Puerto Ck	8.3	8.7	1658	1691	10.4	7.8	<2.0	
Ingram-Hospital Cks	8.4	8.5	1626	1702	10.6	7.7	<2.0	
Ingram-Hospital Cks - chemistry duplicate	8.5	8.8	1618	1678	10.6	7.8	<2.0	
Spanish Grant Combined Drain	8.2	8.5	1345	1393	10.3	8.2	<2.0	
Laboratory control	8.4	8.4	193	211	9.0	8.9		
Dilution control	8.3	8.2	130	147	9.8	8.8		

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 27 April 1992								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5]
	start	end	start[4]	end	start	end		(%)
Salt Slough	7.9	8.3	2160/1652	1618	9.4	8.4	<2.0	29
SJR[6] @ Hills Ferry	8.1	8.3	2900/2030	2010	10.2	8.4	<2.0	35
SJR @ Laird Park	8.4	8.7	1753	1794	12.2	8.4	<2.0	
SJR @ Airport Way	8.5	8.3	533	565	10.8	8.2	<2.0	
Merced R.	8.0	8.4	312	333	10.4	8.4	<2.0	
Tuolumne R.	7.8	7.9	128	145	10.4	8.2	<2.0	
Stanislaus R.	7.9	8.0	89	110	10.4	8.2	<2.0	
TID[7] 6	7.9	8.3	513	543	10.3	7.8	<2.0	
TID 5	7.9	8.3	655	712	10.1	7.6	<2.0	
TID 3	8.2	8.7	978	1013	10.8	7.6	<2.0	
Orestimba Ck	8.4	8.6	1041	1088	10.4	9.6	<2.0	
Del Puerto Ck	8.4	8.7	1368	1403	10.6	7.8	<2.0	
Ingram-Hospital Cks	8.5	8.7	1782	1802	8.8	7.5	<2.0	
Spanish Grant Combined Drain	8.1	8.3	1328	1378	8.9	8.7	<2.0	
Laboratory control	8.4	8.4	197	209	8.6	8.2		
Dilution control	7.0	8.0	127	146	8.8	8.7	<2.0	

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 4 May 1992								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
Salt Slough	8.2	8.2	2530/1896	1734	10.1	8.7	<2.0	35
SJR[6] @ Hills Ferry	8.3	8.5	2650/1722	1822	10.4	9.1	<2.0	
SJR @ Laird Park	8.4	8.5	1843	1847	12.0	8.6	<2.0	
SJR @ Airport Way	8.1	8.2	447	482	10.6	8.8	<2.0	
Merced R.	7.9	8.2	196	214	10.0	8.4	<2.0	
Tuolumne R.	7.7	7.9	57	78	10.1	8.6	<2.0	
Stanislaus R.	7.9	7.9	114	146	9.6	8.6	<2.0	
TID[7] 6	8.6	8.7	538	565	10.3	8.6	<2.0	
TID 5	8.2	8.6	594	626	9.8	8.4	<2.0	
TID 3	7.6	8.7	732	734	6.9	8.6	<2.0	
Orestimba Ck	8.3	8.4	896	908	9.6	9.4	<2.0	
Del Puerto Ck	8.4	8.6	1386	946	10.0	8.4	<2.0	
Ingram-Hospital Cks	8.5	8.7	1733	1666	9.9	9.4	<2.0	
Ingram-Hospital Cks - chemistry duplicate	8.4	8.7	1748	1784	10.6	9.2	<2.0	
Spanish Grant Combined Drain	7.8	8.4	1343	1344	8.6	9.3	<2.0	
Extra sample	used for water chemistry duplicate							
Laboratory control	8.3	8.4	196	220	10.1	8.6	<2.0	
Dilution control	8.4	8.3	132	155	10.1	8.7	<2.0	

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 11 May 1992								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5]
	start	end	start[4]	end	start	end		(%)
Salt Slough	8.1	8.2	2560/1832	1862	10.8	7.3	<2.0	35
SJR[6] @ Hills Ferry	8.3	8.4	2800/1931	1902	10.9	7.1	<2.0	38
SJR @ Laird Park	8.4	8.7	1699	1939	12.4	7.1	<2.0	
SJR @ Airport Way	8.7	8.2	610	490	12.4	7.5	<2.0	
Merced R.	7.9	8.0	186	227	10.5	7.2	<2.0	
Tuolumne R.	7.7	7.9	81.6	77.0	10.3	7.1	<2.0	
Tuolumne R. - chemistry duplicate	7.9	8.1	95	142	10.3	7.5	<2.0	
Stanislaus R.	used for water chemistry duplicate							
TID[7] 6	7.5	8.4	291	320	8.6	8.8	<2.0	
TID 5	8.0		1051		10.5		<2.0	
TID 3	7.6		870		8.3		<2.0	
Orestimba Ck	8.2	8.5	928	994	10.3	9.6	<2.0	
Del Puerto Ck	8.5	8.6	1484	1546	10.7	8.7	<2.0	
Ingram-Hospital Cks	8.4	8.3	1432	1458	10.1	12.0	<2.0	
Spanish Grant Combined Drain	8.2	8.6	1420	1421	10.1	10.8	<2.0	
Laboratory control	8.5	8.4	190	219	9.4	7.4	<2.0	
Dilution control	8.4	8.2	129	129	9.6	7.5	<2.0	

[1] Electrical conductivity (μmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 18 May 1992								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5]
	start	end	start[4]	end	start	end		(%)
Salt Slough	8.2	8.3	2300/1800	1726	9.4	9.3	<2.0	29
SJR[6] @ Hills Ferry	9.0	7.9	2890/2040	2070	16.0	9.4	<2.0	35
SJR @ Laird Park	8.8	8.7	1785	1844	14.2	9.4	<2.0	
SJR @ Airport Way	8.7	8.3	558	594	10.5	9.4	<2.0	
Merced R.	used for chemistry duplicate							
Tuolumne R.	7.9	8.4	286	321	8.5	9.3	<2.0	
Tuolumne R. - chemistry duplicate	8.0	8.2	297	318	9.3	9.0	<2.0	
Stanislaus R.	7.8	8.0	87	108	8.6	9.2	<2.0	
TID[7] 6	8.2	8.5	520	585	8.8	9.3	<2.0	
TID 5	8.0	8.6	659	683	7.9	8.7	3.0	
TID 3	8.4	8.6	600	645	9.6	8.6	<2.0	
Orestimba Ck	8.5	8.7	1048	1090	8.8	8.4	<2.0	
Del Puerto Ck	8.4	8.7	1490	1090	8.7	8.4	<2.0	
Ingram-Hospital Cks	8.5	8.5	1538	1579	8.7	7.8	<2.0	
Spanish Grant Combined Drain	8.1	8.5	1500	1508	8.2	8.7	<2.0	
Laboratory control	7.5	8.3	204	201	7.9	9.4	<2.0	
Dilution control	7.6	8.2	135	145	8.3	9.4	<2.0	

[1] Electrical conductivity (μmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 25 May 1992								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
Salt Slough	8.1	8.4	2480/1919	1918	10.8	9.6	<2.0	29
SJR[6] @ Hills Ferry	8.4	8.5	2680/1885	1912	12.4	10.0	<2.0	35
SJR @ Laird Park	9.1	8.8	1530	1598	18.9	9.9	<2.0	
SJR @ Airport Way	9.3	8.6	904	958	18.7	9.8	<2.0	
Merced R.	7.9	8.1	203	226	10.6	9.8	<2.0	
Tuolumne R.	8.0	8.4	307	356	10.8	9.8	<2.0	
Stanislaus R.	8.0	8.0	102	125	10.6	9.7	<2.0	
TID[7] 6	sample used for chemistry duplicate							
TID 5	8.1	8.5	693	729	10.7	9.8	<2.0	
TID 3	8.6	8.3	530	652	12.5	8.9	<2.0	
Orestimba Ck	8.4	8.7	1115	1149	10.5	9.8	<2.0	
Del Puerto Ck	8.6	8.6	1240	1264	12.2	9.4	<2.0	
Ingram-Hospital Cks	8.5	8.6	1530	1590	12.1	9.7	<2.0	
Ingram-Hospital Cks - chemistry duplicate	8.6	8.6	1517	1510	12.2	9.9	<2.0	
Spanish Grant Combined Drain	8.2	8.6	1272	1286	10.4	9.4	<2.0	
Laboratory control	8.3	8.4	183	199	9.9	9.7	<2.0	
Dilution control	8.3	8.4	129	197	9.9	9.9	<2.0	

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] Volume dilution water / (volume dilution water + volume sample) X 100 [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 1 June 1992								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
Salt Slough	8.4	8.4	2490/1957	1942	12.6	8.0	<2.0	29
SJR[6] @ Hills Ferry	8.8	8.4	2820/2000	2010	16.1	8.2	<2.0	35
SJR @ Laird Park	9.4	8.4	1620	1678	20.0	8.2	<2.0	
SJR @ Airport Way	9.4	8.4	806	857	18.7	8.2	<2.0	
Merced R.	8.0	8.2	805	819	10.7	8.0	<2.0	
Tuolumne R.	8.4	8.4	385	418	12.4	8.3	<2.0	
Stanislaus R.	7.9	7.8	109	126	10.8	8.2	<2.0	
TID[7] 6	7.4	8.1	313	342	7.5	11.8	<2.0	
TID 5	8.1	8.5	557	598	10.8	10.3	<2.0	
TID 3	used for water chemistry duplicate							
Orestimba Ck	8.4	8.7	1126	1144	10.8	10.1	<2.0	
Del Puerto Ck	8.8	8.6	1542	1592	12.1	10.2	<2.0	
Ingram-Hospital Cks	8.7	8.9	1548	1607	12.0	10.0	<2.0	
Ingram-Hospital Cks - chemistry duplicate	8.7	8.6	1557	1603	12.1	10.2	<2.0	
Spanish Grant Combined Drain	8.3	8.5	1498	1605	10.6	12.2	<2.0	
Laboratory control	8.4	8.2	191	205	10.5	8.3	<2.0	
Dilution control	8.5	8.2	126	146	10.5	8.2	<2.0	

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 15 June 1992								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5]
	start	end	start[4]	end	start	end		(%)
Salt Slough	8.2	8.4	2180/1680	1710	12.3	7.9	<2.0	29
SJR[6] @ Hills Ferry	8.6	8.6	2490/1819	1920	14.3	8.1	<2.0	35
SJR @ Laird Park	9.0	8.2	1526	1620	16.9	8.8	<2.0	
SJR @ Airport Way	9.0	8.1	842	903	16.1	7.9	<2.0	
Merced R.	8.1	8.4	468	504	12.4	7.8	<2.0	
Tuolumne R.	8.1	8.5	375	424	12.0	8.0	<2.0	
Stanislaus R.	7.8	7.9	98	132	10.8	7.6	<2.0	
TID[7] 6	7.9	8.4	480	516	10.9	8.0	<2.0	
TID 5	8.2	8.5	709	787	10.9	7.9	<2.0	
TID 3	used for water chemistry replicate							
Orestimba Ck	8.3	8.4	1068	1138	12.0	8.0	<2.0	
Del Puerto Ck	8.8	8.4	1481	1526	12.0	8.0	<2.0	
Ingram-Hospital Cks	8.5	8.4	1642	1739	10.7	7.9	<2.0	
Ingram-Hospital Cks - chemistry duplicate	8.5	8.4	1653	1713	10.8	7.7	<2.0	
Spanish Grant Combined Drain	8.5	8.4	1508	1656	10.7	7.7	<2.0	
Laboratory control	8.3	8.3	188	211	10.2	7.9	<2.0	
Dilution control	8.2	8.0	130	161	10.3	7.8	<2.0	

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l). [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}} \times 100$ [6] San Joaquin River [7] Turlock Irrigation District

Table 1. (Continued).

Date: 22 June 1992								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
Salt Slough	8.2	7.9	1679	1163	12.8	9.4	<2.0	
SJR[6] @ Hills Ferry	8.7	8.2	2260/1647	1706	16.8	8.8	<2.0	35
SJR @ Laird Park	9.5	8.6	1130	1397	20.8	9.6	<2.0	
SJR @ Airport Way	9.5	8.4	880	985	20.8	9.8	<2.0	
Merced R.	8.0	8.1	220	266	14.1	9.4	<2.0	
Tuolumne R.	8.3	8.4	380	439	14.2	10.0	<2.0	
Stanislaus R.	8.3	8.1	123	151	14.3	8.0	<2.0	
TID[7] 6	8.0	8.6	524	576	12.5	7.9	<2.0	
TID 5	7.9	8.3	413	478	12.8	8.0	<2.0	
TID 3	7.9	8.4	609	634	10.4	8.1	9.0	
Orestimba Ck	8.3	8.4	1171	1225	14.1	10.5	<2.0	
Del Puerto Ck	8.7	8.5	1264	1402	14.1	7.9	<2.0	
Ingram-Hospital Cks	8.8	8.4	1394	1528	12.3	8.0	<2.0	
Ingram-Hospital Cks - chemistry duplicate	8.8	8.5	1431	1607	12.3	8.0	<2.0	
Spanish Grant Combined Drain	8.4	8.3	1333	1468	14.1	10.8	<2.0	
Extra sample	used for water chemistry duplicate							
Laboratory control	8.4	8.4	186	226	12.8	7.9	<2.0	
Dilution control	8.1		123		12.8		<2.0	

[1] Electrical conductivity (µmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l). [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}}$ X 100 [6] San Joaquin River [7] Turlock Irrigation District

Table 2. Bioassay water quality measurements for Lagrangian survey conducted on 23-26 April 1991.

Date: Lagrangian Survey 23 to 26 April 1991								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
SJR[6] @ Hwy 165[8]	8.1	8.5	2000	2000	7.8	8.2	<2.0	
Salt Slough @ Hwy 165[8]	8.0	8.5	2080	2100	7.5	8.2	<2.0	
Mud Slough @ Kesterson[8]	8.3	8.6	3760/2180	2200	7.7	8.2	<2.0	50
Los Banos[8]	8.4	8.8	2870/2010	2040	7.7	8.1	<2.0	35
Newman Wasteway[8]	7.9	8.6	970	1050	7.7	8.0	<2.0	
Merced River[8]	7.9	8.2	201	292	7.7	8.0	<2.0	
SJR @ Hills Ferry[8]	8.4	8.5	1626	1601	7.6	8.0	<2.0	
SJR @ Fremont Ford[8]	8.1	8.5	2210/1920	1980	7.5	8.1	<2.0	12
TID 5[7]	7.3	7.9	605	606	8.6	8.4	3.0	
SJR @ West Main	8.0	8.5	1589	1662	8.8	8.8	<2.0	
Del Puerto Ck	8.5	8.7	1560	1586	9.0	8.8	<2.0	
Stanislaus River	7.9	8.2	180	183	9.0	8.8	<2.0	
SJR @ Maze Blvd	8.0	8.3	768	802	9.1	8.7	<2.0	
SJR @ Airport Way	8.4	8.4	702	732	9.0	8.8	<2.0	
Orestimba Ck	8.5	8.7	870	905	9.1	8.8	<2.0	
Tuolumne River	7.8	8.1	106	120	9.2	8.8	<2.0	
SJR @ Laird Park	8.1	8.7	1585	1627	9.0	8.8	<2.0	
Ingram Hospital Cks	8.2	8.6	1553	1589	9.0	8.8	<2.0	
Laboratory control #1	8.1	8.4	307	360	8.4	8.0	<2.0	
Dilution Control #1	7.3	8.1	154	155	8.4	8.2	<2.0	
Laboratory Control #2	8.2	8.5	244	250	8.2	8.8	<2.0	

[1] Electrical conductivity (μmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.

[5] $\frac{\text{Volume dilution water}}{\text{(volume dilution water + volume sample)}}$ X 100 [6] San Joaquin River [7] Turlock Irrigation District [8] Laboratory and dilution control #1 apply

Table 3. Water quality measurements for Lagrangian survey conducted on 28-30 January 1992.

Date: Lagrangian Survey 28-30 January 1992								
Site	pH		EC[1]		DO[2]		NH_3-N[3]	dilution[5] (%)
	start	end	start[4]	end	start	end		
SJR[6] @ Hwy 165[8]	7.9	8.3	1290	1304	10.1	8.0	<2.0	
Salt Slough @ Hwy 165[8]	7.9	8.2	3040/2010	2330	10.1	8.1	<2.0	39
Mud Slough @ Kesterson	7.9	8.5	3230/1980	2100	9.8	8.2	<2.0	44
Los Banos	8.2	8.5	4860/1999	2300	10.6	8.0	<2.0	54
Newman Wasteway	7.7	8.6	1093	1150	9.2	7.9	<2.0	
Merced River[8]	7.6	7.6	105	126	10.6	7.9	<2.0	
SJR @ Hills Ferry[8]	8.0	8.0	1340	1300	10.4	8.0	<2.0	
SJR @ Fremont Ford[8]	8.0	8.1	3100/2010	2010	10.2	8.0	<2.0	42
TID 5[7]	7.8	7.8	1650	1625	7.0	4.6	<2.0	
SJR @ West Main	7.6	8.1	1470	1548	9.5	8.1	<2.0	
Stanislaus River	7.6	7.8	144	165	10.2	8.0	<2.0	
SJR @ Maze Blvd	7.7	8.2	1107	1243	10.0	7.9	<2.0	
SJR @ Airport Way	7.7	8.2	992	1068	10.0	7.9	<2.0	
Tuolumne River	7.8	7.9	231	288	10.2	7.9	<2.0	
SJR @ Laird Park	7.7	8.4	1426	1555	10.4	7.9	<2.0	
Ingram Hospital Cks	8.1	8.4	1491	1542	10.2	8.0	<2.0	
Laboratory control #1	8.1	8.1	188	200	8.1	8.1	<2.0	
Dilution Control #1	8.0	7.6	196	197	8.2	7.6	<2.0	
Laboratory Control #2	8.2	8.3	193	214	8.2	7.9	<2.0	
Dilution Control #2	8.3	8.1	124	133	7.8	8.0	<2.0	

[1] Electrical conductivity (μmhos/cm). [2] Dissolved oxygen (mg/l). [3] Ammonia (mg/l) [4] EC (before/after) dilution.
[5] Volume dilution water / (volume dilution water + volume sample) X 100 [6] San Joaquin River [7] Turlock Irrigation District
[8] Laboratory control and dilution control #1 apply

APPENDIX C

LOCATION OF SAMPLING SITES

Table 1. Description of sampling sites employed in the San Joaquin study, 1991-92. All samples were collected from the bank or by wading into the River. River miles are from U.S. Army Corps of Engineers (1984 a, b)

LOCATION	DESCRIPTION
SALT SLOUGH	Sample collected from the north side of the Slough at the Landers Avenue Bridge (Highway 165). Salt Slough enters the San Joaquin River at River mile 129.
SAN JOAQUIN RIVER AT HILLS FERRY ROAD	Sample collected from the west bank of the River about 0.5 miles upstream of its confluence with the Merced River at an abandoned tallow factory. River Mile 118.5
MERCED RIVER	Sample collected from the north bank of the River at the George J. Hatfield State Park. The confluence of the Merced and San Joaquin Rivers is at River mile 118.
TURLOCK IRRIGATION DISTRICT LATERAL NO. 6	Sample collected about 200 yards west of where the drain crosses under Central Avenue. TID 6 discharges at River mile 115.5.
ORESTIMBA CREEK	Sample collected at River Road bridge. The Creek discharges to the San Joaquin River at River mile 109.
SPANISH GRANT COMBINED DRAIN	Sample collected at intersection of Marshall and River Roads by trespassing through an abandoned dairy, up onto the eastern flood control levee of the San Joaquin and across a field to where three drains combine and discharge to the drain. The drain discharges at River mile 105.
TURLOCK IRRIGATION DISTRICT LATERAL No. 5	Sample collected from Drain at Carpenter Road bridge. The drain enters the River at mile 103.5
TURLOCK IRRIGATION DISTRICT LATERAL No. 3.	Sample collected at the Jennings Road bridge. The lateral discharges at River mile 93.5

Table 1. (Continued).

LOCATION	DESCRIPTION

DEL PUERTO CREEK Sample collected from south bank at end of Loquat Road. Del Puerto flows into the San Joaquin at River mile 93.0.-

SAN JOAQUIN RIVER AT LAIRD PARK Sample collected off east bank upstream of the confluence of lower Lateral No. 2 at Laird Park. River mile 90.5

TUOLUMNE RIVER Sample collected on north side of River at Shiloh Road bridge. The confluence of the Tuolumne and the San Joaquin Rivers is at River mile 83.8

INGRAM-HOSPITAL CREEKS Sample collected off Dairy Road by trespassing through dairy and onto the Creek's north levee bank road. Sample collected where levee Road makes an abrupt turn north. Ingram-Hospital Creek discharges at River mile 81.

STANISLAUS RIVER Sample collected off north bank of River at Caswell State Park. The Stanislaus River discharges to the San Joaquin River at River mile 75.0

APPENDIX D

SUMMARY OF BIOASSAY MORTALITY AND AMMONIA AND PESTICIDE CONCENTRATIONS

Table 1. Summary of bioassay, pesticide and ammonia data by survey date. Shading indicates sites testing toxic. Toxicity is defined as a statistically lower survival rate ($P<0.05$, Fisher Exact Test) than in the laboratory control.

Date: 25 February 1991						
Station	4 Day Survival (%)				Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
Salt Slough	100	100	100	100		
SJR[2] @ Laird Park	100	100	100	100		
SJR @ Airport Road	100	100	100	100		
Merced River	100	100	100	100		
Tuolumne River	100	100	100	100		
Stanislaus River	90	90	90	90		
TID[3] 6	100	100	100	100		
TID 5	100	100	100	100		
TID 5- bioassay duplicate	90	90	90	90		
TID 3	100	100	100	100		
Orestimba Creek	90	90	40	20	parathion=0.24 (3.4), carbamates=nd	P=3.4
Del Puerto Creek	used for bioassay duplicate					
Ingram Hospital Creek	100	100	100	100		
Spanish Grant Combined Drain	100	100	100	100		
Laboratory control	100	100	100	100		
Dilution control	100	100	100	100		

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units.

Table 1. (Continued).

Station	4 Day Survival (%)				Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
Date: 4 March 1991						
SJR[2] @ Hills Ferry Road	100	100	100	100		
SJR @ Laird Park	100	100	100	100		
SJR @ Airport Road	100	80	80	80		
SJR @ Airport Road- bioassay duplicate	100	100	100	100		
Merced River	100	100	100	100		
Tuolumne River	100	100	100	100		
Stanislaus River	used for bioassay duplicate					
TID[3] 6	100	100	100	100		
TID 5	0	0	0	0	organophosphates=nd carbamates NH_3=3.56 (1.9)	N=1.9
TID 3	0	0	0	0	chlorpyrifos=0.12 (1.2) malathion=0.01 NH_3=0.23 diazinon=0.19 parathion=0.37 (5.3) carbamates=nd	P=6.5
Orestimba Creek	0	0	0	0	carbaryl=1.7 diazinon=0.02 parathion=0.31 (4.4)	P=4.4
Del Puerto Creek	30	0	0	0	diazinon=0.1 m.parathion=0.02 fonofos=0.03 parathion=0.13 (1.9) carbamates=nd NH_3=0.54	P=1.9
Ingram Hospital Creek	60	0	0	0	diazinon=0.02 parathion=0.12 (1.7) fonofos=0.06 carbamates=nd	P=1.7
Spanish Grant Combined Drain	40	0	0	0	diazinon=0.02 parathion=0.09 (1.3) fonofos=0.01 carbamates=nd	P=1.3
Laboratory control	100	100	100	100		
Dilution control						

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units.

Table 1. (Continued).

Date: 19 March 1991						
Station	4 Day Survival (%)				Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
SJR[2] @ Hills Ferry Road	100	100	90	90		
SJR @ Laird Park	80	80	80	80		
SJR @ Airport Road	90	90	90	90		
Merced River	100	100	100	100		
Tuolumne River	100	100	100	100		
Stanislaus River	100	100	100	100		
TID[3] 6	used for bioassay duplicate					
TID 5	0	0	0	0	chlorpyrifos=0.05(0.5) malathion=0.01 diazinon=0.03 carbamates=nd NH_3=13.75(7.2)	N=7.2 P=0.5
TID 3	0	0	0	0	chlorpyrifos=0.23(2.3) diazinon=0.04 carbamates=nd	P=2.3
Orestimba Creek	60	0	0	0	parathion=0.02 diazinon=0.3(0.6) chlorpyrifos=0.05(0.5) carbamates=nd	P=1.1
Orestimba Creek- bioassay duplicate	60	0	0	0		
Del Puerto Creek	40	0	0	0	chlorpyrifos=0.12(1.2) diazinon=0.03 parathion=0.02 carbamates=nd	P=1.2
Ingram Hospital Creek	0	0	0	0	chlorpyrifos=0.57(5.7) parathion=0.01 diazinon=0.02 fonofos=0.01 carbamates=nd	P=5.7
Spanish Grant Combined Drain	0	0	0	0	chlorpyrifos=0.47(4.7) parathion=0.04(0.6) diazinon=0.02 carbamates=nd	P=5.3
Laboratory control	100	100	100	100		
Dilution control						

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units.

Table 1. (Continued).

Date: 4 April 1991						
Station	4 Day Survival (%)				Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
SJR[2] @ Hills Ferry Road	100	90	90	90		
SJR @ Hills Ferry Road- bioassay duplicate	100	100	100	100		
SJR @ Laird Park	100	90	90	90		
SJR @ Airport Road	100	100	100	100		
Merced River	100	100	100	100		
Tuolumne River	100	100	100	100		
Stanislaus River	100	100	100	100		
TID[3] 6	70	70	70	70		
TID 5	80	10	10	10	chlorpyrifos=0.02 malathion=0.01 diazinon=0.04 carbamates=nd NH_3=2.7(1.4)	N=1.4
TID 3	100	50	10	0	chlorpyrifos=0.06(0.6) diazinon=0.02 carbamates=nd NH_3=2.25(1.2)	N=1.2 P=0.6
Orestimba Creek	no flow					
Del Puerto Creek	100	100	100	100		
Ingram Hospital Creek	100	90	90	90		
Spanish Grant Combined Drain	used for bioassay duplicate					
Laboratory control	100	100	100	90		
Dilution control	90	90	90	90		

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units.

Table 1. (Continued).

Station	4 Day Survival (%)				Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
Date: 18 April 1991						
SJR[2] @ Hills Ferry Road	100	100	80	70		
SJR @ Laird Park	100	100	100	100		
SJR @ Airport Road	100	100	90	90		
Merced River	100	100	100	100		
Tuolumne River	100	100	80	80		
Stanislaus River	100	90[5]	50	50	organophosphates=nd=carbamates	
TID[3] 6	used for bioassay duplicate					
TID 5	100	100	100	100		
TID 5- bioassay duplicate	100	100	100	100		
TID 3	100	100	100	100		
Orestimba Creek	50	0	0	0	diazinon=0.02 chlorpyrifos=0.15(1.5) carbamates=nd	P=1.5
Del Puerto Creek	100	90	90	80		
Ingram Hospital Creek	100	100	100	100		
Spanish Grant Combined Drain	100	90	80	60	chlorpyrifos=0.11(1.1) diazinon=0.01 carbamates=nd	P=1.1
Laboratory control	100	90	90	90		
Dilution control	100	100	90	80		

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units.

Table 1. (Continued).

Date: 3 May 1991						
Station	4 Day Survival (%)				Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
SJR[2] @ Hills Ferry Road	100	100	100	100		
SJR @ Laird Park	100	100	100	100		
SJR @ Airport Road	100	100	100	90		
Merced River	100	100	100	100		
Tuolumne River	100	100	80	80		
Stanislaus River	100	100	100	100		
TID[3] 6	used for bioassay duplicate					
TID 5	100	100	100	100		
TID 5- bioassay duplicate	100	100	100	100		
TID 3	100	100	100	100		
Orestimba Creek	100	100	100	100		
Del Puerto Creek	90	90	90	90		
Ingram Hospital Creek	100	100	100	100		
Spanish Grant Combined Drain	100	100	90	90		
Laboratory control	100	100	100	100		
Dilution control	100	100	100	100		

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units.

Table 1. (Continued).

Date: 15 May 1991						
Station	4 Day Survival (%)				Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
SJR[2] @ Hills Ferry Road	100	100	100	100		
SJR @ Laird Park	100	100	100	100	chlorpyrifos=0.01[5] diazinon=0.01 fonofos=0.01 carbamates=nd	
SJR @ Airport Road	80	80	80	80	chlorpyrifos=0.01[5] diazinon=0.01 carbamates=nd	
Merced River	100	100	100	100		
Tuolumne River	100	100	100	100		
Stanislaus River	100	100	100	100		
TID[3] 6	100	100	100	100		
TID 6- bioassay duplicate	100	100	100	100		
TID 5	used for bioassay duplicate					
TID 3	100	100	100	100		
Orestimba Creek	0	0	0	0	chlorpyrifos=0.12(1.2) fonofos=0.01 diazinon=0.01 carbamates=nd	P=1.2
Del Puerto Creek	100	20	0	0	chlorpyrifos=0.02 fonofos=0.09 diazinon=0.04 parathion=0.01 carbaryl=1.6	
Ingram Hospital Creek	0	0	0	0	chlorpyrifos=0.01 fonofos=0.06 carbaryl=8.4(0.7) diazinon=0.03	P=0.7
Spanish Grant Combined Drain	0	0	0	0	chlorpyrifos=0.22(2.2) fonofos=0.01 diazinon=0.02 parathion=0.01 carbamates=nd	P=2.2
Laboratory control	100	100	100	100		
Dilution control	100	100	100	100		

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units.
[5]Organophosphate samples not extracted for two months. Reported values may be low.

Table 1. (Continued).

Date: 28 May 1991						
Station	4 Day Survival (%)				Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
SJR[2] @ Hills Ferry Road	100	90	90	90		
SJR @ Laird Park	100	80	80	80	chlorpyrifos=0.02 fonofos=0.02 diazinon=0.06 parathion=0.03 carbamates=nd	
SJR @ Airport Road	100	100	80	80		
Merced River	90	90	90	90		
Tuolumne River	90	90	90	90		
Stanislaus River	100	100	100	100		
TID[3] 6	100	50	0	0	chlorpyrifos=0.15(1.5) carbamates=nd	P=1.5
TID 5	100	100	100	100		
TID 3 sample bottle dropped						
Orestimba Creek	100	100	100	100		
Del Puerto Creek	0	0	0	0	chlorpyrifos=0.01 fonofos=0.12 carbamates=nd diazinon=0.42(0.8) parathion=0.72(10.3)	P=11.1
Ingram Hospital Creek	0	0	0	0	chlorpyrifos=0.02 fonofos=0.01 diazinon=0.03 parathion=0.91(9.1) carbamates=nd	P=9.1
Spanish Grant Combined Drain	0	0	0	0	chlorpyrifos=0.21(2.1) fonofos=0.20(0.7) diazinon=0.05 parathion=0.01 carbamates=nd	P=2.8
Laboratory control	100	100	100	100		
Dilution control	100	100	100	100		

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units.

Table 1. (Continued).

Date: 12 June 1991						
Station	4 Day Survival (%)				Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
SJR[2] @ Hills Ferry Road	0	0	0	0	chlorpyrifos=0.01 diazinon=0.01 carbamates=nd	
SJR @ Laird Park	20	0	0	0	organophosphates=nd carbamates=bottle broken	
SJR @ Airport Road	100	90	90	90	isofenfos=0.074(?) diazinon=0.01 carbamates=nd	
Merced River	100	100	100	100		
Tuolumne River	100	100	100	100		
Stanislaus River	60	60	60	60	chlorpyrifos=0.01 diazinon=0.02 fonofos=0.01 carbamates=bottle broken	
TID[3] 6	used for bioassay duplicate					
TID 5	100	100	100	100	NH_3=0.46	
TID 3	100	100	100	100		
TID 3- bioassay duplicate	90	90	90	90		
Orestimba Creek	100	100	100	100		
Del Puerto Creek	100	100	100	100		
Ingram Hospital Creek	100	100	100	100		
Spanish Grant Combined Drain	100	100	70	10	chlorpyrifos=0.08(0.8) diazinon=0.02 fonofos=0.03 carbamates=nd	P=0.8
Laboratory control	100	100	100	100		
Dilution control	100	100	100	100		

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). (?) indicates no toxicity data. [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units.

Table 1. (Continued).

Date: 26 June 1991						
Station	4 Day Survival (%)				Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
SJR[2] @ Hills Ferry Road	100	100	100	100		
SJR @ Laird Park	100	100	100	100		
SJR @ Airport Road	100	100	100	100		
Merced River	90	90	90	90		
Tuolumne River	100	100	100	100		
Stanislaus River	90	90	90	90		
TID[3] 6	90	90	90	90		
TID 5	100	100	100	100	NH_3=0.59	
TID 3	100	100	100	100		
Orestimba Creek	100	100	100	100		
Del Puerto Creek	used for bioassay duplicate					
Ingram Hospital Creek	100	100	100	100		
Spanish Grant Combined Drain	100	100	100	100		
Spanish Grant Combined Drain-bioassay duplicate	100	100	90	90		
Laboratory control	100	100	100	100		
Dilution control						

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units.

Table 1. (Continued).

Date: 2 July 1991						
Station	4 Day Survival (%)				Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
Salt Slough	100	90	90	80[5]		
SJR[2] @ Hills Ferry Road	100	100	100	100		
SJR @ Laird Park	100	90	90	90		
SJR @ Airport Road	100	100	100	100		
SJR @ Airport Road- bioassay duplicate	100	100	100	100		
TID[3] 5	used for bioassay duplicate					
TID 3	100	100	100	100		
Orestimba Creek	100	100	100	100		
Del Puerto Creek	100	100	100	100		
Ingram Hospital Creek	100	100	100	100		
Spanish Grant Combined Drain	100	100	100	100		
Laboratory control	100	100	100	100		
Dilution control						

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units.
[5]One animal accidentally killed by laboratory personnel.

Table 1. (Continued).

Date: 15 July 1991						
Station	4 Day Survival (%)				Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
Salt Slough	100	90	90	90		
SJR[2] @ Hills Ferry Road	100	100	90	90		
SJR @ Laird Park	100	100	90	90		
SJR @ Airport Road	100	100	100	100		
TID[3] 6	90	90	60	60	chlorpyrifos=0.01 carbamates=nd	
TID 5	used for bioassay duplicate					
TID 3	100	100	100	100		
TID 3- bioassay duplicate	100	100	100	100		
Orestimba Creek	90	90	90	90		
Del Puerto Creek	100	100	100	100		
Ingram Hospital Creek	100	100	100	100		
Spanish Grant Combined Drain	90	90	90	90		
Laboratory control	100	100	100	100		
Dilution control						

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units.

Table 1. (Continued).

Date: 30 July 1991						
Station	4 Day Survival (%)				Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
Salt Slough	100	100	100	100		
SJR[2] @ Hills Ferry Road	100	100	100	100		
SJR @ Laird Park	100	100	100	100		
SJR @ Airport Road	100	100	100	100		
TID[3] 5	100	100	100	100		
TID 3	90	90	90	90		
Orestimba Creek	0	0	0	0	chlorpyrifos=0.72(7.2) carbamates=nd	P=7.2
Del Puerto Creek	100	100	100	100		
Ingram Hospital Creek	used for bioassay duplicate					
Spanish Grant Combined Drain	90	90	90	90		
Spanish Grant Combined Drain-bioassay duplicate	100	100	100	100		
Laboratory control	90	90	90	90		
Dilution control						

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units.

Table 1. (Continued).

Date: 16 August 1991						
Station	4 Day Survival (%)				Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
Salt Slough	90	90	90	90		
SJR[2] @ Hills Ferry Road	100	100	100	100		
SJR @ Laird Park	100	100	100	100		
SJR @ Airport Road	100	100	100	100		
TID[3] 6	90	90	90	90		
TID 5	100	100	100	100		
TID 3	100	100	100	100		
Orestimba Creek	used for bioassay duplicate					
Del Puerto Creek	100	100	100	100		
Ingram Hospital Creek	100	100	100	100		
Spanish Grant Combined Drain	100	80	80	80		
Spanish Grant Combined Drain-bioassay duplicate	100	100	100	100		
Laboratory control	100	100	100	100		
Dilution control						

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units.

Table 1. (Continued).

Date: 6 September 1991						
Station	4 Day Survival (%)				Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
Salt Slough	100	100	100	100		
SJR[2] @ Hills Ferry Road	100	100	100	100		
SJR @ Laird Park	100	100	100	100	diazinon=0.01 carbamates=nd	
SJR @ Airport Road	100	100	100	100		
TID[3] 6	100	90	90	90	NH_3=0.59	
TID 5	100	100	100	100	NH_3=1.19(0.6)	N=0.6
TID 3	100	100	100	100		
Orestimba Creek	used for bioassay duplicate					
Del Puerto Creek	100	90	90	90	diazinon=0.01 NH_3=0.78	
Ingram Hospital Creek	0	0	0	0	chlorpyrifos=0.33(3.3) diazinon=0.01 carbamates=bottle broken	P=3.3
Spanish Grant Combined Drain	100	100	100	100		
Spanish Grant Combined Drain-bioassay duplicate	100	100	100	100		
Laboratory control	100	100	100	100		
Dilution control	100	100	100	100		

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units.

Table 1. (Continued).

Date: 18 September 1991						
Station	4 Day Survival (%)				Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
Salt Slough	100	100	100	100		
SJR[2] @ Hills Ferry Road	100	100	100	100		
SJR @ Laird Park	100	90[5]	90	90		
SJR @ Airport Road	100	100	100	100		
TID[3] 6	100	100	100	100		
TID 5	100	100	100	100		
TID 3	no flow					
Orestimba Creek	100	100	100	100		
Orestimba Creek- bioassay duplicate	100	100	100	100		
Del Puerto Creek	100	100	100	100		
Ingram Hospital Creek	100	100	100	100		
Spanish Grant Combined Drain	90	90	90	90		
Laboratory control	100	100	100	100		
Dilution control						

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units.
[5]One animal accidentally killed by laboratory personnel.

Table 1. (Continued).

Date: 26 September 1991						
Station	4 Day Survival (%)				Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
Salt Slough	80	80	80	80		
SJR[2] @ Hills Ferry Road	100	100	100	100		
SJR @ Laird Park	90	90	90	90	diazinon=0.01 carbamates=nd	
SJR @ Airport Road	100	100	100	100		
TID[3] 6	no flow					
TID 5	90	90	90	90		
TID 3	used for bioassay duplicate					
Orestimba Creek	100	100	100	100		
Del Puerto Creek	90	90	90	90		
Ingram Hospital Creek	90	90	90	90		
Ingram Hospital Creek- bioassay duplicate	100	100	100	100		
Spanish Grant Combined Drain	100	100	100	100		
Laboratory control	100	100	100	100		
Dilution control						

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units.

Table 1. (Continued).

Date: 9 October 1991						
Station	4 Day Survival (%)				Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
SJR[2] @ Hills Ferry Road	100	100	100	100	NH_3=0.71	
SJR @ Laird Park	100	100	100	100		
SJR @ Airport Road	100	100	100	100		
Merced River	90	80	80	70	organophosphates=nd=carbamates	
Tuolumne River	100	100	100	100		
Stanislaus River	100	100	100	80	organophosphates=nd=carbamates	
TID[3] 6	100	100	100	100		
TID 5	used for bioassay duplicate					
TID 3	90	90	90	90	NH_3=1.67(0.9)	N=0.9
TID 3- bioassay duplicate	100	90	90	90	NH_3=1.67(0.9)	N=0.9
Orestimba Creek	100	100	100	100		
Del Puerto Creek	100	100	100	100		
Ingram Hospital Creek	100	100	100	100		
Spanish Grant Combined Drain	100	100	100	100		
Laboratory control	100	100	100	100		
Dilution control	100	100	100	100		

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units.

Table 1. (Continued).

Date: 24 October 1991						
Station	4 Day Survival (%)				Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
SJR[2] @ Hills Ferry Road	100	100	100	90		
SJR @ Laird Park	100	100	100	100	diazinon=0.01 carbamates=nd	
SJR @ Airport Road	100	100	100	100		
Merced River	100	100	100	100		
Tuolumne River	100	100	100	100		
Stanislaus River	100	100	100	100		
TID[3] 6	used for bioassay duplicate					
TID 5	100	100	100	100		
TID 5- bioassay duplicate	100	100	100	100		
TID 3	no flow					
Orestimba Creek	100	100	90	90		
Del Puerto Creek	100	100	100	100		
Ingram Hospital Creek	0	0	0	0	methomyl=3.2(0.6) fonofos=0.05 diazinon=0.19	P=0.6
Spanish Grant Combined Drain	100	100	100	100		
Laboratory control	100	100	100	100		
Dilution control	100	100	100	100		

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units.

Table 1. (Continued).

Date: 30 October 1991						
Station	4 Day Survival (%)				Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
SJR[2] @ Hills Ferry Road	100	100	100	100	NH_3=0.46	
SJR @ Laird Park	100	100	100	100	diazinon=0.01 carbamates=nd	
SJR @ Airport Road	100	100	100	100		
Merced River	100	100	100	100		
Tuolumne River	100	100	100	100		
Stanislaus River	100	100	100	100		
TID[3] 6	no flow					
TID 5	100	100	100	100		
TID 3	no flow					
Orestimba Creek	used for bioassay duplicate					
Del Puerto Creek	100	100	100	100		
Ingram Hospital Creek	no flow					
Spanish Grant Combined Drain	100	100	100	100		
Spanish Grant Combined Drain-bioassay duplicate	100	100	100	100		
Laboratory control	100	100	100	100		
Dilution control						

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units.

Table 1. (Continued).

Date: 13 November 1991						
Station	4 Day Survival (%)				Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
SJR[2] @ Hills Ferry Road	100	100	100	100		
SJR @ Laird Park	100	100	100	100	diazinon=0.01 carbamates=nd	
SJR @ Airport Road	100	100	100	100		
Merced River	100	100	100	100		
Tuolumne River	100	90	90	90		
Stanislaus River	100	90	90	90		
TID[3] 6	used for bioassay duplicate					
TID 5	100	100	100	100	NH_3=1.66(0.9)	N=0.9
TID 5- bioassay duplicate	100	100	100	100	NH_3=1.66(0.9)	N=0.9
TID 3	100	100	100	100		
Orestimba Creek	100	100	100	100		
Del Puerto Creek	100	100	100	100		
Ingram Hospital Creek	100	100	100	100		
Spanish Grant Combined Drain	100	100	100	100		
Laboratory control	*100*	*100*	*100*	*100*		
Dilution control						

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in *parenthesis is the calculated number of 96 hr* LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units.

Table 1. (Continued).

Date: 25 November 1991						
Station	4 Day Survival (%)				Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
SJR[2] @ Hills Ferry Road	100	100	100	100		
SJR @ Laird Park	100	100	100	100		
SJR @ Airport Road	100	100	100	100		
Merced River	100	100	100	100		
Tuolumne River	100	100	100	100		
Stanislaus River	100	100	100	100		
TID[3] 6	50	0	0	0	organophosphates=nd=carbamates NH_3=1.84(1.0)	N=1.0
TID 5	100	100	100	100	NH_3=1.33(0.7)	N=0.7
TID 3	no flow					
Orestimba Creek	100	100	100	100		
Orestimba Creek- bioassay duplicate	100	100	100	100		
Del Puerto Creek	100	100	100	100		
Ingram Hospital Creek	100	100	100	100		
Spanish Grant Combined Drain	used for bioassay duplicate					
Laboratory control	100	100	100	100		
Dilution control						

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units.

Table 1. (Continued).

Date: 4 December 1991									
Station	Ceriodaphnia dubia Survival (%) by day							Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
SJR[2] @ Hills Ferry Road	100	100	100	100	100	100	100		
SJR @ Laird Park	100	100	100	100	100	100	100		
SJR @ Airport Road	100	100	100	100	100	100	70	NH_3=0.40	
Merced River	100	100	100	100	100	100	60		
Tuolumne River	100	100	100	90[5]	90	90	90		
Stanislaus River	100	100	100	100	100	80	80		
TID[3] 6	used for bioassay duplicate								
TID 5	100	100	100	100				NH_3=0.40	
TID 3	no flow								
Orestimba Creek	100	100	100	100					
Del Puerto Creek	100	100	100	100				NH_3=0.53	
Ingram Hospital Creek	0	0	0	0				diazinon=0.31(0.6) fonofos=0.28(1.0) methomyl=2.6(0.5)	P=2.1
Ingram Hospital Creek- bioassay duplicate	0	0	0	0					
Spanish Grant Combined Drain	100	100	100	100					
Laboratory control	100	100	100	100	100	100	100		
Dilution control									

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units. [5]One animal accidentally killed by laboratory personnel.

Table 1. (Continued).

Date: 11 December 1991									
Station	Ceriodaphnia dubia Survival (%) by day							Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
SJR[2] @ Hills Ferry Road	100	100	100	100	100	100	90		
SJR @ Laird Park	100	100	100	100	100	100	100		
SJR @ Airport Road	100	100	90	90	90	90	90		
Merced River	100	100	100	80	80	80	80		
Tuolumne River	100	100	100	100	100	100	100		
Stanislaus River	90	90	90	90	90	90	90		
TID[3] 6	100	100	80	80					
TID 5	100	90	90	90				NH_3=1.13(0.6)	N=0.6
TID 3	100	100	100	100					
Orestimba Creek	70	50	50	50				organophosphates=bottle broken carbamates=nd	
Del Puerto Creek	used for bioassay duplicate								
Ingram Hospital Creek	90	90	90	90					
Spanish Grant Combined Drain	100	100	100	100					
Spanish Grant Combined Drain-bioassay duplicate	100	100	100	100					
Laboratory control	100	100	100	100	100	100	100		
Dilution control	100	100	100	100	100	90	90		

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units.

Table 1. (Continued).

Station	Ceriodaphnia dubia Survival (%) by day							Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
Date: 18 December 1991									
SJR[2] @ Hills Ferry Road	100	100	100	100	100	100	90		
SJR @ Laird Park	100	100	100	100	100	100	100	parathion=0.01 carbamates=nd	
SJR @ Airport Road	100	100	90	90	90	90	90		
Merced River	100	100	90	90	90	90	90		
Tuolumne River	100	100	100	100	90[5]	90	90		
Stanislaus River	90	90	90	90	90	90	90		
TID[3] 6	used for bioassay duplicate								
TID 5	30	20	0	0				chlorpyrifos=0.01 NH_3=3.06(1.6) diazinon=0.08 carbamates=nd	N=1.6
TID 3	100	100	100	100					
TID 3- bioassay duplicate	100	100	100	100					
Orestimba Creek	no flow								
Del Puerto Creek	0	0	0	0				parathion=2.1(30) carbamates=nd	P=30
Ingram Hospital Creek	no flow								
Spanish Grant Combined Drain	100	100	70	70					
Laboratory control	100	100	100	100	100	100	100		
Dilution control	100	100	100	100	100	100	100		

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units.
[5]One animal accidentally killed by laboratory personnel.

Table 1. (Continued).

Date: 23 December 1991									
Station	Ceriodaphnia dubia Survival (%) by day							Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
SJR[2] @ Hills Ferry Road	100	100	90	90	90	90	90		
SJR @ Laird Park	100	100	100	100	100	90	90	parathion=0.01 carbamates=nd	
SJR @ Airport Road	100	90	90	90	90	90	90		
Merced River	100	100	100	100	100	100	100		
Tuolumne River	100	100	100	100	100	100	100		
Stanislaus River	100	100	90[5]	90	90	90	90		
TID[3] 6	100	90	90	90					
TID 5	100	100	100	100				NH_3=1.17(0.6)	N=0.6
TID 3	no flow								
Orestimba Creek	no flow								
Del Puerto Creek	40	40	0	0				chlorpyrifos=0.01 diazinon=0.01 parathion=0.24(3.4) carbamates=nd	P=3.4
Ingram Hospital Creek	100	100	0	0				diazinon=0.01 parathion=0.16(2.3) carbamates=nd	P=2.3
Spanish Grant Combined Drain	100	100	100	70					
Laboratory control	100	100	100	100	100	100	100		
Dilution control	100	100	100	100	100	100	100		

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units. [5]One animal accidentally killed by laboratory personnel.

Table 1. (Continued).

Date: 5 January 1992									
Station	Ceriodaphnia dubia Survival (%) by day							Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
SJR[2] @ Hills Ferry Road	90	90	90	90	90	90	90		
SJR @ Laird Park	100	100	100	100	100	100	100	diazinon=0.02 parathion=0.02 carbamates=nd	
SJR @ Airport Road	100	100	100	100	100	100	100		
Merced River	100	100	100	100	100	100	100		
Merced River- bioassay duplicate[5]	100	100	100	100	100	100	100		
Tuolumne River	used for bioassay duplicate								
Stanislaus River	100	100	100	100	100	100	100		
TID[3] 6	100	100	100	100					
TID 5	80	60	40	40				chlorpyrifos=0.01 diazinon=0.05 carbamates=nd NH_3=13.69(7.2)	N=7.2
TID 3	20	0	0	0				chlorpyrifos=0.02 diazinon=0.20 parathion=0.10(1.4) carbamates=nd	P=1.4
Orestimba Creek	100	100	100	100					
Del Puerto Creek	0	0	0	0				chlorpyrifos=0.01 fonofos=0.01 diazinon=0.12 parathion=0.51(7.3) carbamates=nd	P=7.3
Ingram Hospital Creek	0	0	0	0				parathion=0.12(1.7) methomyl=5.4(0.6) diazinon=0.16 fonofos=0.09	P=2.3
Spanish Grant Combined Drain	0	0	0	0				DEF=0.01(?) parathion=0.29(4.1) diazinon=0.08 carbamates=nd	P=4.1
Laboratory control	100	100	100	100	100	100	100		
Dilution control	100	100	100	100	100	100	100		

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). (?) indicates no toxicity data. [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units.

Table 1. (Continued).

Date: 13 January 1992									
Station	Ceriodaphnia dubia Survival (%) by day							Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
SJR[2] @ Hills Ferry Road	100	100	100	100	100	100	100	NH_3=0.40	
SJR @ Laird Park	100	100	100	100	100	100	100	diazinon=0.01 carbamates=nd	
SJR @ Airport Road	100	100	90	90	90	90	80		
Merced River	100	100	100	100	100	100	100		
Tuolumne River	100	100	100	100	100	100	100		
Stanislaus River	100	100	100	100	100	80[5]	80		
TID[3] 6	0	0	0	0				chlorpyrifos=0.24(2.4) diazinon=0.02 parathion=0.05(0.7) carbamates=nd NH_3=1.66(0.9)	N=0.9 P=3.1
TID 5	100	90	30	0				chlorpyrifos=0.01 DEF=0.01(?) diazinon=0.17 carbamates=nd NH_3=5.32(2.8)	N=2.8
TID 3	no flow								
Orestimba Creek	no flow								
Del Puerto Creek	0	0	0	0				diazinon=0.2 parathion=0.46(6.6) carbamates=nd	P=6.6
Ingram Hospital Creek	used for bioassay duplicate								
Spanish Grant Combined Drain	no flow								
Laboratory control	100	100	100	100	100	100	100		
Dilution control	100	100	100	100	100	90	90		

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). (?) indicates no toxicity data. [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units. [5]One animal accidentally killed by laboratory personnel.

Table 1. (Continued).

Date: 20 January 1992

Station	*Ceriodaphnia* Survival (%) by day							Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
SJR[2] @ Hills Ferry Road	100	100	90	80					
SJR @ Laird Park	100	100	100	100				chlorpyrifos=0.01 diazinon=0.01 carbamates=nd NH_3=0.53	
SJR @ Airport Road	100	100	60	60				chlorpyrifos=0.01 diazinon=0.04 carbamates=nd	
Merced River	90	90	70	50				chlorpyrifos=0.01 diazinon=0.08 carbamates=nd	
Tuolumne River	100	100	20	20				chlorpyrifos=0.02 diazinon=0.03 carbamates=nd	
Stanislaus River	100	100	50	50				diazinon=0.02 carbamates=nd	
TID[3] 6	0	0	0	0				chlorpyrifos=0.17(1.7) parathion=0.01 diazinon=0.02 carbamates=nd	P=1.7
TID 6- bioassay duplicate[6]	0	0	0	0					
TID 5	0	0	0	0				chlorpyrifos=0.01 diazinon=0.09 carbamates=nd NH_3=11.7(6.1)	N=6.1
TID 3	0	0	0	0				chlorpyrifos=1.6(16) diazinon=0.09 carbamates=nd	P=16
Orestimba Creek	no flow								
Ingram Hospital Creek	100	90	80	80					
Spanish Grant Combined Drain	no flow								
Laboratory control	100	100	90	60[5]					
Dilution control	100	70	50	40[5]					

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units. [5]Poor control survival invalidates bioassay results. Toxicity subsequently traced to the use of a new type of plastic wrap in the laboratory. [6]Del Puerto Creek used for bioassay duplicate.

Table 1 (Continued).

Station	Ceriodaphnia dubia Survival (%) by day							Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
Date: 3 February 1992									
SJR[2] @ Hills Ferry Road	100	100	100	100	90	90	90		
SJR @ Laird Park	100	100	100	100	100	100	100	chlorpyrifos=0.01 diazinon=0.06 carbamates=nd	
SJR @ Airport Road	100	100	100	100	100	100	100		
Merced River	100	100	100	100	100	100	100		
Tuolumne River	100	100	100	100	100	100	100		
Stanislaus River	100	100	100	100	100	100	100		
TID[3] 6	100	30	0	0				chlorpyrifos=0.05(0.5) parathion=0.01 diazinon=0.11 carbamates=nd	P=0.5
TID 5	100	20	0	0				chlorpyrifos=0.01 diazinon=0.26(0.5) carbamates=nd NH_3=2.66(1.4)	N=1.4 P=0.5
TID 3	no flow								
Orestimba Creek	100	100	100	90					
Del Puerto Creek	0	0	0	0				chlorpyrifos=0.01 malathion=0.01 carbamates=nd diazinon=2.6(5.0)) parathion=0.22(3.1) NH_3=3.99(2.1)	N=2.1 P=8.1
Ingram Hospital Creek	100	100	100	100					
Ingram Hospital Creek- bioassay duplicate	100	100	100	100					
Spanish Grant Drain	used for bioassay duplicate								
Laboratory control	100	100	100	100	100	100	100		
Dilution control	100	100	100	100	100	100	100		

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units.

Table 1. (Continued).

Date: 10 February 1992									
Station	Ceriodaphnia dubia Survival (%) by day							Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
SJR[2] @ Hills Ferry Road	100	100	100	100	100	100	100	NH_3=0.21	
SJR @ Laird Park	100	100	100	100	90	90	90	diazinon=0.07[6]	
SJR @ Airport Road	100	100	100	100	100	100	100		
Merced River	100	100	100	100	100	100	100		
Merced River- bioassay duplicate[7]	100	100	100	100	100	100	100		
Tuolumne River	100	100	100	100	90	90	80		
TID[3] 6	0	0	0	0				chlorpyrifos=0.12(1.2) diazinon=0.91(1.8) carbamates=nd NH_3=10.64(5.6)	N=5.6 P=3.0
TID 5	0	0	0	0				chlorpyrifos=0.04 diazinon=0.29(0.6) carbamates=nd NH_3=9.31(4.9)	N=4.9 P=0.6
TID 3	0	0	0	0				chlorpyrifos=0.73(7.3)[8] diazinon=2.6(5.2)	P=12.5
Orestimba Creek	60	0	0	0				chlorpyrifos=0.02[8] parathion=0.01 diazinon=0.26(0.5)	P=0.5
Del Puerto Creek	0	0	0	0				chlorpyrifos=0.03[8] malathion=0.28 diazinon=1.3(2.6) parathion=0.07(1.0)	P=3.6
Ingram Hospital Creek	80	0	0	0				chlorpyrifos=0.01 fonofos=0.02 diazinon=0.24(0.5) parathion=0.02 carbamates=nd	P=0.5
Spanish Grant Combined Drain	100	90	30	10				chlorpyrifos=0.08(0.8) parathion=0.12(1.7) diazinon=0.02[6]	P=2.5
Laboratory control	100	100	100	100	100	100	100		
Dilution control	100	100	100	100	100	100	100		

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units. [5]One animal accidentally killed by laboratory personnel. [6] No samples submitted for carbamate analysis. [7] Stanislaus River used for bioassay duplicate. [8]Carbamate=nd.

Table 1. (Continued).

Date: 17 February 1992									
Station	*Ceriodaphnia dubia* Survival (%) by day							Pesticide (ppb) and ammonia (mg/l) detections[1,6]	Sum of LC_{50} units[4]
SJR[2] @ Hills Ferry Road	100	100	100	100	100	100	100		
SJR @ Laird Park	no sample (see Lagrangian run, 19 February 1992)								
SJR @ Airport Road	20	0	0	0	0	0	0	chlorpyrifos=0.02 parathion=0.01 diazinon=0.28(0.6)	P=0.6
Merced River	30	0	0	0	0	0	0	chlorpyrifos=0.05(0.5) parathion=0.03 diazinon=0.32(0.6)	P=1.1
Tuolumne River	100	100	100	50	10	0	0	chlorpyrifos=0.03 diazinon=0.35(0.7)	P=0.7
Stanislaus River	100	100	100	90[7]	90	90	90	diazinon=0.06	
TID[3] 6	0	0	0	0				chlorpyrifos=0.04 malathion=0.01 diazinon=0.35(0.7) parathion=0.01	P=0.7
TID 5	0	0	0	0				chlorpyrifos=0.08(0.8) parathion=0.01 diazinon=0.5(1.0) NH_3=0.28	P=1.8
TID 3	0	0	0	0				chlorpyrifos=0.17(1.7) malathion=0.02 diazinon=0.82(1.6) parathion=0.02	P=3.3
Orestimba Creek	20	0	0	0				diazinon=0.38(0.8) parathion=0.04(0.6)	P=1.4
Del Puerto Creek	100	100	100	100					
Ingram Hospital Creek	100	100	100	100					
Spanish Grant Combined Drain	40	0	0	0				diazinon=0.06 parathion=0.01	
Laboratory control	100	100	100	100	100	100	100		
Dilution control	100	100	100	100					

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units. [5]San Joaquin River was backing up into the El Solyo Drain. [6] No samples submitted for carbamate analysis.[7] One animal accidentally killed by laboratory personnel.

Table 1. (Continued).

Date: 24 February 1992									
Station	Ceriodaphnia dubia Survival (%) by day							Pesticide (ppb) and ammonia (mg/l) detections[1,5]	Sum of LC_{50} units[4]
SJR[2] @ Hills Ferry Road	100	100	100	100	100	100	100		
SJR @ Laird Park	100	100	100	90	90	80	80	chlorpyrifos=0.01 diazinon=0.08 carbamates=nd	
SJR @ Airport Road	90	90	80	80	80	80	80		
Merced River	100	100	100	100	100	100	100		
Tuolumne River	100	100	100	100	100	100	100		
Stanislaus River	100	100	100	100	100	100	90		
TID[3] 6	100	100	100	100				chlorpyrifos=0.01 diazinon=0.02	
TID 5	0	0	0	0				chlorpyrifos=0.02 parathion=0.02 diazinon=0.45(0.9) NH_3=2.66(1.4)	N=1.4 P=0.9
TID 3	0	0	0	0				chlorpyrifos=0.03 diazinon=0.23	
Orestimba Creek	used for bioassay duplicate								
Del Puerto Creek	100	100	100	100					
Del Puerto Creek- bioassay duplicate									
Ingram Hospital Creek	100	0	0	0				chlorpyrifos=0.01 parathion=0.01 diazinon=0.2	
Spanish Grant Combined Drain	100	100	100	80					
Laboratory control	100	100	100	100	100	100	100		
Dilution control	100	100	100	100	100	100	100		

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units. [5]No carbamate analyis conducted

Table 1. (Continued).

Date: 2 March 1992									
Station	Ceriodaphnia dubia Survival (%) by day							Pesticide (ppb) and ammonia (mg/l) detections[1,5]	Sum of LC_{50} units[4]
Salt Slough	100	100	100	100	100	100	100		
SJR[2] @ Hills Ferry Road	100	100	100	100	100	100	100		
SJR @ Laird Park	no sample								
SJR @ Airport Road	100	100	100	100	100	90	90		
Merced River	100	100	100	100	100	100	100		
Tuolumne River	100	100	100	100	100	100	100		
Stanislaus River	100	100	100	100	100	100	100		
TID[3] 6	100	100	100	100				NH_3=2.23(1.2)	N=1.2
TID 6- bioassay duplicate	100	100	100	100				NH_3=1.90(1.0)	N=1.0
TID 5	used for bioassay duplicate								
TID 3	80	0	0	0				chlorpyrifos=0.04 diazinon=0.33(0.7)	P=0.7
Orestimba Creek	no flow								
Del Puerto Creek	100	100	100	100					
Ingram Hospital Creek	100	100	100	100					
Spanish Grant Combined Drain	100	100	100	100					
Laboratory control	100	100	100	100	100	100	100		
Dilution control	100	100	100	100	100	100	100		

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units.

Table 1. (Continued).

Date: 9 March 1992									
Station	Ceriodaphnia dubia Survival (%) by day							Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
SJR[2] @ Hills Ferry Road	100	100	100	100	100	100	100		
SJR @ Laird Park	100	90	90	40	0	0	0	chlorpyrifos=0.04 diazinon=0.04 carbamates=nd	
SJR @ Airport Road	100	100	100	90	40	0	0	chlorpyrifos=0.03 diazinon=0.04 carbamates=nd	
Merced River	100	100	100	100	100	80	40	chlorpyrifos=0.01=parathion diazinon=0.04 carbamates=nd	
Tuolumne River	100	100	100	100	100	100	100		
Tuolumne River- bioassay duplicate[6]	100	100	100	100	100	100	100		
Stanislaus River	used for bioassay duplicate								
TID[3] 6	100	100	100	90					
TID 5	0	0	0	0				chlorpyrifos=0.08(0.8) diazinon=0.08 carbamates=nd NH_3=0.98	P=0.8
TID 3	0	0	0	0				chlorpyrifos=0.12(1.2) parathion=0.01 diazinon=0.27(0.5)	P=1.7
Orestimba Creek	100	90	90	80					
Del Puerto Creek	100	100	100	100					
Ingram Hospital Creek	0	0	0	0				chlorpyrifos=0.01 fonofos=0.01 diazinon=0.06	
Spanish Grant Combined Drain	100	100	100	90					
Laboratory control	100	100	100	100	100	100	100		
Dilution control	100	100	100	90	90	90	90		

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units.

Table 1. (Continued).

Date: 16 March 1992									
Station	Ceriodaphnia dubia Survival (%) by day[8]							Pesticide (ppb) and ammonia (mg/l) detections[1,5]	Sum of LC_{50} units[4]
Salt Slough	30	0	0	0				chlorpyrifos=0.01[7] malathion=0.16 diazinon=0.33(0.7)	P=0.7
SJR[2] @ Hills Ferry Road	100	100	100	20				chlorpyrifos=0.01[7] malathion=0.16 diazinon=0.38(0.8)	P=0.8
SJR @ Laird Park	100	100	100	100				chlorpyrifos=0.01[7] malathion=0.08 diazinon=0.07	
SJR @ Airport Road	100	80	80	80					
Merced River	100	100	100	80					
Tuolumne River	100	90	90	90					
Stanislaus River	100	100	100	100					
TID[3] 6	100	100	100	100					
TID 5	100	100	100	100					
TID 5- bioassay duplicate	100	100	90	90					
TID 3	100	100	0	0				chlorpyrifos=0.04 diazinon=0.18 carbamates=nd	
Orestimba Creek	used for bioassay duplicate								
Del Puerto Creek	100	100	70	70					
Ingram Hospital Creek	90	10	0	0				chlorpyrifos=0.06(0.6) diazinon=0.02 carbamates=nd	P=0.6
Spanish Grant Combined Drain	100	100	100	100					
Laboratory control	100	100	100	100					
Dilution control	100	100	100	90					

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units. [5]Refrigerator broke. Samples held incidentally for 72 hours without refrigeration at about 20 °C. [7]carbamates=nd. [8]Bioassay testing terminated at 96 hours to treat laboratory for fungal outbreak in water baths.

Table 1. (Continued).

Date: 23 March 1992									
Station	Ceriodaphnia dubia Survival (%) by day[4]							Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
Salt Slough	100	100	100	100	100	100	100		
SJR[2] @ Hills Ferry Road	100	100	100	100	100	100	100		
SJR @ Laird Park	100	100	100	100	100	100	90	chlorpyrifos=0.01 malathion=0.01 diazinon=0.14	
SJR @ Airport Road	100	100	100	100	100	100	100		
Merced River	*100*	*100*	*100*	*100*	*100*	*90*[6]	*90*		
Tuolumne River	100	100	100	100	100	100	100		
Stanislaus River	100	100	100	100	90	80	80		
TID[3] 6	100	100	100	100					
TID 5	100	100	100	100					
TID 3	90[5]	0	0	0					
Orestimba Creek	0	0	0	0				chlorpyrifos=0.29(2.9) malathion=0.18 diazinon=0.1 carbamates=nd	P=2.9
Del Puerto Creek	0	0	0	0				chlorpyrifos=0.02 fonofos=0.54(2.0) diazinon=0.13 malathion=0.01 carbamates=nd	P=2.0
Ingram Hospital Creek	0	0	0	0				chlorpyrifos=0.05(0.5) fonofos=0.02 diazinon=0.29(0.6) malathion=0.42 carbamates=nd parathion=0.04(0.6)	P=1.7
Spanish Grant Combined Drain	0	0	0	0				chlorpyrifos=0.06(0.6) parathion=0.11(1.1) carbofuran=0.8 diazinon=0.06	P=1.7
Laboratory control	100	100	100	100	90	90	90		
Dilution control	100	100	100	100	100	100	100		

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units. [5]Refrigerator froze sample--no analysis. [6]Animal accidentally killed by laboratory personnel.

Table 1. (Continued).

Date: 30 March 1992									
Station	Ceriodaphnia dubia Survival (%) by day							Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
Salt Slough	used for bioassay duplicate								
SJR[2] @ Hills Ferry Road	100	100	100	100	100	100	100		
SJR @ Hills Ferry Road- bioassay duplicate	100	100	100	100	100	100	100		
SJR @ Laird Park	100	100	100	100	100	100	100	chlorpyrifos=0.01 diazinon=0.03 carbamates=nd	
SJR @ Airport Road	100	100	100	90	90	90	90		
Merced River	100	100	100	90	90	90	90		
Tuolumne River	100	100	100	100	100	100	100		
Stanislaus River	100	90	70	70	70	70	70		
TID[3] 6	100	100	100	100					
TID 5	100	100	100	100					
TID 3	100	100	100	100					
Orestimba Creek	100	100	100	100					
Del Puerto Creek	100	100	100	100					
Ingram Hospital Creek	100	100	100	100					
Spanish Grant Combined Drain	100	100	100	100					
Laboratory control	100	100	100	100	100	100	100		
Dilution control	100	100	100	100	100	100	100		

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units.

Table 1. (Continued).

Date: 6 April 1992									
Station	Ceriodaphnia dubia Survival (%) by day							Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
Salt Slough	100	100	100	100	100	100	100		
SJR[2] @ Hills Ferry Road	100	100	100	100	100	100	100		
SJR @ Laird Park	100	90	90	90	80	80	70	diazinon=0.02 fonofos=0.01 carbamates=nd	
SJR @ Airport Road	100	100	100	100	100	100	100		
Merced River	*100*	*100*	*100*	*100*	*100*	*100*	*100*		
Tuolumne River	100	100	100	100	100	100	100		
Stanislaus River	100	100	100	100	90[5]	90	90		
TID[3] 6	40	0	0	0				chloropyrifos=0.14(1.4) diazinon=0.01 carbamates=nd	P=1.4
TID 5	100	100	100	100					
TID 3	used for bioassay duplicate								
Orestimba Creek	100	100	100	100					
Del Puerto Creek	100	100	70	10				diazinon=0.02 fonofos=0.52(1.9) carbamates=nd	P=1.9
Ingram Hospital Creek	100	100	100	100					
Ingram Hospital Creek- bioassay duplicate	100	100	100	100					
Spanish Grant Combined Drain	100	100	100	100					
Laboratory control	100	100	100	100	100	100	90[5]		
Dilution control	100	100	100	100	90[5]	90	90		

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units. [5]One animal accidentally killed by laboratory personnel.

Table 1. (Continued).

Date: 13 April 1992									
Station	*Ceriodaphnia dubia* Survival (%) by day							Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
Salt Slough	100	90	90	90	90	90	0	chlorpyrifos=0.12(1.2) diazinon=0.01 carbamates=nd	P=1.2
SJR[2] @ Hills Ferry Road	100	100	100	100	100	100	100		
SJR @ Laird Park	100	100	100	100	100	100	100	chlorpyrifos=0.02 diazinon=0.02 carbamates=nd	
SJR @ Airport Road	100	100	100	100	100	100	100		
Merced River	100	100	100	100	100	100	0	chlorpyrifos=0.13(1.3) fonofos=0.01 diazinon=0.01 carbamates=nd	P=1.3
Tuolumne River	100	100	100	100	100	100	80		
Stanislaus River	100	100	100	100	100	100	90		
TID[3] 6	100	100	80	80					
TID 6- bioassay duplicate	100	100	100	100					
TID 5	used for bioassay duplicate								
TID 3	100	100	90	90					
Orestimba Creek	100	100	100	100					
Del Puerto Creek	100	100	100	100					
Ingram Hospital Creek	100	100	100	100					
Spanish Grant Combined Drain	100	100	80	40				diazinon=0.03 carbamates=nd	
Laboratory control	100	100	100	100	100	100	100		
Dilution control	100	100	100	100	100	100	100		

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units.

Table 1. (Continued).

Date: 20 April 1992									
Station	Ceriodaphnia dubia Survival (%) by day							Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
Salt Slough	100	100	100	100	90	90	90		
SJR[2] @ Hills Ferry Road	100	100	90[5]	90	90	90	90		
SJR @ Laird Park	100	100	100	100	100	100	100	chlorpyrifos=0.03 diazinon=0.02 carbamates=nd	
SJR @ Airport Road	100	100	100	100	100	100	100		
Merced River	100	100	100	100	100	100	100		
Tuolumne River	100	100	100	90[5]	90	90	90		
Stanislaus River	100	100	100	100	100	100	100		
TID[3] 6	100	100	100	100					
TID 5	100	100	100	100					
TID 3	used for bioassay duplicate								
Orestimba Creek	100	100	90	70				chlorpyrifos=0.02 fonofos=0.21(0.8) diazinon=0.01 carbamates=nd	P=0.8
Del Puerto Creek	100	100	100	100					
Ingram Hospital Creek	100	100	90	90					
Ingram Hospital Creek- bioassay duplicate	100	100	80	80					
Spanish Grant Combined Drain	80	0	0	0				organophosphates=nd=carbamates	
Laboratory control	100	100	100	100	100	100	100		
Dilution control	100	100	60	60	60	60	60		

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units. [5]One animal accidentally killed by laboratory personnel.

Table 1. (Continued).

Date: 27 April 1992									
Station	Ceriodaphnia dubia Survival (%) by day							Pesticide (ppb) and ammonia (mg/l) detections	Sum of LC_{50} units[4]
Salt Slough	100	100	100	100	100	100	100	diazinon=0.17	
SJR[2] @ Hills Ferry Road	100	100	100	100	100	100	100	chlorpyrifos=0.01 diazinon=0.07	
SJR @ Laird Park	100	100	100	100	90	90	90	chlorpyrifos=0.02 diazinon=0.03 carbamates=nd	
SJR @ Airport Road	100	100	80	80	80	80	70	chlorpyrifos=0.01	
Merced River	100	100	100	100	100	100	100	chlorpyrifos=0.01	
Tuolumne River	100	100	100	90	90	90	90	chlorpyrifos=0.01	
Stanislaus River	100	100	100	100	90[5]	90	90		
TID[3] 6	100	100	90	90				chlorpyrifos=0.01	
TID 5	100	100	100	100				chlorpyrifos=0.02 diazinon=0.01	
TID 3	100	90	80[5]	80				organophosphates=nd	
Orestimba Creek	100	10	0	0				chlorpyrifos=0.09(0.9) fonofos=0.06 diazinon=0.01 carbamates=nd	P=0.9
Del Puerto Creek	100	100	100	100				chloryprifos=0.03 diazinon=0.02	
Ingram Hospital Creek	100	90	90	70				chlorpyrifos=0.01 diazinon=0.02	
Spanish Grant Combined Drain	0	0	0	0				chlorpyrifos=0.19(1.9) diazinon=0.02 parathion=0.01 fonofos=0.06 carbamates=nd	P=1.9
Laboratory control	100	100	100	100	100	100	90		
Dilution control	100	100	100	100	100	100	100		

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. No carbamate analysis conducted. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units. [5]One animal accidentally killed by laboratory personnel.

Table 1. (Continued).

Date: 4 May 1992									
Station	Ceriodaphnia dubia Survival (%) by day							Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
Salt Slough	100	100	80	70	70	70	70	diazinon=0.06 carbamates=nd	
SJR[2] @ Hills Ferry Road	100	100	100	100	100	100	100	diazinon=0.06	
SJR @ Laird Park	100	100	100	100	100	100	100	chlorpyrifos=0.02 diazinon=0.02 carbamates=nd	
SJR @ Airport Road	100	100	90	90	90	90	80	chlorpyrifos=0.01 carbamates=nd	
Merced River	100	100	100	90[4]	90	90	90	chlorpyrifos=0.01	
Tuolumne River	100	100	100	100	80	70	70	chlorpyrifos=0.01 carbamates=nd	
Stanislaus River	100	90	80	80	60	60	60	organophosphates=nd=carbamates	
TID[3] 6	100	100	100	100				chlorpyrifos=0.01	
TID 5	100	100	100	100				chlorpyrifos=0.01 diazinon=0.01	
TID 3	100	100	100	100				chlorpyrifos=0.01 diazinon=0.03	
Orestimba Creek	0	0	0	0				chlorpyrifos=0.08(0.8) fonofos=0.03 ethion=0.05(?) diazinon=0.01 carbamates=nd	P=0.8
Del Puerto Creek	100	100	0	0				chlorpyrifos=0.02 diazinon=0.01 carbamates=nd	
Ingram Hospital Creek	0	0	0	0				chlorpyrifos=0.02 diazinon=0.01 carbaryl=2.0	
Ingram Hospital Creek- bioass. duplicate	0	0	0	0					
Spanish Grant Combined Drain	0	0	0	0				chlorpyrifos=0.07(0.7) fonofos=0.07 diazinon=0.01 carbamates=nd	P=0.7
Laboratory control	100	100	100	100	100	100	100		
Dilution control	100	100	100	90[5]	90	90	90		

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Carbamate analysis not conducted unless indicated otherwise. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units. [5]One animal accidentally killed by laboratory personnel.

Table 1. (Continued).

Date: 11 May 1992									
Station	Ceriodaphnia dubia Survival (%) by day							Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
Salt Slough	100	100	100	100	100	100	100	diazinon=0.02	
SJR[2] @ Hills Ferry Road	100	100	100	90	80	80	80	chlorprifos=0.02 diazinon=0.02	
SJR @ Laird Park	100	100	100	100	100	100	90	chlorpyrifos=0.02 disyston=0.06(?) carbamates=nd	
SJR @ Airport Road	100	100	100	100	90	90	90	chlorpyrifos=0.01 diazinon=0.01	
Merced River	100	100	100	100	100	100	100	organophosphates=nd	
Tuolumne River	100	100	90	90	90	90	90	chlorpyrifos=0.01	
Tuolumne River- bioassay duplicate	100	100	100	100	100	100	100		
Stanislaus River	used for bioassay duplicate								
TID[3] 6	100	70	50	50				chlorpyrifos=0.07(0.7) carbamates=nd	P=0.7
TID 5	100	100	100	100				chlorpyrifos=0.05(0.5) diazinon=0.01	P=0.5
TID 3	90	90	90	90				chlorpyrifos=0.01 diazinon=0.01	
Orestimba Creek	70	0	0	0				chlorpyrifos=0.02 fonofos=0.02 ethion=0.01(?) diazinon=0.18 carbamates=nd	
Del Puerto Creek	100	100	20	0				chlorpyrifos=0.02 fonofos=0.03 diazinon=0.22 carbamates=nd	
Ingram Hospital Creek	0	0	0	0				chlorpyrifos=0.01 diazinon=0.06 carbaryl=2.8	
Spanish Grant Combined Drain	0	0	0	0				chlorpyrifos=0.04 fonofos=0.03 diazinon=1.2(2.4) carbamates=nd	P=2.4
Laboratory control	100	100	100	100	100	100	100		
Dilution control	100	100	100	100	100	100	100		

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Carbamate analysis not conducted unless indicated otherwise. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units.

Table 1. (Continued).

Station	Ceriodaphnia dubia Survival (%) by day							Pesticide (ppb) and ammonia (mg/l) detections[1]	Sum of LC_{50} units[4]
Date: 18 May 1992									
Salt Slough	100	100	100	100	100	100	90	diazinon=0.03	
SJR[2] @ Hills Ferry Road	100	100	100	100	100	100	100	diazinon=0.02	
SJR @ Laird Park	100	100	100	100	100	100	100	chlorpyrifos=0.01 diazinon=0.04 carbamates=nd	
SJR @ Airport Road	100	100	100	100	100	100	90	diazinon=0.05	
Merced River	used for bioassay duplicate								
Tuolumne River	100	100	100	100	100	100	100	diazinon=0.02	
Tuolomne River- bioassay duplicate	100	100	100	100	100	100	100		
Stanislaus River	100	100	100	100	100	100	90[5]	organophosphates=nd	
TID[3] 6	100	100	100	100				organophosphates=nd	
TID 5	100	100	100	100				NH_3=0.59	
TID 3	100	100	100	100				chlorpyrifos=0.01	
Orestimba Creek	100	100	100	90				chlorpyrifos=0.01 diazinon=0.07	
Del Puerto Creek	100	100	100	100				chlorpyrifos=0.01 diazinon=0.01	
Ingram Hospital Creek	0	0	0	0				chlorpyrifos=0.01 diazinon=0.05 carbaryl=0.6	
Spanish Grant Combined Drain	100	70	0	0				chlorpyrifos=0.05(0.5) fonofos=0.04 diazinon=0.08 carbamates=nd	P=0.5
Laboratory control	100	100	100	100	100	100	100		
Dilution control	100	100	100	90[5]	90	90	90		

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Carbamate analysis not conducted unless indicated otherwise. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units. [5]One animal accidentally killed by laboratory personnel.

Table 1. (Continued).

Date: 25 May 1992									
Station	Ceriodaphnia dubia Survival (%) by day							Pesticide (ppb) and ammonia (mg/l) detections	Sum of LC_{50} units[4]
Salt Slough	100	100	100	100	100	100	100	diazinon=0.04	
SJR[2] @ Hills Ferry Road	100	100	100	100	100	100	100	diazinon=0.03	
SJR @ Laird Park	100	100	100	90	90	90	80	diazinon=0.02 carbamates=nd	
SJR @ Airport Road	100	100	100	100	100	100	80	diazinon=0.06	
Merced River	100	100	100	100	100	100	100	organophosphates=nd	
Tuolumne River	100	100	100	100	100	100	100	chlorpyrifos=0.01 diazinon=0.03	
Stanislaus River	100	100	100	100	100	100	70	organophosphates=nd	
TID[3] 6	used for bioassay duplicate								
TID 5	100	100	100	100				chlorpyrifos=0.01	
TID 3	100	100	100	100				organophosphates=nd	
Orestimba Creek	0	0	0	0				chlorpyrifos=0.01 fonofos=0.01 diazinon=0.88(1.8) carbamates=nd	P=1.8
Del Puerto Creek	100	100	30	0				chlorpyrifos=0.01 diazinon=0.2 carbamates=nd	
Ingram Hospital Creek	0	0	0	0				chlorpyrifos=0.01 diazinon=1.8(3.6) carbamates=nd	P=3.6
Ingram Hospital Creek- bioassay duplicate	0	0	0	0					
Spanish Grant Combined Drain	100	100	100	70				chlorpyrifos=0.03 diazinon=0.07 fonofos=0.02	
Laboratory control	100	100	100	100	100	100	100		
Dilution control	100	100	100	100	90	90	90		

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. No carbamate analysis conducted unless indicated otherwise. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units.

Table 1. (Continued).

Date: 1 June 1992									
Station	*Ceriodaphnia dubia* Survival (%) by day							Pesticide (ppb) and ammonia (mg/l) detections	Sum of LC_{50} units[4]
Salt Slough	100	100	100	100	100	100	100	diazinon=0.02	
SJR[2] @ Hills Ferry Road	100	100	100	100	100	100	100	diazinon=0.02	
SJR @ Laird Park	100	100	100	100	100	100	100	chlorpyrifos=0.01 diazinon=0.02 carbamates=nd	
SJR @ Airport Road	100	100	100	100	100	100	100	diazinon=0.01	
Merced River	100	100	100	100	100	100	100	organophosphates=nd	
Tuolumne River	100	100	100	100	100	100	100	diazinon=0.01	
Stanislaus River	100	100	100	100	100	100	100	organophosphates=nd	
TID[3] 6	0	0	0	0				chlorpyrifos=0.25(2.5) carbamates=nd	P=2.5
TID 5	100	100	100	100				chlorpyrifos=0.01[5]	
TID 3	used for bioassay duplicate								
Orestimba Creek	100	100	100	100				diazinon=0.02 fonofos=0.02	
Del Puerto Creek	100	100	100	100				chlorpyrifos=0.02 diazinon=0.02 fonofos=0.01	
Ingram Hospital Creek	100	100	100	100				diazinon=0.07	
Ingram Hospital Creek- bioassay duplicate	100	100	100	100					
Spanish Grant Combined Drain	0	0	0	0				chlorpyrifos=0.17(1.7) diazinon=0.02 carbamates=nd	P=1.7
Laboratory control	100	100	100	100	100	100	100		
Dilution control	100	100	100	100	100	100	100		

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. Carbamate analysis not conducted unless indicated otherwise. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units. [5]Data may be unreliable as surrogate recovery was out of bounds.

Table 1. (Continued).

Date: 15 June 1992									
Station	Ceriodaphnia dubia Survival (%) by day							Pesticide (ppb) and ammonia (mg/l) detections	Sum of LC_{50} units[4]
Salt Slough	100	100	90	90	90	90	90	organophosphates=nd	
SJR[2] @ Hills Ferry Road	100	100	100	100	100	100	100	organophosphates=nd	
SJR @ Laird Park	100	100	100	100	100	100	100	chlorpyrifos=0.01 carbamates=nd	
SJR @ Airport Road	100	100	100	100	100	100	100	organophosphates=nd	
Merced River	100	100	100	80	80	80	80	organophosphates=nd	
Tuolumne River	100	100	90	90	90	90	90	chlorpyrifos=0.01	
Stanislaus River	100	100	100	100	100	100	100	organophosphates=nd	
TID[3] 6	100	100	100	100				organophosphates=nd	
TID 5	100	100	100	100				organophosphates=nd	
TID 3	used for bioassay duplicate								
Orestimba Creek	100	100	100	100				chlorpyrifos=0.01	
Del Puerto Creek	100	100	100	100				chlorpyrifos=0.01 diazinon=0.01 fonofos=0.03	
Ingram Hospital Creek	100	100	100	100				chlorpyrifos=0.01 diazinon=0.01	
Ingram Hospital Creek- bioassay duplicate	100	100	100	100					
Spanish Grant Combined Drain	100	100	100	100				chlorpyrifos=0.01 diazinon=0.01	
Laboratory control	100	100	100	100	100	100	100		
Dilution control	100	100	100	100	100	100	100		

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. No carbamate analysis conducted unless indicated otherwise. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units.

Table 1. (Continued).

Date: 22 June 1992									
Station	Ceriodaphnia dubia Survival (%) by day							Pesticide (ppb) and ammonia (mg/l) detections	Sum of LC_{50} units[4]
Salt Slough	100	100	100	90[4]	90	90	90	diazinon=0.01	
SJR[2] @ Hills Ferry Road	100	100	100	100	100	100	100	diazinon=0.01	
SJR @ Laird Park	100	90	90	90	90	90	90	chlorpyrifos=0.01 diazinon=0.02 carbamates=nd	
SJR @ Airport Road	100	100	100	100	100	100	100	organophosphates=nd	
Merced River	100	100	100	80	80	50	50	organophosphates=nd=carbamates	
Tuolumne River	100	100	90	70	70	50	40	diazinon=0.01 carbamates=nd	
Stanislaus River	100	90	90	70	70	40	40	chlorpyrifos=0.01 carbamates=nd	
TID[3] 6	100	100	100	100				chlorpyrifos=0.01[5]	
TID 5	100	100	100	100				chlorpyrifos=0.01	
TID 3	100	100	100	0				organophosphates=nd=carbamates NH_3=1.20	
Orestimba Creek	100	0	0	0				chlorpyrifos=0.02 fonofos=0.01 diazinon=0.03 carbamates=nd	
Del Puerto Creek	100	100	100	100				chlorpyrifos=0.04 diazinon=0.02	
Ingram Hospital Creek	100	80	80	80				chlorpyrifos=0.01 diazinon=0.01 carbamates=nd	
Ingram Hospital Creek- bioassay duplicate	100	100	90	90					
Spanish Grant Combined Drain	0	0	0	0				chlorpyrifos=0.01 fonofos=0.01 diazinon=0.02 carbamates=nd	
Laboratory control	100	100	100	100	100	100	100		
Dilution control	100	100	100	100	100	100	100		

[1]Blanks indicate that no pesticide analysis was conducted and that ammonia was less than 2.0 mg/l; nd=no detections. No carbamate analysis conducted unless indicated otherwise. Unionized ammonia as NH_3. Value in parenthesis is the calculated number of 96 hr LC_{50} units (pesticide concentration/LC_{50} value). [2]San Joaquin River. [3]Turlock Irrigation District. [4]P=Sum of pesticide LC_{50} units. N=Ammonia LC_{50} units. [5]Data should be viewed with caution because of low surrogate recovery.

Table 1. Chlorpyrifos use during 1990 (Department of Pesticide Reguluation, 1990). All commodities receiving more than 30 pounds of active ingredient are reported.

Commodity	Stanislaus County		San Joaquin County		Merced County	
	Number of applications	Pounds applied	Number of applications	Pounds applied	Number of applications	Pounds applied
Alfalfa	410	20,622	323	16,132	297	13,078
Almonds	1100	66,404	440	25,535	470	36,310
Apples	70	3,081	39	1,643	8	408
Asparagus			21	1,150		
Broccoli			1	80		
Cabbage	4	364				
Cauliflower			6	338		
Cherries			6	42		
Corn	91	7083	44	3345	42	2328
Cotton					15	956
Landscape Maintenace			62	128	17	56
Container Plants	55	33			24	52
Nectarine			1	60		
Nut Crops	2	196				
Peach	17	399	1	30	5	280
Pear	1	50			2	50
Pecan	1	50			2	50
Plum					2	62
Public Health					3	181
Prune			2	57		

Table 1. Chlorpyrifos use continued.

Commodity	Stanislaus County		San Joaquin County		Merced County	
	Number of applications	Pounds applied	Number of applications	Pounds applied	Number of applications	Pounds applied
Sorghum			2	117		
Structural	317	3,437	638	5,809	390	3,599
Sugarbeets			284	15,986	45	2,734
Sweet Potato	5	130			21	645
Walnuts	500	30,993	517	39,762	214	14,453
Wheat			12	1,552		
Total						

Table 2. Diazinon use during 1990 (Department of Pesticide Reguluation, 1990). All commodities receiving more than 30 pounds of active ingredient are reported.

Commodity	Stanislaus County		San Joaquin County		Merced County	
	Number of applications	Pounds applied	Number of applications	Pounds applied	Number of applications	Pounds applied
Alfalfa	40	680	154	4,353	316	6,458
Almonds	536	57,073	319	16,427	403	50,470
Apples	21	509	55	1,705	16	606
Apricots	144	2,943	48	1,445	46	3,644
Beans					5	79
Beets	35	34				
Broccoli			6	40		
Cauliflower	8	410	11	56		
Cherries	8	410	321	9,107		
Corn			79	4,152	10	701
Cucumbers			3	98	1	96
Figs					3	219
Grapes			98	2,810		
Landscape Maintenance			74	462		
Lettuce	20	513				
Melons	44	957			93	2,974
Container Plants	19	97	61	225	7	38
Nectarines			4	86	4	57
Nut Crops	4	120				
Onions	11	76	12	52	2	32

Table 2. Diazinon use continued.

Commodity	Stanislaus County		San Joaquin County		Merced County	
	Number of applications	Pounds applied	Number of applications	Pounds applied	Number of applications	Pounds applied
Peaches	83	1,691	28	560	4	934
Pears			10	356		
Peppers	8	61				
Plums					17	616
Prunes	1	42			19	1,398
Structural	235	2,226			328	4,947
Sugarbeets	10	299			12	308
Sweet Potatoes					1	39
Swiss Chard	64	36				
Tomato	21	260			14	148
Walnuts	24	966			13	569
Watermelon					7	134
Total						

Table 3. Parathion use during 1990 (Department of Pesticide Reguluation, 1990). All commodities receiving more than 30 pounds of active ingredient are reported.

Commodity	Stanislaus County		San Joaquin County		Merced County	
	Number of applications	Pounds applied	Number of applications	Pounds applied	Number of applications	Pounds applied
Alfalfa			1	96	7	133
Almonds	415	33,055	122	6,496	781	62,074
Apples	3	40	3	76		
Apricots	320	11,439	8	6,161	20	555
Beans			6	137		
Cherries	17	693	14	856		
Oats			1	72		
Nectarines					5	58
Nut Crops					1	210
Peaches	165	5,301	5	228	142	5,402
Pears			2	83		
Plums	3	83			2	31
Prunes	5	242			19	1,218
Pumpkins	17	231	22	576		
Spinach	25	657				
Squash			3	60		
Swiss Chard	2	105				
Tomatoes	4	120	4	127	1	78
Wheat					2	109
Total						

Table 4. Fonofos use during 1990 (Department of Pesticide Reguluation, 1990). All commodities receiving more than 30 pounds of active ingredient are reported.

Commodity	Stanislaus County		San Joaquin County		Merced County	
	Number of applications	Pounds applied	Number of applications	Pounds applied	Number of applications	Pounds applied
Asparagus			26	2,954		
Beans	13	1,259	15	2,200	1	40
Broccoli	1	110				
Corn			40	3,775		
Peppers	14	936	5	293		
Sugarbeets			4	333		
Tomatoes	42	2886	37	3,101	3	183
Total						

Table 5. Carbaryl use during 1990 (Department of Pesticide Reguluation, 1990). All commodities receiving more than 30 pounds of active ingredient are reported.

Commodity	Stanislaus County		San Joaquin County		Merced County	
	Number of applications	Pounds applied	Number of applications	Pounds applied	Number of applications	Pounds applied
Alfalfa	5	429	3	96	5	764
Almonds	8	1,514	5	370	12	535
Apples	4	51	16	521	6	456
Apricots	3	91	2	98	3	243
Beans	14	1,568	9	720		
Beets			18	681		
Boysenberries			2	41	3	45
Citrus					3	207
Cherries			80	4,146		
Corn	98	3,795	149	5,866	61	2,485
Cotton			3	81	3	57
Grapes	72	6,150	67	7,543	16	3,457
Landscape maintenace	8	1,603	16	425	6	177
Lettuce	16	137				
Melons					7	408
Nectarines	5	67	2	46	9	147
Peaches	162	8,683	16	816	105	7,817
Peppers	19	954	9	273	1	70
Pumpkins	4	115				
Rangeland			3	75		

Table 5. Carbaryl use continued.

Commodity	Stanislaus County		San Joaquin County		Merced County	
	Number of applications	Pounds applied	Number of applications	Pounds applied	Number of applications	Pounds applied
Right of Way	3	77				
Small Fruit	2	41				
Sorghum			3	196		
Structural	25	1,794	41	212	55	19,433
Sugarbeets	1	128	89	5,711	11	426
Sunflowers			2	75		
Tomato	117	7,396	160	1,980	24	955
Walnuts			26	982		
Total						

Table 6. Methomyl use during 1990 (Department of Pesticide Reguluation, 1990). All commodities receiving more than 30 pounds of active ingredient are reported.

Commodity	Stanislaus County		San Joaquin County		Merced County	
	Number of applications	Pounds applied	Number of applications	Pounds applied	Number of applications	Pounds applied
Alfalfa	90	2,433	291	9,296	303	7,568
Apples					8	188
Beans	206	6,576	35	1,423	43	1,525
Beets	89	405	4	141	7	169
Bokchoy	119	124				
Broccoli	9	199			9	192
Cabbage	143	149	10	226		
Cauliflower	57	2,442	15	529	14	509
Celery	35	801	1	31		
Collards	67	101				
Corn	5	137	171	1,065	11	283
Cucumbers			2	47		
Grapes	4	127	18	914	34	1,068
Kale	131	109				
Lettuce	285	646				
Melon	12	672			85	2,194
Mustard	71	84				
N-grms	133	1,986	37	34	16	246
Onions	16	318			3	64
Peaches					1	35

Table 6. Methomyl use continued.

Commodity	Stanislaus County		San Joaquin County		Merced County	
	Number of applications	Pounds applied	Number of applications	Pounds applied	Number of applications	Pounds applied
Peppers	55	2,034	79	1,519	1	67
Potatoes			7	406		
Pumpkins	9	247	39	1,042		
Right of Way					1	356
Sorghum			2	65	4	216
Spinach	2	68				
Sugarbeets	10	156	55	1,745	271	7,633
Swiss chard	150	136				
Tomatoes	150	5,643	374	8,725	216	7,222
Watermelon			5	310	1	34
Total						

Table 7. Malathion use during 1990 (Department of Pesticide Reguluation, 1990). All commodities receiving more than 30 pounds of active ingredient are reported.

Commodity	Stanislaus County		San Joaquin County		Merced County	
	Number of applications	Pounds applied	Number of applications	Pounds applied	Number of applications	Pounds applied
Alfalfa	20	927	42	2,354	168	13,807
Almonds	2	123				
Apricots			1	95		
Asparagus			5	92		
Barley					1	46
Beans	7	412				
Corn			2	74		
Cucumbers			1	36		
Eggplant			3	50		
Figs					2	200
Grapes	4	167	11	349		
Landscape Maintenace			20	170		
Leeks			3	78		
Melon			1	42	6	397
Oats					3	113
Onions			21	969		
Peppers			3	96		
Public Health	3	1,642	4	1,580	5	2,523
Squash			2	56		
Structural Pest Control	50	2,591	75	935	96	42,752

Table 7. Malathion use continued.

Commodity	Stanislaus County		San Joaquin County		Merced County	
	Number of applications	Pounds applied	Number of applications	Pounds applied	Number of applications	Pounds applied
Sugarbeets			3	225		
Tomatoes			18	928	6	676
Walnuts	1	98	6	157		
Wheat			6	1,731	1	46
Totals						

Putnam Crk –
Hg & UTX

B.1.39 Lower Putah Creek, Mercury

Summary of Proposed Action

The California Regional Water Quality Control Board, Central Valley Region, (Regional Board) recommends the addition of lower Putah Creek to California's Clean Water Act Section 303(d) list due to impairment by mercury. Information available to the Regional Board on mercury levels in fish tissue samples indicates that water quality objectives are not being attained in Putah Creek. The description for the basis for this determination is given below.

Table B-1. 303(d) Listing/TMDL Information

Waterbody Name	Lower Putah Creek	**Pollutants/Stressors**	Mercury
Hydrologic Unit	511.20	**Sources**	Mining, source unknown
Total Waterbody Size	30 miles	**TMDL Priority**	
Size Affected	24 miles	**TMDL Start Date (Mo/Yr)**	
Extent of Impairment	Lake Solano to Putah Creek Sinks	**TMDL End Date (Mo/Yr)**	
Upstream Extent Latitude	38° 30' 48"	**Upstream Extent Longitude**	122° 06' 15"
Downstream Extent Latitude	38° 30' 57"	**Downstream Extent Longitude**	121° 36' 46"

Watershed Characteristics

Lower Putah Creek is located in Yolo and Solano counties. The creek extends approximately 30 miles from Lake Berryessa to its mouth (the Putah Creek Sinks) at the Yolo Bypass. During low flow periods, Putah Creek is not contiguous with the Yolo Bypass. The land and water uses for the area are diverse (e.g., municipal, agricultural, recreational uses and freshwater habitat).

Water Quality Objectives Not Attained

The narrative objective for toxicity is not being attained for mercury in lower Putah Creek. The narrative toxicity objective in the Basin Plan states, in part, "All waters shall be maintained free of toxic substances *in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life.*" The narrative toxicity objective further states that "The Regional Water Board will also consider ... numerical criteria and guidelines for toxic substances developed by the State Water Board, the California Office of Environmental Health Hazard Assessment, the California Department of Health Services (OEHHA), the U.S. Food and Drug Administration, the National Academy of Sciences, the U.S. Environmental Protection Agency, and other appropriate organizations to evaluate compliance with this objective (CRWQCB-CVR, 1998; http://www.swrcb.ca.gov/~rwqcb5/bsnplnab.pdf)."

Numeric criteria for mercury in fish tissue have been developed for both human health and wildlife protection. The U.S. Environmental Protection Agency (USEPA) recently established a human health protection criterion of 0.3 milligrams per kilogram (mg/kg; equivalent to parts per million [ppm]) methylmercury in the edible portions of fish (USEPA, 2001b). This criterion is used to determine *attainment with of the narrative toxicity objective.*

Evidence of Impairment

The Agency for Toxic Substance and Disease Registry (USDHHS-ATSDR) and the Department of Environmental Science and Policy, University of California, Davis (UCD) collected fish tissue samples from Putah Creek at multiple locations between Lake Berryessa and the Putah Creek Sinks (USDHHS-ATSDR, 1997 and 1998; Slotton *et al*, 1999). In 1997 and 1998, the USDHHS-ATSDR and UCD sampled 204 trophic level 3 fish from multiple locations downstream of Lake Berryessa and 67 trophic level 4 fish from multiple locations downstream of Lake Solano, which is approximately 6 miles downstream from Lake Berryessa. Trophic level (TL) 3 fish feed on zooplankton, phytoplankton, and benthic invertebrates.

Trophic level (TL) 4 fish consume TL 3 fish as part of their diet. Methylmercury and total mercury bioaccumulate in aquatic organisms and tend to increase with increasing trophic levels (USEPA, 1997a). The TL4 fish had an average mercury concentration of 0.28 ppm, which is slightly less than the USEPA criterion of 0.3 ppm. However, several of the TL 4 fish species (black crappie, largemouth bass, Sacramento pike minnow, and smallmouth bass) from Putah Creek had average mercury concentrations that exceeded the USEPA criterion. Table B-2 summarizes the available mercury concentration data for TL 4 fish. In addition, several of the TL 3 fish sampled also had mercury concentrations greater than 0.3 ppm. For example, five Sacramento sucker and one hitch were sampled from Lake Solano; five of these six TL 3 fish had mercury concentrations greater than 0.3 ppm.

Table B-2. Summary of Mercury Concentration Data for Putah Creek Trophic Level 4 Fish

Fish Species[a]	Mean Mercury Concentration (ppm)[a]	# of Fish Sampled
Black Crappie	**0.33**	1
Channel Catfish	0.14	14
Largemouth Bass	**0.35**	30
Sacramento Pike Minnow	**0.44**	6
Smallmouth Bass	**0.30**	2
White Catfish	0.18	10
White Crappie	0.28	4
Trophic Level 4 Fish Summary:	0.28	67

Bold text indicates fish species with average mercury concentrations equal to or greater than the USEPA criterion of 0.3 ppm.

Extent of Impairment

Available fish tissue data suggest that Putah Creek is impaired by mercury from Lake Solano to the Putah Creek Sinks. Trophic level 4 fish collected from Putah Creek downstream of Lake Solano had mercury concentrations that frequently exceeded the USEPA criterion of 0.3 ppm.

Potential Sources

Mercury sources likely include mining-related wastes and possible unknown sources. Extensive historic mercury mining occurred within the Lake Berryessa/Putah Creek watershed.

B.1.40 Lower Putah Creek, Unknown Toxicity

Summary of Proposed Action

The California Regional Water Quality Control Board-Central Valley Region, Regional Board, recommends the addition of lower Putah Creek to California's Clean Water Act Section 303(d) list due to impairment by an unknown toxicity. Information available to the Regional Board on toxicity test results for in lower Putah Creek indicates that water quality objectives are not being attained. A description for the basis for this determination is given below.

Table B-1. 303(d) Listing/TMDL Information

Waterbody Name	Putah Creek, lower	**Pollutants/Stressors**	Unknown Toxicity
Hydrologic Unit	511.20	**Sources**	Source Unknown
Total Waterbody Size	30 miles	**TMDL Priority**	
Size Affected	30 miles	**TMDL Start Date (Mo/Yr)**	
Extent of Impairment	From Lake Berryessa to Putah Creek Sinks	**TMDL End Date (Mo/Yr)**	
Upstream Extent Latitude	38° 30' 48"	**Upstream Extent Longitude**	122° 06' 15"
Downstream Extent Latitude	38° 30' 57"	**Downstream Extent Longitude**	121° 36' 46"

Watershed Characteristics

Lower Putah Creek is located in Yolo and Solano counties. It flows for approximately 30 miles, from Lake Berryessa to its mouth (the Putah Creek Sinks) at the Yolo Bypass. However, during low flow periods, lower Putah Creek is not contiguous with Yolo Bypass. The land and water use for the area is diverse, and impacts the water quality in a variety of ways. The lower Putah Creek watershed is farmed and surrounded by towns. An unknown toxicity, from an unknown source, impairs lower Putah Creek.

Water Quality Objectives Not Attained

The narrative objective for toxicity is not being attained for lower Putah Creek. The narrative toxicity objective in the Basin Plan states, in part, "All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life." The narrative toxicity objective further states that, "Compliance with this objective will be determined by analyses of...biotoxicity tests of appropriate duration... (CRWQCB-CVR, 1998; http://www.swrcb.ca.gov/~rwqcb5/bsnplnab.pdf)."

The toxicity objective was evaluated for Putah Creek by comparing toxicity test results of ambient water grab samples collected from Putah Creek with laboratory control results. These toxicity test procedures estimate the acute and chronic responses of aquatic test species from three phyla (representing three trophic levels) as an assessment of the toxicity of the ambient water samples. The tests include fathead minnow (a fish, *Pimephales promelas*) larval survival (mortality) and growth tests, zooplankton (a cladoceran, *Ceriodaphnia dubia*) survival and reproduction (offspring counts) tests, and algal (*Selenastrum capricornutum*) growth (chlorophyll a production) tests. The test results produced by the ambient creek water samples were compared to test results of the laboratory control water samples, to identify ambient creek water samples that caused statistically significant test species impairment.

Evidence of Impairment

Between 1998 and 1999, routine (monthly) and rain event (based on a rain storm) toxicity tests, toxicity identification evaluation tests (TIEs), and water quality analysis were conducted on water samples from lower Putah Creek.

Toxicity tended to occur following rain events and occurred throughout the entire watershed (Larsen *et al*, 2000). Sixteen of the toxicity tests run on ambient samples resulted in impaired growth, impaired reproduction, or mortality to one or more test organisms. The sources of the toxicity may include suspended solids (including particle bound chemicals or toxicants) and diuron. However, other follow-up tests failed to pinpoint potential cause(s) (although some of the tests eliminated ammonia and pathogenicity as sources). In other cases, no follow-up tests were run and the cause of the toxicity is unknown.

Extent of Impairment

Available toxicity data suggest that lower Putah Creek is impaired by toxins from unknown sources from downstream of Lake Berryessa to the Putah Creek Sinks.

Potential Sources

Follow-up tests were conducted on some of the samples that caused toxicity. The results of the follow-up tests indicate that a variety of factors, including suspended solids (including particle bound chemicals or toxicants) and diuron, may have been partially responsible for the toxicity in a few of the cases. However, other follow-up tests failed to pinpoint potential cause(s) (although some of the tests eliminated ammonia and pathogenicity as sources) and in other cases, no follow-up tests were run. Therefore, the cause of the toxicity is unknown, in many cases.

B.1.41 Upper Putah Creek, Unknown Toxicity

Summary of Proposed Action

The California Regional Water Quality Control Board-Central Valley Region, Regional Board, recommends the addition of upper Putah Creek to California's Clean Water Act Section 303(d) list due to impairment by an unknown toxicity. Information available to the Regional Board on toxicity test results in upper Putah Creek indicates that water quality objectives are not being attained. A description for the basis for this determination is given below.

Table B-1. 303(d) Listing/TMDL Information

Waterbody Name	Upper Putah Creek	**Pollutants/Stressors**	Unknown Toxicity
Hydrologic Unit	512.30	**Sources**	Source Unknown
Total Waterbody Size	36 miles	**TMDL Priority**	
Size Affected	27 miles	**TMDL Start Date (Mo/Yr)**	
Extent of Impairment	The lower 27 miles	**TMDL End Date (Mo/Yr)**	
Upstream Extent Latitude	38° 45' 58"	**Upstream Extent Longitude**	122° 36' 19"
Downstream Extent Latitude	38° 42' 15"	**Downstream Extent Longitude**	122° 22' 55"

Watershed Characteristics

Upper Putah Creek is located in Lake and Napa counties. It flows for approximately 36 miles, from its headwaters on Cobb Mountain to Lake Berryessa. Inactive mercury-mining districts and several communities surround the upper Putah Creek watershed.

Water Quality Objectives Not Attained

The narrative objective for toxicity is not being attained in the upper Putah Creek. The narrative toxicity objective in the Basin Plan states, in part, "All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life." The narrative toxicity objective further states that, "Compliance with this objective will be determined by analyses of...biotoxicity tests of appropriate duration... (CRWQCB-CVR, 1998; http://www.swrcb.ca.gov/~rwqcb5/bsnplnab.pdf)."

The toxicity objective was evaluated for Putah Creek by comparing toxicity test results of ambient water grab samples collected from Putah Creek with laboratory control results. These toxicity test procedures estimate the acute and chronic responses of aquatic test species from three phyla (representing three trophic levels) as an assessment of the toxicity of the ambient water samples. The tests include fathead minnow (a fish, *Pimephales promelas*) larval survival (mortality) and growth tests, zooplankton (a cladoceran, *Ceriodaphnia dubia*) survival and reproduction (offspring counts) tests, and algal (*Selenastrum capricornutum*) growth (chlorophyll a production) tests. The test results produced by the ambient creek water samples were compared to test results of the laboratory control water samples, to identify ambient creek water samples that caused statistically significant test species impairment.

Evidence of Impairment
Between November 1998 and October 1999, water samples were collected once a month just upstream from Lake Berryessa. On four of the dates (January, and August through October 1999) the water samples caused reproductive impairments to *Ceriodaphnia*. The source(s) of the toxicity from the water samples collected in August and September were analyzed using TIE (toxicity identification evaluation). Neither the ambient samples (when re-tested) nor the lab water caused toxicity to *Ceriodaphnia*. However, when the eluates (the non-polar molecules from the sample[1]) of the sample were re-added to water without any pollutants, at three times the ambient sample concentration, *Ceriodaphnia* experienced significant reproductive impairments. This suggests that a non-polar, organic chemical may have caused both of the impairments. No follow-up tests, including TIEs, were conducted on the other two dates, so the cause(s) of the toxicity is unknown (Larsen *et al*, 2000).

In July 1999, the water sample caused impaired growth to *Selenastrum*. The ambient water sample was analyzed for metals, but metals could not account for the toxicity. Therefore, the cause of the toxicity is yet unknown (Larsen *et al*, 2000).

Extent of Impairment
The site selected for study was the furthest downstream site, and represents the sum of the watershed. There are several small waterbodies that flow into Putah Creek, but most (except Janche Creek) enter at least 27 miles upstream of the confluence with Lake Berryessa. It seems likely that at least the lower 27 miles is impaired.

Potential Sources
Follow-up tests were conducted on three of the samples that caused toxicity. The results of two of the follow-up tests indicate that a non-polar organic chemical may be partially responsible for the toxicity in those two samples. However, the other follow-up test failed to determine any potential cause(s), and eliminated metals as a potential source. The cause of the toxicity in that sample is unknown. In the other cases, no follow-up tests were run, so the source of the toxicity is unknown. Therefore, the cause of the toxicity is unknown, but may, in some cases, include non-polar organic chemicals.

[1] The water sample was extracted in such a way that the non-polar organic molecules stayed in the solution, but the water and every other toxin were eliminated.

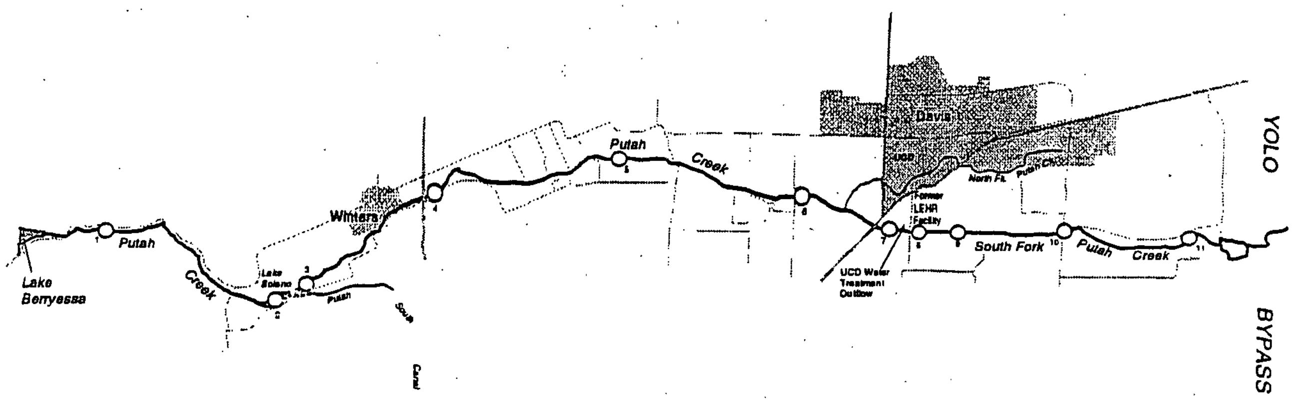
R 30 K

LOWER PUTAH CREEK 1997-1998 MERCURY BIOLOGICAL DISTRIBUTION STUDY

February 1999

CONDUCTED FOR:

The Department of Environmental Health and Safety,
University of California, Davis



STUDY AND REPORT BY:

DARELL G. SLOTTON *
SHAUN M. AYERS
JOHN E. REUTER
CHARLES R. GOLDMAN

Dept. of Environmental Science and Policy,
University of California, Davis

* (530) 756-1001 dgslotton@ucdavis.edu

EXECUTIVE SUMMARY

- In the fall seasons of 1997 and 1998, an extensive study of mercury in biota was conducted in lower Putah Creek. This study was initiated (1) to accurately determine potential spatial variability in mercury contamination in the creek and (2) to provide a large new data base of mercury concentrations in Putah Creek organisms.

- Limited prior sampling by federal agencies in 1996, together with associated public and expert comments, had suggested that the University of California, Davis might in some way exacerbate mercury contamination problems in Putah Creek. It was hypothesized that potential drainage from the University's former Laboratory for Energy-Related Health Research (LEHR, adjacent to the creek) and outflow from the campus wastewater treatment plant could be important. Limited follow-up collections by the same federal agencies in 1997 indicated that, while mercury was indeed elevated in certain Putah Creek organisms, the problem was apparently widespread in the creek and unrelated to the University. Public and expert comment found significant fault with both federal studies and continued to hypothesize that the University might adversely impact mercury dynamics in Putah Creek.

- The current research work utilized eleven sampling sites. In order to place potential mercury-related loadings from the LEHR site and other UC Davis property into geographic context, sites were sampled throughout the length of lower Putah Creek, between the Monticello Dam at Lake Berryessa and the outlet of the creek at the Yolo Bypass. Sites were generally distributed every 3-4 creek miles and chosen so as to sample important potential sources of both inorganic or methylated mercury.

- An extensive array of biological samples was collected and analyzed for mercury, including adult fish edible muscle samples from 16 different species in a range of sizes (127 individual adult fish samples). A wide variety of small and juvenile fish were sampled and analyzed in consistent, multi-individual, whole body composites (48 total), as were 25 composite samples of aquatic insects. Muscle mercury was additionally analyzed in 80 individual samples of adult crayfish, also distributed across the entire length of lower Putah Creek. A primary objective of this work was to provide readily comparable, equivalent samples at different sites to facilitate the meaningful comparison of relative mercury exposure, uptake, and accumulation.

- The study confirmed that many of the Putah Creek fish species contained mercury concentrations in edible muscle at levels of potential concern, depending on the exposure criterion used, with larger individuals of the top predatory species most highly contaminated. The data further indicate that certain Putah Creek crayfish may represent a hazard for both human and wildlife consumption and that certain small or juvenile fish may represent a chronic hazard to fish-eating wildlife.

- Neither the town of Winters, the agricultural fields, nor the UC Davis region of the creek were found to significantly alter biological mercury trends in any of the organisms sampled, including those which exhibit high levels of site fidelity. Where closely comparable data could be collected, the stretch of Putah Creek adjacent to the University and downstream to a distance of at least 3 miles frequently contained among the lowest relative levels. Highest relative levels occurred in selected biota from just below Lake Berryessa, in and downstream of Lake Solano, and near the Yolo Bypass. The results of this study are consistent with remnant, mining-derived mercury (together with some level of ongoing transfer through Lake Berryessa) constituting the primary source of ongoing mercury contamination in lower Putah Creek.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

Largely as a legacy of historic mining activities, water bodies throughout much of Northern and Central California are currently impacted by mercury contamination problems, particularly in relation to the consumption of fish. Mercury is a heavy metal that occurs in a number of different molecular forms. One of these, methyl mercury, has the unfortunate property of bioconcentrating through food webs. This means that the majority of ingested methyl mercury is retained at each trophic (feeding) level, to be passed on to higher level consumers. The result of this is that increasing concentrations of methyl mercury can accumulate at succeeding rungs of the "trophic ladder" and dangerously high levels of methyl mercury can accumulate in the upper level predatory species present in impacted aquatic systems. When these species are utilized as food by humans or wildlife, the concern arises that exposure to neurological toxicity may occur. Methyl mercury is a potent neuro-toxin that has been shown to exhibit effects primarily on rapidly growing nervous system tissue. This places fetuses and young children at greatest risk and is the reason that current fish consumption guidelines are most protective of pregnant women and children under age 6.

Mercury contamination is a serious problem throughout much of the Northern Hemisphere. Across the Midwest and Eastern regions of the United States and Canada, as well as the majority of Europe, trace deposition of global, atmospherically spread mercury (derived from general industrial power production, etc.) has been sufficient to contaminate numerous water bodies to above health guideline levels. In California, we are fortunate to have water quality (typically alkaline and containing higher levels of suspended matter) that is relatively less compatible with the production, solubility, and biological uptake of methyl mercury. However, California water bodies are additionally exposed to massive, bulk mercury contamination from historic mining activities on both sides of the state. The California Coast Ranges contain one of the world's great geologic mercury–enriched belts. When the California Gold Rush occurred in the mid 1800s, relatively inexpensive mercury was used extensively to amalgamate gold, greatly increasing yields. Mercury was used to bind and retain the smaller, otherwise easily lost particles of gold. Upon distilling with heat, the mercury could be vaporized, leaving behind the accumulated gold. This generated a corresponding "Mercury Rush" in California, with dozens of medium to large-scale mercury mining operations in the Coast Ranges supplying refined, elemental mercury ("quicksilver") for use in the Sierra Nevada gold fields. Today, California is the site of numerous abandoned, leaking mercury mines throughout the Coast Ranges and, also, significant tonnage of misplaced elemental mercury throughout the Sierra Nevada gold and silver mining regions. Because of the relatively favorable water quality typical in California, with regard to methyl mercury formation, solubility and biological uptake, mercury accumulations of concern here are typically associated only with instances of bulk mercury contamination. However, bulk mercury contamination is present in numerous water bodies throughout the region (Reuter *et al.* 1989, 1998, Gill and Bruland 1990, TSMP 1990-1997, Slotton *et al.* 1991, 1995a,b, 1996, 1997a,b,c, Suchanek *et al.* 1993, 1995, 1997, 1999).

The research work documented in this report was conducted in response to a previous study conducted by a federal agency, the Agency for Toxic Substances and Disease Registry (ATSDR), together with US EPA Region 9 (ATSDR 1997, NAREL 1997). In 1996, these agencies investigated a large array of potential toxicants in biological samples collected from Putah Creek. The sampling was conducted in relation to the former UC Davis Laboratory for Energy-Related Health Research (LEHR), which had been designated a US EPA Superfund cleanup site. Primarily focusing on a wide range of radioactive isotopes which had been utilized decades earlier at the site, the ATSDR and EPA Region 9 collections from adjacent Putah Creek analyzed for an intensive suite of radionuclides, pesticides, other organic toxics, and heavy metals.

Of the large suite of investigated toxic substances, none of the organics or radionuclides were found at levels of concern (though some controversy continues as to the adequacy of the organic parameter list, Lee 1997, 1998). However, the heavy metals mercury and lead were found at relatively elevated levels in certain samples. Lead was elevated in one composite sample collected from Putah Creek immediately downstream of the UC Davis former LEHR site. Mercury was elevated relative to an upstream control in samples taken downstream near the University. It was suggested that UC Davis and the LEHR site were the source of the elevated levels.

Lead in the creek can probably be ruled out as a serious threat to human and wildlife health. Lead does not typically bioconcentrate in edible (fillet) fish tissue (Forstner and Wittman 1981, Hutchinson and Meema 1987), which is why it is routinely monitored in liver only, where it can concentrate (TSMP 1990-1997). Lead in fish flesh is not typically the subject of health advisories (TSMP 1990-1997, Cal. Fish and Game 1999). Lead could conceivably be detected in apparently elevated concentrations if the gut contents of bottom feeders were included in samples, due to sediment in the gut which contained lead. The concentrations of most metals (other than mercury) in bottom sediments are generally orders of magnitude greater than corresponding concentrations accumulated in the edible muscle tissue of aquatic organisms. Lead from the Putah Creek ATSDR sites followed this pattern, though absolute concentrations of sediment lead were not elevated relative to regional sediments. It is notable that the single case of apparently elevated lead in biological tissues came from a composite sample which included tail meat (presumably including intestinal tracts) of 10 large crayfish, which are bottom dwelling omnivore/detritivores. One conclusion that may be drawn is that crayfish may harbor sediment-associated metals in their digestive tracts. Elevated lead was not found in fish muscle in follow-up studies (ATSDR 1998).

Mercury, in comparison to lead, has been extensively documented to bioconcentrate through aquatic food webs, demonstrating incremental elevations in concentration with trophic level and size/age of fish, reaching highest concentrations in large/old individuals of top predator species (Huckabee *et al.* 1979, EPRI 1991, Wiener 1995). Because of the strong relationships typical between fish trophic level and mercury accumulation, and between fish size/age (for many predatory species) and mercury accumulation, it is imperative that exposure comparisons between different sites be made using similar samples. The sampling design of the ATSDR wide-spectrum screening project, however, required very large sample sizes (2 kg) to supply the myriad analyses undertaken. To provide sufficient sample at each site, it was necessary to pool multiple species of unrelated fishes and multiple individuals of widely varying sizes/ages. This resulted in significantly different samples from each of the sites. Where same species were taken, they were often of different life stage and feeding habit. The varied individuals were then mixed together, primarily into groups of surface and water column species (bass, bluegill, crappie) versus bottom dwellers (carp, catfish, bullhead, and crayfish). It is very notable that the background sample in the ATSDR study from above Pedrick Road was composed entirely of juvenile fish and crayfish. The sample was greatly dominated by low-trophic-level juvenile bluegill and green sunfish (521 g of the 620 g composite, or >84%). The remainder of the sample consisted of young largemouth bass (7% of the sample) much smaller than those near the LEHR site and UC Davis (mean size 64 g, as compared to 400-650 g individuals downstream), crayfish (7% of the sample), and a young white catfish (1% of the sample, 89 g, as compared to individual catfish of 700-2,600 g and bullhead in the 200-300 g range at the near-university site). Relative to the low trophic level background sample, the finding of elevated mercury in the samples taken near the university was not surprising. Those samples were dominated by muscle tissue from large individuals of predatory fish species such as catfish and bass.

While the initial ATSDR work did not provide readily comparable data between sites, it served its purpose as a screening study. The presence of elevated mercury in some of the downstream biological composites indicated that mercury levels of concern existed in some fraction of the creek biota. An eminent local biogeochemist, Dr. G. Fred Lee, advised that follow-up work be conducted (Lee 1997). Dr. Lee hypothesized that, despite the incomparability of the upstream/downstream ATSDR data, potential University discharges (both from the LEHR site and the campus wastewater treatment plant) might exacerbate mercury contamination in the creek. A follow-up set of fish collections was made by ATSDR and EPA Region 9 in 1997 (ATSDR 1998). These collections found relatively elevated, similar mercury levels in fishes taken upstream, adjacent to, and downstream of the University, confirming the presence of mercury at levels of concern in certain fish, and suggesting that the contamination was apparently a regional phenomenon, unrelated to potential University inputs. The ATSDR/EPA follow-up work, though based on samples of individual fish species, was again hampered somewhat by dissimilarity between samples taken at the different sites.

Dr. Lee raised the possibility that lower flow conditions in 1996 may have precluded upstream migration at barriers, isolating fish potentially exposed to University-related mercury effects in that year, and partially explaining the relatively higher mercury found adjacent to and downstream of the university in that year, as compared to upstream (Lee 1998). He suggested that the more uniform upstream/downstream results from 1997, a high water year, could have resulted from migration throughout the creek of fish which had obtained their mercury accumulations at or near the University property. He further hypothesized that while the university might not be a relatively important source of mercury to the system, it might contribute other water quality constituents (primarily dissolved and particulate organics from the wastewater outflow) which might exacerbate the production of methyl mercury, a bacterially mediated process that occurs primarily at the aerobic/anaerobic interface of aquatic systems.

The current study, reported here, utilized eleven sampling sites which were distributed along the entire length of lower Putah Creek, from Lake Berryessa to the Yolo Bypass (Figs. 1 and 2). The primary objective of the research was to compare relative levels of mercury exposure, uptake, and biological accumulation across the full length of the lower creek, testing the hypothesis that potential UC Davis inputs significantly influenced mercury levels in the creek biota. Figure 1 places the study area into regional context, while Figure 2 gives a close-up view of the sites. In addition to making extensive collections of adult fish of numerous species and across a range of sizes for muscle mercury analyses, we collected small and juvenile fish, crayfish, and aquatic insects at each of the sites, as available. These organisms supplemented the fish muscle data and were used as consistent bioindicators of more site-specific conditions.

In addition to the primary focus on possible spatial variation in relative mercury levels, a secondary objective of the study was to develop a substantial data base of absolute mercury concentrations for a wide range of aquatic organisms in Putah Creek. These supplement the preliminary work done by ATSDR and can be used by various agencies in determining potential human health and wildlife health exposures. Table 1 summarizes the numbers of mercury analytical samples collected for this project in 1997 and 1998. Total mercury was analyzed in 280 individual biological samples taken from sites along lower Putah Creek between Lake Berryessa and the Yolo Bypass. Additional analytical samples for the project included numerous field and laboratory duplicates, spike recovery samples, and standard reference materials.

Throughout this report, the data for each major sampling parameter are generally presented both in tabular and graphic form. Where appropriate, map figures of the spatial distribution of key data parameters are included for the entire study region. Tables and figures are placed at the ends of each section.

Table 1. Summary of Samples Analyzed for Mercury in This Project

Aquatic Insect Composites:	25
Small Fish/Tadpole Whole-body Composites:	48
Individual Crayfish Tail Muscle Samples:	80
Individual Adult Fish Fillet Muscle Samples:	127
TOTAL BIOTA SAMPLES:	**280**

Figure 1. Lower Putah Creek, Regional Map

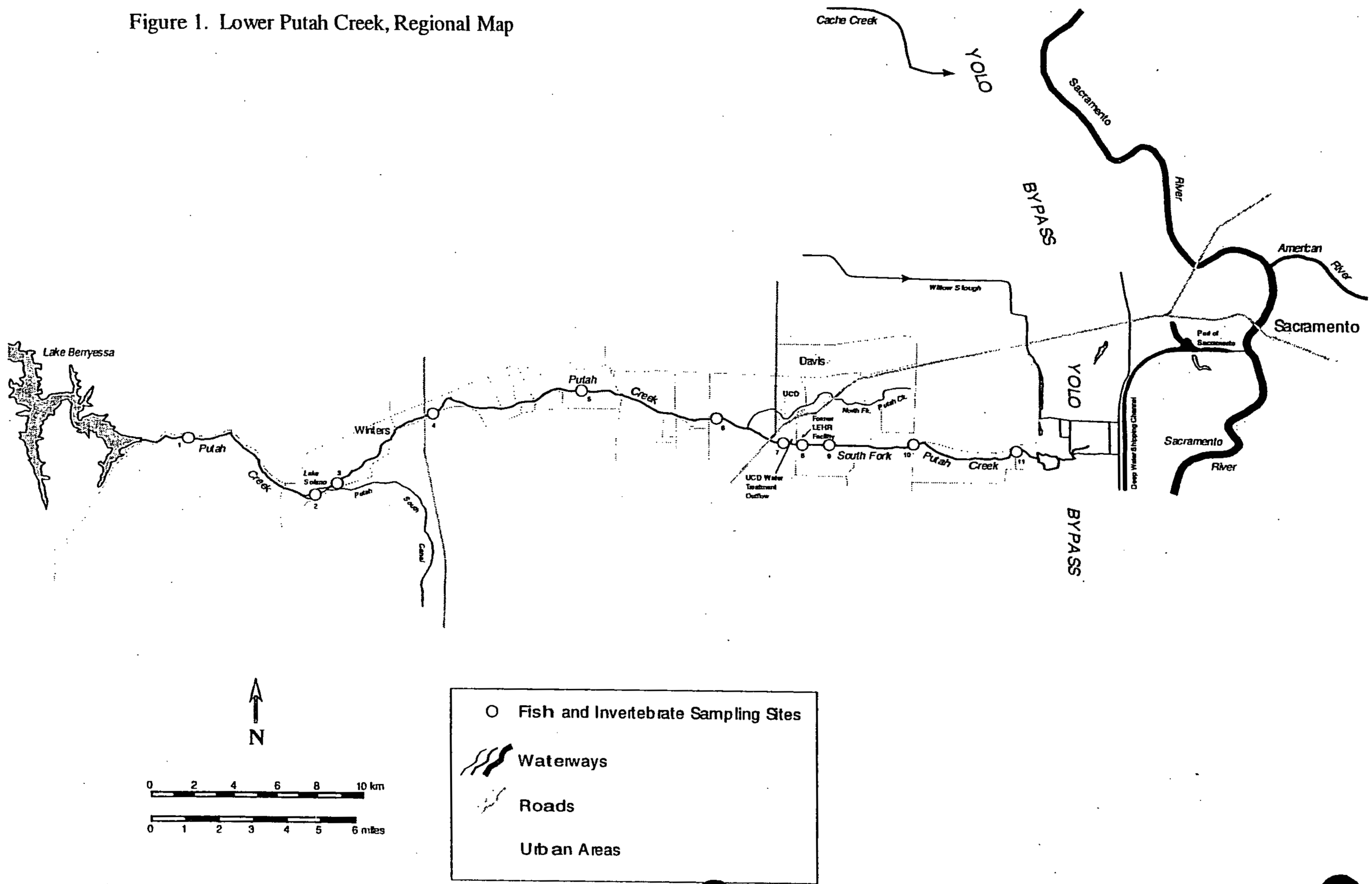
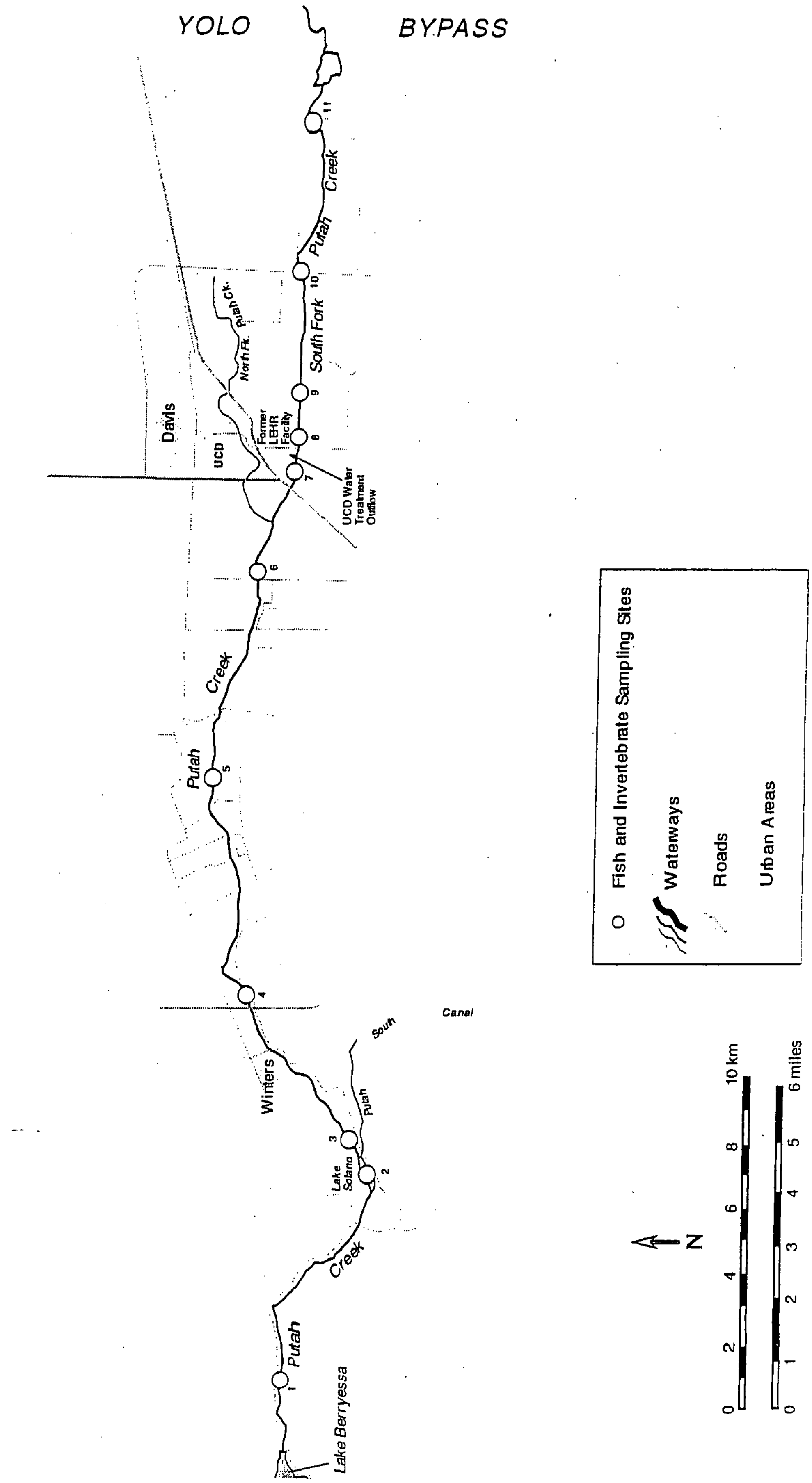


Figure 2. Lower Putah Creek, With Sampling Locations



2. METHODS

2.1 Site Selection

The sampling sites utilized for the project are shown in Figures 1 and 2. In order to place potential mercury loading from the LEHR site and other UC Davis property into geographic context, sites were sampled throughout the length of lower Putah Creek, between the Monticello Dam at Lake Berryessa and the outlet of the creek at the Yolo Bypass. Sites were generally distributed every 3-4 creek miles and chosen so as to sample important potential sources of both inorganic or methylated mercury. Eleven sites were utilized in the study. Site 1, representing Lake Berryessa releases, was located within the upper trout waters. Site 2, in Lake Solano, tested the possibility that this impoundment might result in increased mercury methylation and subsequent bioaccumulation by organisms. Site 3, located directly beneath Lake Solano, sampled the downstream release from the impoundment. Site 4, at Highway 505 below Winters, sampled the potential mercury outputs of that town. Site 5, at Russell Ranch, was located downstream of several miles of agricultural land and accompanying drainage, as was Site 6 at Pedrick Road. The Pedrick Road site was additionally of interest as a control relative to UCD property downstream. Site 7 was located immediately upstream of the outfall of the UC Davis wastewater treatment plant, capturing any potential UCD-related mercury inputs from upstream of this inflow. Site 8 was located a short distance downstream of the wastewater treatment outfall, adjacent to the LEHR site and just downstream of Old Davis Road. Site 9, capturing potential mercury effects of both the wastewater and LEHR inputs, was located 0.5-1.0 mile downstream of the LEHR site. Site 10 was several miles downstream of UC Davis at Mace Road. The most downstream site, Site 11, was located approximately 6 miles below UC Davis at and downstream of Road 106A, very near the creek's outflow into the Yolo Bypass.

Adult fish were sampled from all sites which were sufficiently spaced (or blocked by barrier) to achieve meaningful separation. This included Sites 1-6 and 9-11 (9 total). Small and juvenile fish and aquatic insects, which exhibit greater site fidelity than adult fish, were taken at all sites where they were present and available to our collection techniques. This included, for small fish, Sites 1 and 3-11 (10 sites total) and, for aquatic insects, Sites 1, 3-7, and 10-11 (8 sites total). Crayfish were taken from 10 sites: 1-6 and 8-11.

2.2 Collection and Sample Preparatory Techniques

2.2.1 Fish

Adult fish for muscle (fillet) mercury analysis were taken primarily with several large experimental gill nets containing a wide range of mesh sizes. These were deployed from a small boat equipped with an outboard motor. In several cases the boat needed to be dragged overland a considerable distance to reach the water. Once deployed, nets were monitored closely and were harvested frequently so as to avoid fish mortality. Fish were maintained live in holding tanks and were rapidly processed on the boat and then released, generally in good condition. Processing included species identification, measurement of standard and fork length, weighing, and careful removal of a small sample of fillet muscle (0.20 grams, similar in size to a raisin). Fish were released approximately 0.5 km from their capture point so as not to be re-netted. Multiple days of sampling were required at several of the sites.

Tissue samples for mercury analysis were excised using clean technique, with stainless steel scalpels. Muscle samples were taken from the dorso-lateral ("shoulder") region, as done by the California Department of Fish and Game. A small patch of skin/scales was pulled back to obtain the clean muscle sample. Extraneous surface moisture was blotted off with a laboratory tissue and the sample was placed directly into a pre-weighed laboratory digestion tube, which was capped with a teflon liner. The precise weight of each tissue sample was determined by weighing the tubes containing samples (together with pre-weighed blanks) and subtracting the initial empty weights. We have utilized these non-destructive sampling techniques with great success in similar work over the past 15 years (Reuter *et al.* 1989, 1998, Slotton 1991, Slotton *et al.* 1995a,b, 1996, 1997a,b,c).

2.2.3 Small and juvenile fish

Small and juvenile fish were taken from stream sites, where present, utilizing both a research electroshocker and seines which were pulled through certain stretches to trap fish. Individuals to be analyzed for mercury were held on ice in sealed bags. They were later (within 24 hours) cleaned in DI water at the UCD laboratory, identified, weighed and measured, and homogenized into appropriate composite samples with a laboratory homogenizer. An aliquot of the homogenized sample was precisely weighed into a laboratory digestion tube, which was capped with a teflon liner.

2.2.3 Invertebrates

Stream invertebrates were taken from riffle habitat at each of the sites where they were present, i.e. from rapids or cobble bottomed stretches with maximal flow, where aquatic insects tend to be most concentrated among the rock interstices and other debris. Stream invertebrates were collected primarily with the use of a research kick screen. At each site, one researcher spread and positioned the screen perpendicular to the flow, bracing the side dowels against the bottom, while the other researcher overturned boulders and cobble or dislodged debris piles directly upstream of the screen. These were hand scrubbed into the flow, dislodging any clinging biota. Following the removal of the larger rocks/branches to the side of the stretch, the underlying substrate was disrupted by shuffling the boots repeatedly. Invertebrates were washed into the screen by the current. The screen was then lifted out of the current and taken to the shore, where forceps were used to pick macro-invertebrates from the screen into collection jars. This process was repeated at each site until a sufficient sample size of each taxon of interest was accumulated to permit analysis for mercury.

Samples were maintained in their collection jars on ice, and then cleaned in fresh water within 24 hours of collection. Cleaning was accomplished by suspending sample organisms in fresh water and, as necessary, shaking individuals in the water with teflon-coated forceps to remove any significant clinging surficial material. Cleaned organisms were stored in pre-cleaned glass jars with teflon-lined caps, which were frozen (to kill humanely) and then dried at 50-60 °C. The dried sample was homogenized to a fine powder with teflon-coated instruments and precisely weighed into a laboratory digestion tube, as above. All of these techniques have been well established and tested in extensive prior mercury research work throughout California (Slotton *et al.* 1995a, 1996, 1997a,b,c).

2.2.4 Crayfish

Collection of sufficient crayfish for meaningful inter-site comparison required the overnight setting of numerous baited crayfish traps on many different occasions for each site throughout the fall of 1998. Traps were retrieved and re-set daily. Any captured individuals were retained on ice. Live crayfish were sorted and identified to species (Light 1994). Weight and carapace length (standard crayfish morphometrics) were obtained. After freezing and re-thawing, a sample of tail muscle was excised, using clean technique, with a stainless steel scalpel. Due to variation encountered in the moisture content of these samples, crayfish muscle samples were dried for uniformity. Dry weight concentrations were corrected for individual moisture percentage so as to present this data (for a potential human consumption item) in the same units used for edible fish tissue (fresh/wet weight parts per million mercury).

2.3 Analytical Methodology

Fish were analyzed on a wet (fresh) basis, as is the standard procedure for governmental agencies. Mercury analyses of invertebrate samples were conducted with dried and powdered samples for uniformity, as described in Slotton *et al.* (1995a).

Solid samples of all types were processed by first digesting in concentrated sulfuric and nitric acids, under pressure, at 80-100 °C, followed by refluxing with potassium permanganate in a two stage, three hour process. Digests were subsequently analyzed for total mercury using a well-established modified cold vapor atomic absorption (CVAA) micro-technique, described in Slotton *et al.* (1995b). The level of detection for this technique is app. 0.01 $\mu g\ g^{-1}$ (ppm), sufficient to provide above-detection results for nearly all environmental samples from this region.

2.4 Quality Assurance/Quality Control (QA/QC)

Extensive QA/QC accompanied all of the total mercury analyses. For each sample batch of approximately 40 samples, at least 16 QA/QC samples were included through all phases of the digestion and analysis procedures. These included a minimum of: 1 blank and 7 aqueous mercury standards, 2 pairs of samples of standard reference materials (4 total) with known mercury concentrations, 2 duplicates of analytical samples, and 2 spiked analytical samples. These 16+ additional samples per analytical run were used, as always, to ensure the reliability of the data generated. The QA/QC results for the analytical work are summarized in Table 2.

The extensive set of aqueous standards was used to construct an accurate curve of mercury concentration vs atomic absorbence for each analytical run. The standard curve R^2 values for the mercury runs utilized in this project all fell between 0.997 and 1.000, well above the control range of ≥ 0.975. The reference material samples included two different fish standards. All recoveries were well within the 75-125% control levels, at 89-113% (mean recoveries 95-106%). Sample duplication in laboratory splits was excellent, with relative % difference (RPD) having a mean value of 4.9% among 40 sets of paired samples. Independent field duplicates were also very close, with RPDs of 11 sets of paired, independent field samples averaging 6.2%. Spike recoveries were consistently good, with recoveries of 84-109% (mean = 98.3% for 20 spikes used in the project), as compared to control tolerances of 75-125%.

Table 2. Laboratory QA/QC Summary for Total Mercury Analyses (from 9 analytical runs)

					Standard Reference Materials	
	Std Curve R^2	Spike Recoveries	Field Dup. RPD	Lab Split RPD	BCR Cod	DOLT-2 Dogfish
Certified Level (ppm)					0.56	2.14
Ideal Recovery	1.000	(100%)	(0%)	(0%)	(100%)	(100%)
Control Range (%)	≥0.975	75-125%	≤25%	≤25%	75-125%	75-125%
Control Range (ppm)					0.42-0.70	1.60-2.68
Recoveries (%)	0.997-1.000	84-109%	0.2-17.8%	0.3-22.9%	89-105%	99-113%
Recoveries (ppm)					0.50-0.59	2.11-2.53
(n)	n=9	n=20	n=11	n=40	n=18	n=18
Mean Recoveries (%)	0.999	98.3%	6.2%	4.9%	95.5%	105.8%
Mean Recoveries (ppm)					0.53	2.27

3. RESULTS AND DISCUSSION

3.1 Adult Fish

Muscle mercury data from the adult fish samples are presented in Table 3. The data are plotted graphically by sampling site in Figures 3(a-i), with all individuals and species from a given site plotted together (each species with its own symbol). This allows the inter-site comparison of overall mercury levels in all the fish taken and also displays the relative mercury levels of different species within each site. In Figures 4(a-j), the data are plotted by fish species, with each sampling site having a different symbol. This allows consistent comparison of the various sites. Because mercury concentration frequently varies with size/age of fish, particularly for predatory species, mercury data are plotted against fish weight. Data for individual sites can be compared to the general size:mercury trend for the species. Sites with significantly different mercury exposure levels would be expected to demonstrate correspondingly different fish muscle mercury concentrations, relative to the general size:mercury trend for a given species among all the sites.

The Putah Creek fish muscle mercury data provide comparative information to muscle mercury data from numerous UC Davis research projects conducted over the past 15 years throughout the mercury and gold mining regions of Northern California (Reuter *et al.* 1989, 1996, 1998, Slotton *et al.* 1991, 1995a,b, 1996, 1997a,c, Suchanek *et al.* 1993, 1997, TSMP 1990-1997), as well as the large data base that exists for edible fish fillet tissue throughout the state of California, assembled by the Toxic Substances Monitoring Program (TSMP 1990-1997). The fish muscle mercury data collected in this project supplement the preliminary Putah Creek work done by the ATSDR and EPA Region 9 (ATSDR 1997, 1998, NAREL 1997) and characterize, for the entire Putah Creek study region between Lake Berryessa and the Yolo Bypass, mercury levels in the edible tissue of most numerically significant species, including those commonly taken for human consumption. Fish muscle mercury data will be discussed in relation to two primary considerations: (1) absolute mercury levels in edible muscle tissue, with regard to human health issues, and (2) relative spatial differences in fish mercury concentrations, primarily in relation to potential effects related to UC Davis.

As is typical, muscle mercury concentrations were lowest in fish species which feed on low trophic level food items such as plankton and small aquatic insects and were highest in large individuals of top predator species which feed primarily on other fishes. Intermediate mercury levels were seen in species which feed on intermediate trophic level food items such as large aquatic insects and juvenile fish. Because of the changing nature of Putah Creek across the study region, different assemblages of fish species occur in different reaches. This phenomenon is typical of most creeks/rivers and has been studied intensive in Putah Creek by UC Davis ichthyologist Dr. Peter Moyle and his graduate students for many years (Moyle *et al.* 1998). The upper reaches of the creek between Monticello Dam and Lake Solano (Sites 1-3) are dominated by introduced rainbow trout and several native species. Native species such as Sacramento sucker, Sacramento squawfish, and hitch dominate the central region to approximately Russell Ranch (Site 5). Warm water, introduced game fish species such as largemouth bass, white crappie, bluegill, white catfish, and channel catfish occur primarily in the bottom reaches of Putah Creek, near UC Davis and downstream (Sites 6-11).

The different fish assemblages resident in different reaches of the creek make it difficult to assess potential inter-site differences in mercury exposure levels. In particular, because large individuals of top predatory species occur primarily in the lower portion of the creek, downstream sites demonstrate some of the highest levels of individual fish muscle mercury. However, as highest levels are expected to occur in precisely these individuals, the relatively elevated concentrations found in these particular fish do not, in themselves, indicate any enhanced level of mercury exposure associated with those sites. In order to accurately compare the relative mercury exposures at the various sites, it is critical to compare same or similar test organisms. While this was not always possible with the adult fish sampling, the fish data provide a number of useful comparisons between different sets of sites along Putah Creek. In following sections of the report, we present data from alternate bioindicator organisms, some of which provide enhanced levels of both site-specificity and consistency of sample organism between sites. Below, the fish muscle mercury data for the most numerically significant types are discussed by species, in approximate order of increasing mercury concentration.

<u>Rainbow Trout</u> (*Salmo gairdneri*, Fig. 4a): Some of the lowest muscle mercury in the study region was found in rainbow trout above Lake Solano, which we know to subsist almost entirely on tiny, herbivorous mayflies which are low in mercury. Concentrations of 0.05-0.15 ppm were found in trout to 580 g (1.3 lb), with levels of 0.05-0.07 ppm in all individuals under 1 lb. In trout taken immediately below Lake Solano, concentrations were also relatively low (0.08-0.12 ppm), but were somewhat elevated relative to the small size of the fish (Fig. 4a), as compared to the fish taken upstream of Lake Solano.

<u>Hitch</u> (*Lavinia exilicauda*, Fig. 4b): Hitch, a native planktivore, had relatively low muscle mercury, at ~0.09 ppm, in a group of 5 individuals taken below UC Davis at Site 9.

A single individual taken upstream from Lake Solano was somewhat elevated at 0.12 ppm, particularly in relation to the size of the fish (95 g, vs 305-360 g at Site 9).

Sacramento blackfish (*Orthodon microlepidotus*, Fig. 4c): Planktivorous Sacramento blackfish were relatively low in muscle mercury throughout, with 19 of 20 individuals having concentrations ≤ 0.15 ppm. Mean blackfish mercury levels increased slightly across a range of sizes (200-1200 g), from ~0.06 ppm to ~0.10 ppm, with an overall mean of approximately 0.08 ppm. Consistent samples of this species were taken at Site 6 (above UC Davis near Pedrick Rd), Site 9 (0.5-1.0 mile downstream of the UC Davis water treatment outflow and the LEHR site), and Site 11 (6 miles downstream of UCD at Rd 106A). Concentrations from Sites 6 and 9, above and below UC Davis, fell within an identical size:Hg pattern, indicating very similar levels of mercury exposure/uptake in these two reaches of the creek. At the furthest downstream site (Site 11, 6 miles downstream of UC Davis), the blackfish data indicate a possible elevation in localized mercury exposure/uptake. Of the seven fish sampled at that site, one exhibited an anomalously elevated concentration (600 g, 0.23 ppm Hg) and slightly above-trend concentrations were apparent in some of the others.

Sacramento sucker (*Catostomus occidentalis*, Fig. 4d): This species is a native bottom fish which feeds primarily on small bottom-dwelling invertebrates. Adult Sacramento suckers were available for collection only at sites located above UC Davis. Individuals taken from Sites 3, 5, and 6 (below Lake Solano to just above UC Davis) had a very similar pattern of concentrations (0.10-0.18 ppm Hg in all 9 individuals, 100-900 g). Mean levels increased slightly with size of fish. The sample of five suckers taken from within Lake Solano (Site 2) was significantly elevated in muscle mercury relative to the trend seen at the other sites (0.32-0.52 ppm Hg in all 5 fish). While these lake-dwelling individuals were also significantly larger (1,100-1,900 g) than the individuals collected from the downstream creek, their muscle mercury concentrations were clearly elevated above the trend line described by the creek population.

Carp (*Cyprinus carpio*, Fig. 4e): Fifteen large, adult carp were sampled from Putah Creek, primarily from downstream sites, within the extended size range of 500-4,900 g (1.1-10.8 lbs). All of these individuals exhibited low to moderate muscle mercury concentrations between 0.12 and 0.25 ppm, consistent with their relatively low trophic position, consuming small benthic invertebrates and plant material from the bottom (Moyle 1976). Little or no size-based increase in concentrations was noted, with mean levels remaining at approximately 0.18 ppm Hg throughout. Only one of the sampled large carp was taken from upstream of UC Davis. This individual contained 0.22 ppm muscle Hg, among the 4 highest concentrations in the total data set. While all samples from Site 6 (above the University) and Sites 9 and 11 (below the University) contained Hg within the same 0.12-0.25 range and demonstrated no significant differences between sites, the two highest numbers came from individuals taken at the furthest downstream site (Site 11).

<u>Sunfish</u> (*Lepomis macrochirus*, etc. Fig. 4f): Five bluegill sunfish were taken from Site 9 below UC Davis and 7 bluegill, one redear sunfish, and a hybrid sunfish were sampled upstream of UCD at Site 6. The fish were small to medium in size (20-160 g). Muscle mercury ranged between 0.12 and 0.33 ppm, with a mean of approximately 0.20 ppm Hg. Across the size range available, no size:Hg relationship was apparent. Sunfish taken above and below UC Davis exhibited muscle mercury in an identical range. These water column fish feed on zooplankton and a variety of larger invertebrates. They are perhaps the creek fish most frequently taken by anglers, particularly young anglers.

<u>White catfish, channel catfish</u> (*Ictalurus catus*, *Ictalurus punctatus*, Fig. 4g): Catfish are popular gamefish which are bottom feeding predators with a varied diet. White catfish were present only at the most downstream sites (9 and 11). Channel catfish were also taken at those sites, as well as from Site 6 upstream of the University. The data for both species fall within the same general size:Hg relationship, with a slight increase in mean muscle mercury with size. Concentrations ranged between 0.07 and 0.34 ppm in both species, with 19 of 21 individuals having ≤ 0.20 ppm, including the largest individuals (1,200-2,700 g; 2.6-5.9 lbs; n=7). Channel catfish were more variable in their concentrations (0.07-0.34 ppm); white catfish mercury ranged between 0.10 and 0.19 ppm. The 2 highest catfish mercury levels (0.23 and 0.34 ppm) were found in individuals taken at Pedrick Rd, well upstream of the university. Downstream collections exhibited no relative elevation in muscle mercury concentrations, even in the largest fish sampled (2,700 g, 0.20 ppm Hg, Site 9).

<u>Sacramento squawfish</u> (*Ptychocheilus grandis*, Fig. 4h): The squawfish is a native top predator species that preys upon other fish when adult. Squawfish are not typically targets of anglers, are difficult to catch, and infrequently eaten. Individuals larger than juvenile size were taken at two sites: Site 5 (Russell Ranch, between Winters and Davis) and Site 11, the furthest downstream site. The samples from Russell Ranch included 3 smaller individuals (105-150 g) which had muscle mercury at 0.17-0.29 ppm, increasing with size,

and a single full-sized adult weighing 990 g (2.2 lbs) and containing 0.48 ppm muscle mercury. While this sample was not sufficient to produce a tight size:Hg relationship for the species, the two fish taken at Site 11 appear to demonstrate relatively elevated muscle mercury levels. At 165 and 250 g, these two fish had very similar, very high muscle mercury levels (0.72, 0.73 ppm), notably elevated above the apparent relationship seen at Site 5.

White crappie, black crappie (*Pomoxis annularis*, *Pomoxis nigromaculatus*, Fig. 4i): Crappie become predators of other fish as adults and are prized by anglers. A single large individual (735 g) was taken at Site 11, 6 miles below UC Davis at Rd. 106A. This individual contained one of the highest muscle mercury concentrations found in the study (0.63 ppm). Comparable, large individual crappie were not available from other sites. A sample of 3 young individuals was collected from Site 6, upstream of the university (48-83 g, 0.15-0.19 ppm Hg), together with a slightly larger black crappie (103 g, 0.33 ppm Hg). As no fish of intermediate size were collected, it is not clear whether the downstream adult represented anomalously high, site-specific levels or an elevation solely attributable to size and feeding habits. A very steep size:Hg relationship, with similar high top-end levels, was found in collections we made for Yolo County in the lower portion of Cache Creek (Slotton *et al.* 1997c).

Largemouth bass, smallmouth bass (*Micropterus salmoides*, *Micropterus dolomieui*, Fig. 4j): These prized, warmwater gamefish species use their large mouths to capture other fish and a variety of large prey items. Adult largemouth bass are one of the primary top predator fish species in the lower portion of the creek. Collections at upstream sites yielded only juveniles and post-juveniles (40-110 g) of either species, which had muscle mercury at 0.15-0.35 ppm. Four adult largemouth bass of 600-2,000 g were taken at Site 9 approximately 1 mile downstream of UC Davis. The two smaller individuals of these adults had mercury concentrations similar to the smaller bass (0.20-0.23 ppm), while the larger, piscivorous (fish-eating) individuals demonstrated a typical predatory size:Hg relationship (1,120 g and 0.34 ppm Hg, 1,920 g and 0.62 ppm Hg). Two 900-1,000 g adult largemouth bass were taken at the most downstream site (Site 11). At 0.63 and 0.73 ppm Hg, the concentrations from this site appear to be elevated above the general size:Hg relationship described by bass data from the other sites.

Table 3. Putah Creek Fish Muscle (Fillet) Mercury.
(fresh/wet weight ppm Hg)

Site #	Site Description	Fish Species	Weight (g)	Length (mm)	Muscle Hg (wet wt ppm)
1	Putah Ck below L. Berryessa	Rainbow Trout	82	192	**0.07**
1	Putah Ck below L. Berryessa	Rainbow Trout	159	225	**0.07**
1	Putah Ck below L. Berryessa	Rainbow Trout	205	245	**0.06**
1	Putah Ck below L. Berryessa	Rainbow Trout	215	259	**0.07**
1	Putah Ck below L. Berryessa	Rainbow Trout	425	337	**0.05**
1	Putah Ck below L. Berryessa	Rainbow Trout	505	348	**0.08**
1	Putah Ck below L. Berryessa	Rainbow Trout	580	383	**0.15**
2	In Lake Solano	Hitch	95	194	**0.12**
2	In Lake Solano	Sac. Sucker	1,115	434	**0.42**
2	In Lake Solano	Sac. Sucker	1,300	467	**0.32**
2	In Lake Solano	Sac. Sucker	1,425	462	**0.41**
2	In Lake Solano	Sac. Sucker	1,660	481	**0.46**
2	In Lake Solano	Sac. Sucker	1,910	511	**0.52**
3	Putah Ck below L. Solano	Sac. Sucker	430	335	**0.16**
3	Putah Ck below L. Solano	Rainbow Trout	60	166	**0.12**
3	Putah Ck below L. Solano	Rainbow Trout	72	189	**0.10**
3	Putah Ck below L. Solano	Rainbow Trout	75	185	**0.09**
3	Putah Ck below L. Solano	Rainbow Trout	105	193	**0.08**
4	Putah Ck below Winters	Tule Perch	16	90	**0.11**
4	Putah Ck below Winters	Tule Perch	42	129	**0.15**
4	Putah Ck below Winters	Green Sunfish	23	108	**0.19**
4	Putah Ck below Winters	Green Sunfish	25	108	**0.15**
4	Putah Ck below Winters	Largemouth Bass	110	194	**0.15**
5	Putah Ck at Russell Ranch	Sac. Sucker	115	217	**0.10**
5	Putah Ck at Russell Ranch	Sac. Sucker	550	371	**0.12**
5	Putah Ck at Russell Ranch	Sac. Sucker	680	379	**0.11**
5	Putah Ck at Russell Ranch	Sac. Sucker	800	388	**0.18**
5	Putah Ck at Russell Ranch	Sac. Sucker	810	405	**0.13**
5	Putah Ck at Russell Ranch	Sac. Sucker	860	408	**0.11**
5	Putah Ck at Russell Ranch	Smallmouth Bass	40	143	**0.25**
5	Putah Ck at Russell Ranch	Squawfish	107	232	**0.17**
5	Putah Ck at Russell Ranch	Squawfish	135	257	**0.26**
5	Putah Ck at Russell Ranch	Squawfish	150	270	**0.29**
5	Putah Ck at Russell Ranch	Squawfish	990	453	**0.48**

(continued)

Table 3. Putah Creek Fish Muscle (Fillet) Mercury. ***(continued)***
(fresh/wet weight ppm Hg)

Site #	Site Description	Fish Species	Weight (g)	Length (mm)	Muscle Hg (wet wt ppm)
6	Putah Ck 2 mi above UCD	Sac. Blackfish	580	335	0.06
6	Putah Ck 2 mi above UCD	Sac. Blackfish	630	335	0.09
6	Putah Ck 2 mi above UCD	Sac. Blackfish	700	366	0.09
6	Putah Ck 2 mi above UCD	Sac. Blackfish	920	379	0.09
6	Putah Ck 2 mi above UCD	Sac. Blackfish	1,000	397	0.10
6	Putah Ck 2 mi above UCD	Sac. Sucker	470	377	0.13
6	Putah Ck 2 mi above UCD	Sac. Sucker	625	364	0.13
6	Putah Ck 2 mi above UCD	Carp	1,520	435	0.22
6	Putah Ck 2 mi above UCD	Redear Sunfish	153	192	0.15
6	Putah Ck 2 mi above UCD	Sunfish (Hybrid)	131	178	0.19
6	Putah Ck 2 mi above UCD	Bluegill	50	135	0.19
6	Putah Ck 2 mi above UCD	Bluegill	55	140	0.22
6	Putah Ck 2 mi above UCD	Bluegill	75	135	0.20
6	Putah Ck 2 mi above UCD	Bluegill	85	147	0.14
6	Putah Ck 2 mi above UCD	Bluegill	85	148	0.24
6	Putah Ck 2 mi above UCD	Bluegill	112	177	0.32
6	Putah Ck 2 mi above UCD	Bluegill	112	153	0.18
6	Putah Ck 2 mi above UCD	Channel Catfish	205	256	0.13
6	Putah Ck 2 mi above UCD	Channel Catfish	710	365	0.34
6	Putah Ck 2 mi above UCD	Channel Catfish	750	378	0.11
6	Putah Ck 2 mi above UCD	Channel Catfish	1,110	437	0.23
6	Putah Ck 2 mi above UCD	Channel Catfish	1,280	413	0.17
6	Putah Ck 2 mi above UCD	Channel Catfish	1,570	470	0.12
6	Putah Ck 2 mi above UCD	Channel Catfish	1,660	510	0.07
6	Putah Ck 2 mi above UCD	Channel Catfish	1,970	500	0.18
6	Putah Ck 2 mi above UCD	White Crappie	48	165	0.19
6	Putah Ck 2 mi above UCD	White Crappie	50	167	0.15
6	Putah Ck 2 mi above UCD	White Crappie	83	190	0.16
6	Putah Ck 2 mi above UCD	Black Crappie	103	192	0.33
6	Putah Ck 2 mi above UCD	Smallmouth Bass	100	209	0.35
6	Putah Ck 2 mi above UCD	Largemouth Bass	52	160	0.34

(continued)

Table 3. Putah Creek Fish Muscle (Fillet) Mercury. ***(continued)***
(fresh/wet weight ppm Hg)

Site #	Site Description	Fish Species	Weight *(g)*	Length *(mm)*	Muscle Hg *(wet wt ppm)*
9	Putah Ck. 0.7 mi blw UCD	Clam (Proptera)		75x56	0.03
9	Putah Ck. 0.7 mi blw UCD	Sac. Blackfish	290	272	0.04
9	Putah Ck. 0.7 mi blw UCD	Sac. Blackfish	430	311	0.05
9	Putah Ck. 0.7 mi blw UCD	Sac. Blackfish	505	319	0.05
9	Putah Ck. 0.7 mi blw UCD	Sac. Blackfish	555	355	0.09
9	Putah Ck. 0.7 mi blw UCD	Sac. Blackfish	685	354	0.07
9	Putah Ck. 0.7 mi blw UCD	Sac. Blackfish	790	377	0.07
9	Putah Ck. 0.7 mi blw UCD	Sac. Blackfish	820	365	0.11
9	Putah Ck. 0.7 mi blw UCD	Sac. Blackfish	1,140	419	0.08
9	Putah Ck. 0.7 mi blw UCD	Hitch	305	274	0.10
9	Putah Ck. 0.7 mi blw UCD	Hitch	315	278	0.07
9	Putah Ck. 0.7 mi blw UCD	Hitch	345	288	0.09
9	Putah Ck. 0.7 mi blw UCD	Hitch	355	294	0.08
9	Putah Ck. 0.7 mi blw UCD	Hitch	360	306	0.11
9	Putah Ck. 0.7 mi blw UCD	Carp	555	311	0.16
9	Putah Ck. 0.7 mi blw UCD	Carp	1,060	398	0.12
9	Putah Ck. 0.7 mi blw UCD	Carp	1,450	429	0.22
9	Putah Ck. 0.7 mi blw UCD	Carp	2,025	460	0.15
9	Putah Ck. 0.7 mi blw UCD	Carp	2,800	525	0.13
9	Putah Ck. 0.7 mi blw UCD	Carp	3,300	541	0.21
9	Putah Ck. 0.7 mi blw UCD	Carp	4,900	620	0.21
9	Putah Ck. 0.7 mi blw UCD	Bluegill	22	104	0.12
9	Putah Ck. 0.7 mi blw UCD	Bluegill	29	109	0.25
9	Putah Ck. 0.7 mi blw UCD	Bluegill	30	117	0.16
9	Putah Ck. 0.7 mi blw UCD	Bluegill	35	119	0.16
9	Putah Ck. 0.7 mi blw UCD	Bluegill	45	142	0.33
9	Putah Ck. 0.7 mi blw UCD	Channel Catfish	310	294	0.09
9	Putah Ck. 0.7 mi blw UCD	Channel Catfish	340	310	0.10
9	Putah Ck. 0.7 mi blw UCD	Channel Catfish	2,700	539	0.20
9	Putah Ck. 0.7 mi blw UCD	White Catfish	595	332	0.13
9	Putah Ck. 0.7 mi blw UCD	White Catfish	610	340	0.19
9	Putah Ck. 0.7 mi blw UCD	White Catfish	655	348	0.12
9	Putah Ck. 0.7 mi blw UCD	White Catfish	720	359	0.13
9	Putah Ck. 0.7 mi blw UCD	White Catfish	745	360	0.10
9	Putah Ck. 0.7 mi blw UCD	White Catfish	1,310	413	0.11
9	Putah Ck. 0.7 mi blw UCD	White Catfish	1,390	431	0.16
9	Putah Ck. 0.7 mi blw UCD	Largemouth Bass	635	342	0.23
9	Putah Ck. 0.7 mi blw UCD	Largemouth Bass	705	321	0.20
9	Putah Ck. 0.7 mi blw UCD	Largemouth Bass	1,120	394	0.34
9	Putah Ck. 0.7 mi blw UCD	Largemouth Bass	1,920	474	0.62

(continued)

Table 3. Putah Creek Fish Muscle (Fillet) Mercury. ***(continued)***
(fresh/wet weight ppm Hg)

Site #	Site Description	Fish Species	Weight *(g)*	Length *(mm)*	Muscle Hg *(wet wt ppm)*
11	Putah Ck. at Rd. 106A	Sac. Blackfish	285	276	**0.07**
11	Putah Ck. at Rd. 106A	Sac. Blackfish	315	284	**0.08**
11	Putah Ck. at Rd. 106A	Sac. Blackfish	355	303	**0.12**
11	Putah Ck. at Rd. 106A	Sac. Blackfish	385	303	**0.07**
11	Putah Ck. at Rd. 106A	Sac. Blackfish	505	338	**0.06**
11	Putah Ck. at Rd. 106A	Sac. Blackfish	600	367	**0.23**
11	Putah Ck. at Rd. 106A	Sac. Blackfish	840	398	**0.14**
11	Putah Ck. at Rd. 106A	Carp	535	333	**0.23**
11	Putah Ck. at Rd. 106A	Carp	805	362	**0.14**
11	Putah Ck. at Rd. 106A	Carp	1,040	411	**0.15**
11	Putah Ck. at Rd. 106A	Carp	1,210	402	**0.15**
11	Putah Ck. at Rd. 106A	Carp	1,280	432	**0.20**
11	Putah Ck. at Rd. 106A	Carp	1,440	427	**0.16**
11	Putah Ck. at Rd. 106A	Carp	1,750	457	**0.25**
11	Putah Ck. at Rd. 106A	Channel Catfish	480	349	**0.08**
11	Putah Ck. at Rd. 106A	Channel Catfish	740	394	**0.07**
11	Putah Ck. at Rd. 106A	White Catfish	545	320	**0.18**
11	Putah Ck. at Rd. 106A	Largemouth Bass	930	387	**0.73**
11	Putah Ck. at Rd. 106A	Largemouth Bass	970	385	**0.63**
11	Putah Ck. at Rd. 106A	White Crappie	735	359	**0.63**
11	Putah Ck. at Rd. 106A	Squawfish	165	252	**0.72**
11	Putah Ck. at Rd. 106A	Squawfish	250	318	**0.73**

Fig. 3(a) Fish muscle mercury
SITE 1: TROUT WATERS JUST BELOW LAKE BERRYESSA

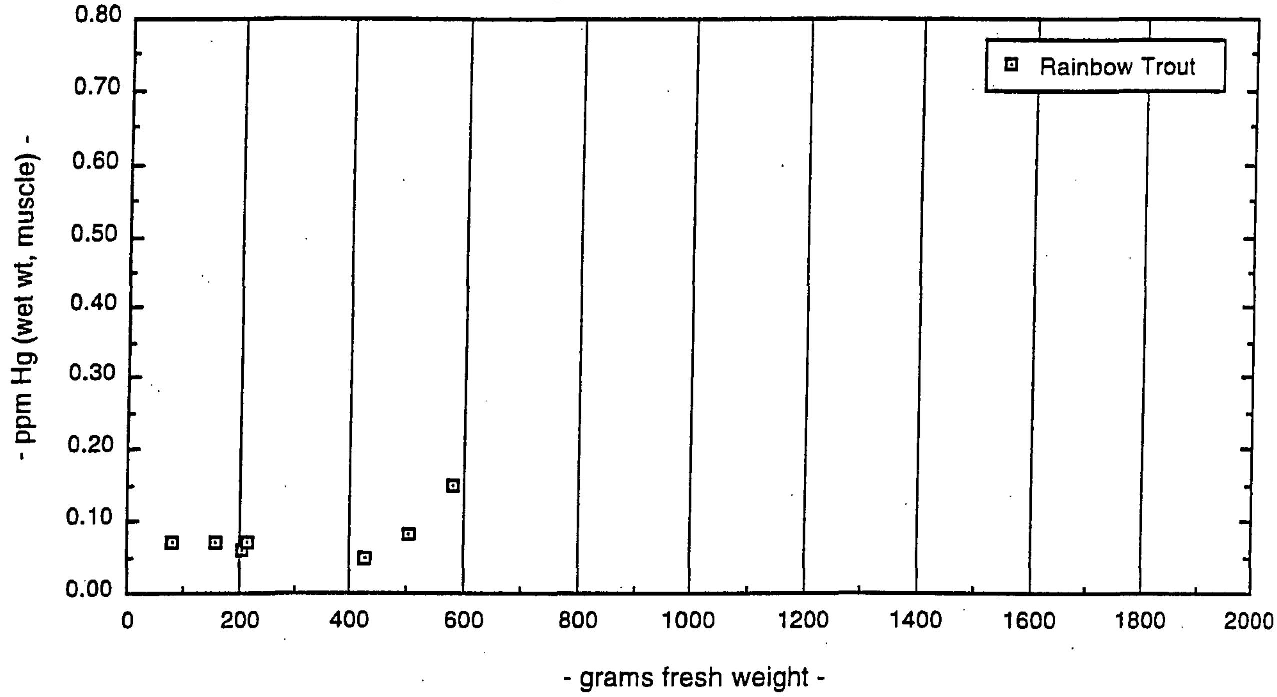


Fig. 3(b) Fish muscle mercury
SITE 2: IN LAKE SOLANO

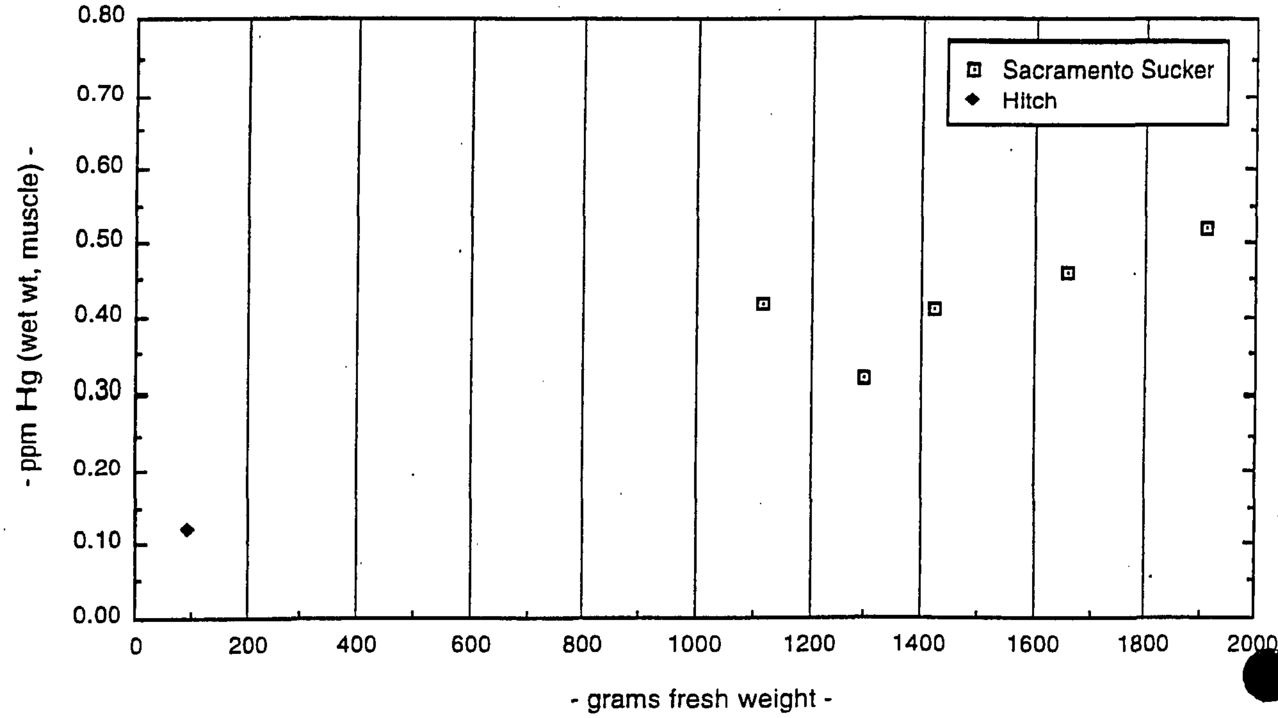


Fig. 3(c) Fish muscle mercury
SITE 3: JUST BELOW LAKE SOLANO

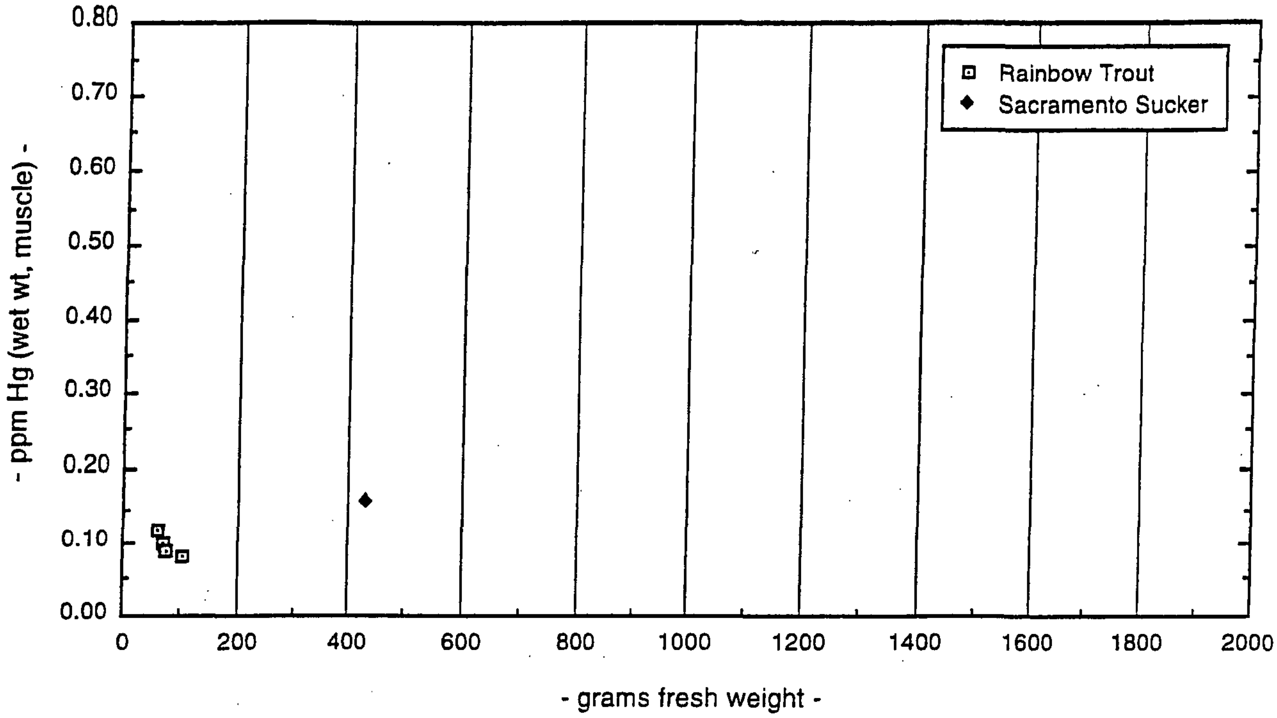


Fig. 3(d) Fish muscle mercury
SITE 4: BELOW WINTERS AT HIGHWAY 505

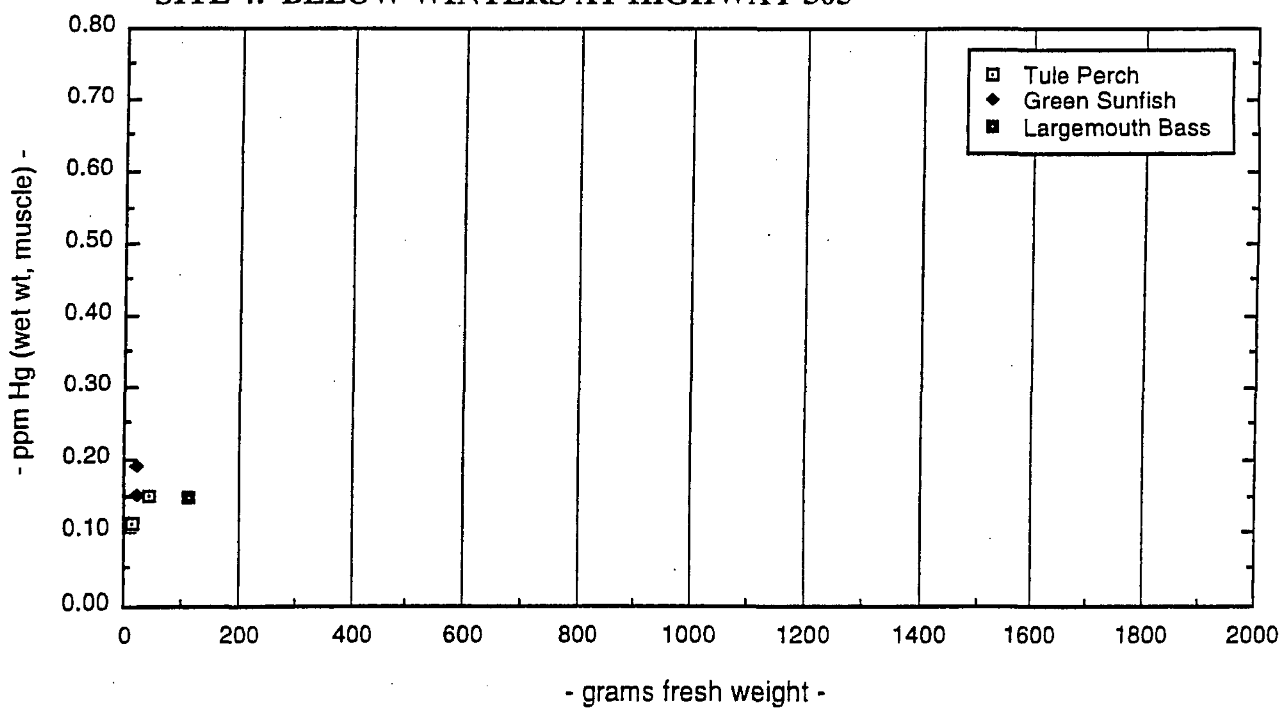


Fig. 3(e) Fish muscle mercury
SITE 5: AT RUSSELL RANCH

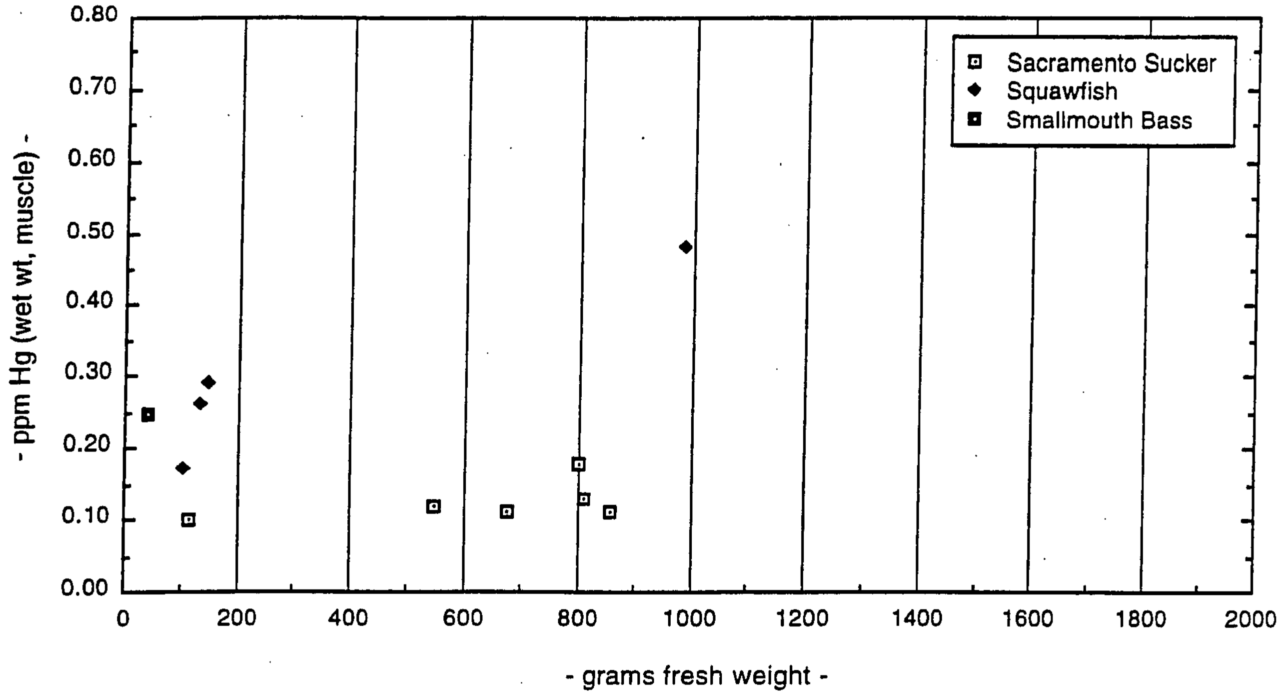


Fig. 3(f) Fish muscle mercury
SITE 6: UPSTREAM OF UC DAVIS NEAR PEDRICK ROAD

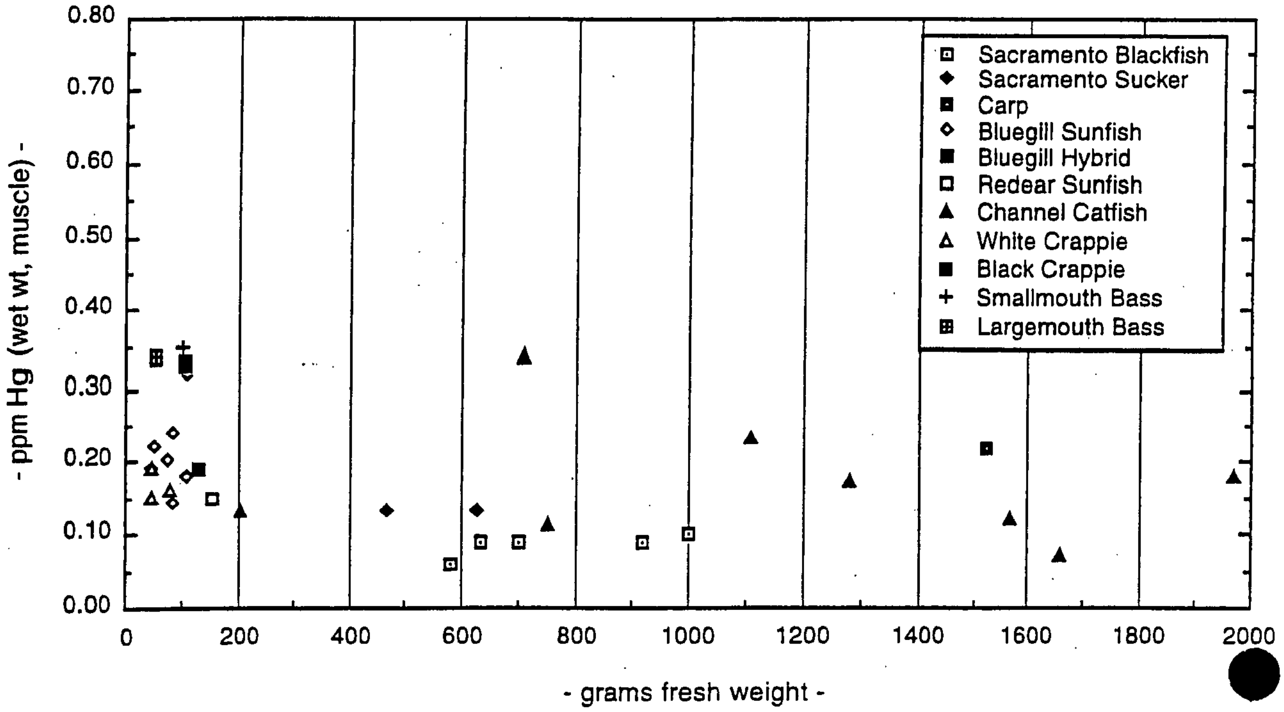


Fig. 3(g) Fish muscle mercury
SITE 9: 0.5-1.0 MILE BELOW LEHR (Fish ≤2,000 g)

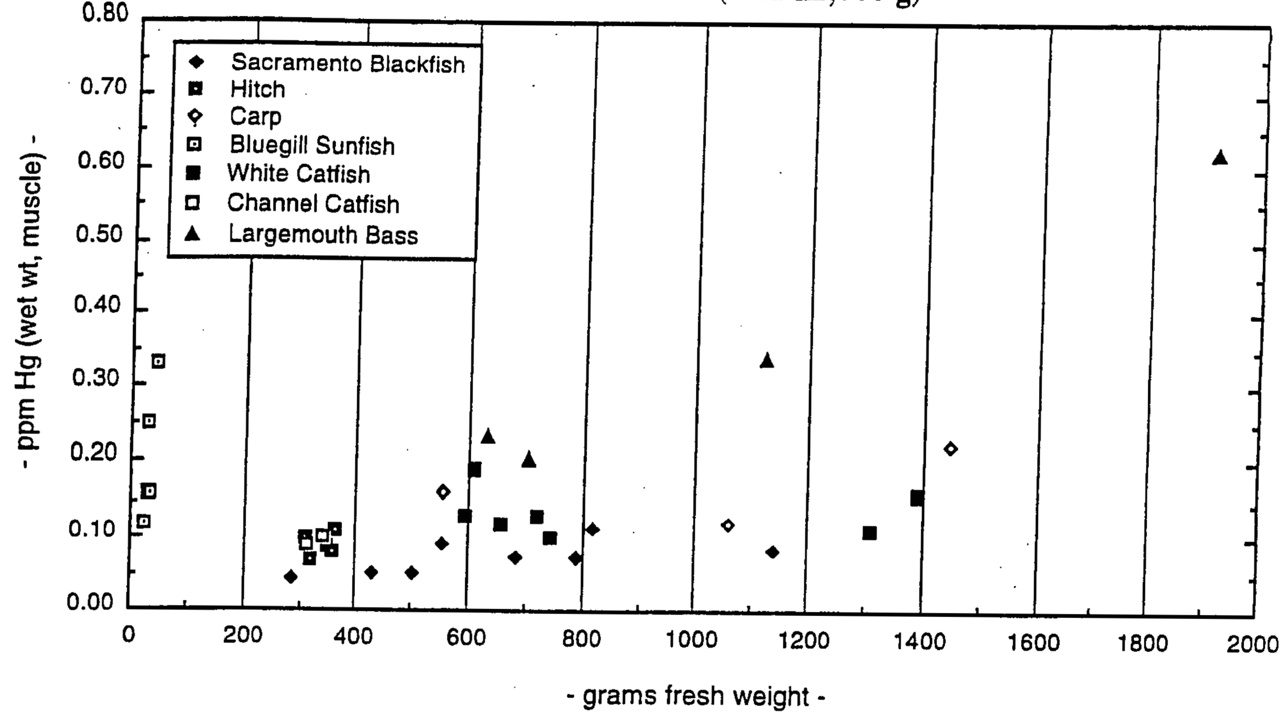


Fig. 3(h) Fish muscle mercury
SITE 9: 0.5-1.0 MILE BELOW LEHR (all fish: to 5,000 g)

NOTE EXPANDED X-AXIS

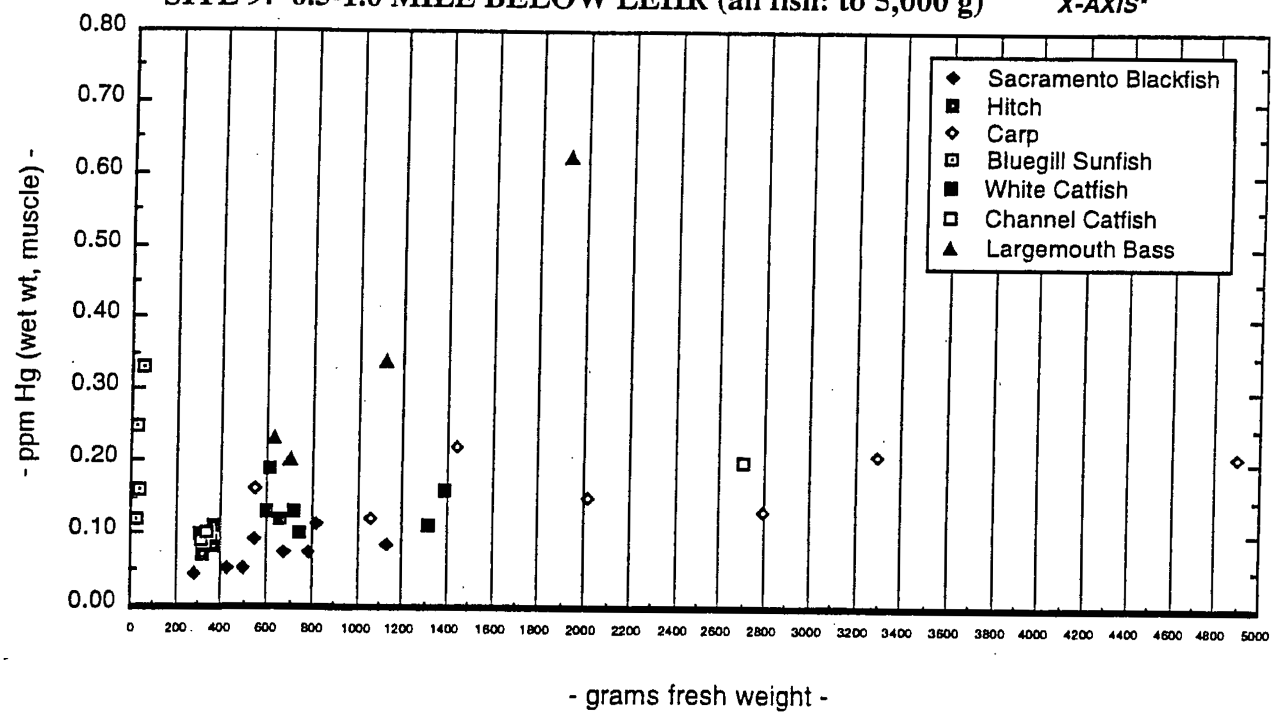


Fig. 3(i) Fish muscle mercury
SITE 11: AT ROAD 106A

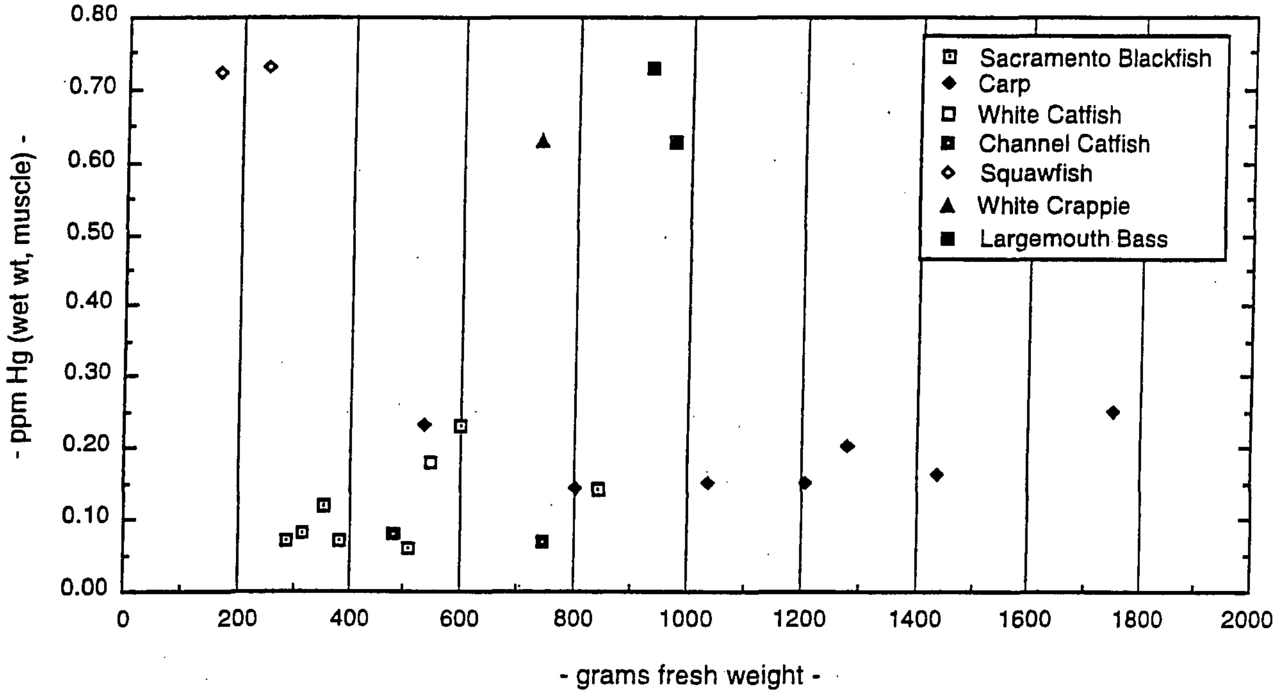


Fig. 4(a)
RAINBOW TROUT

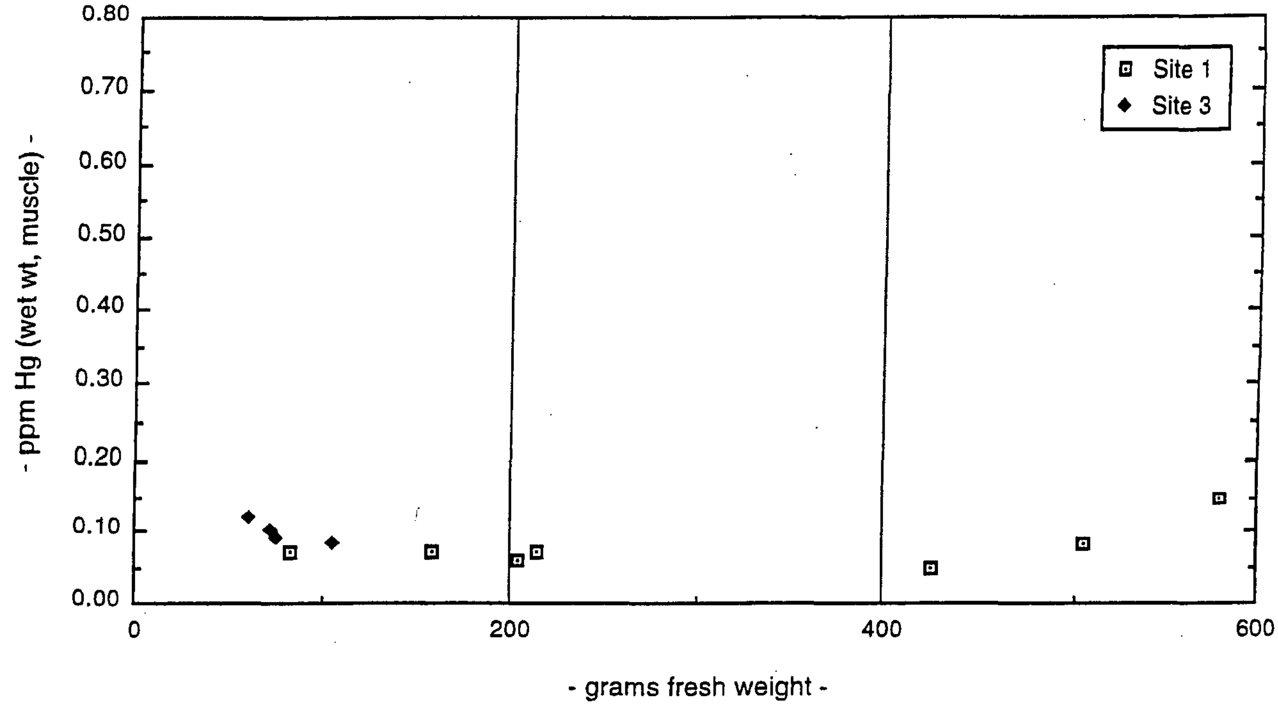


Fig. 4(b)
HITCH

Fig. 4(c)
SACRAMENTO BLACKFISH

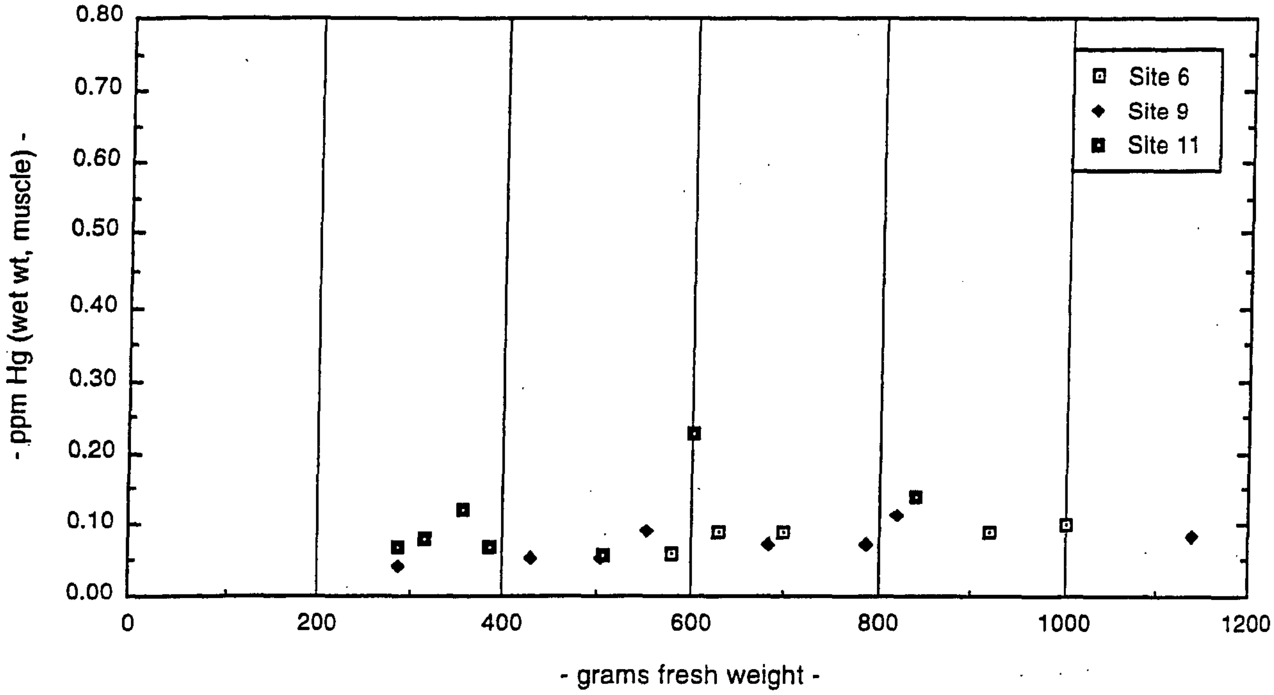


Fig. 4(d)
SACRAMENTO SUCKER

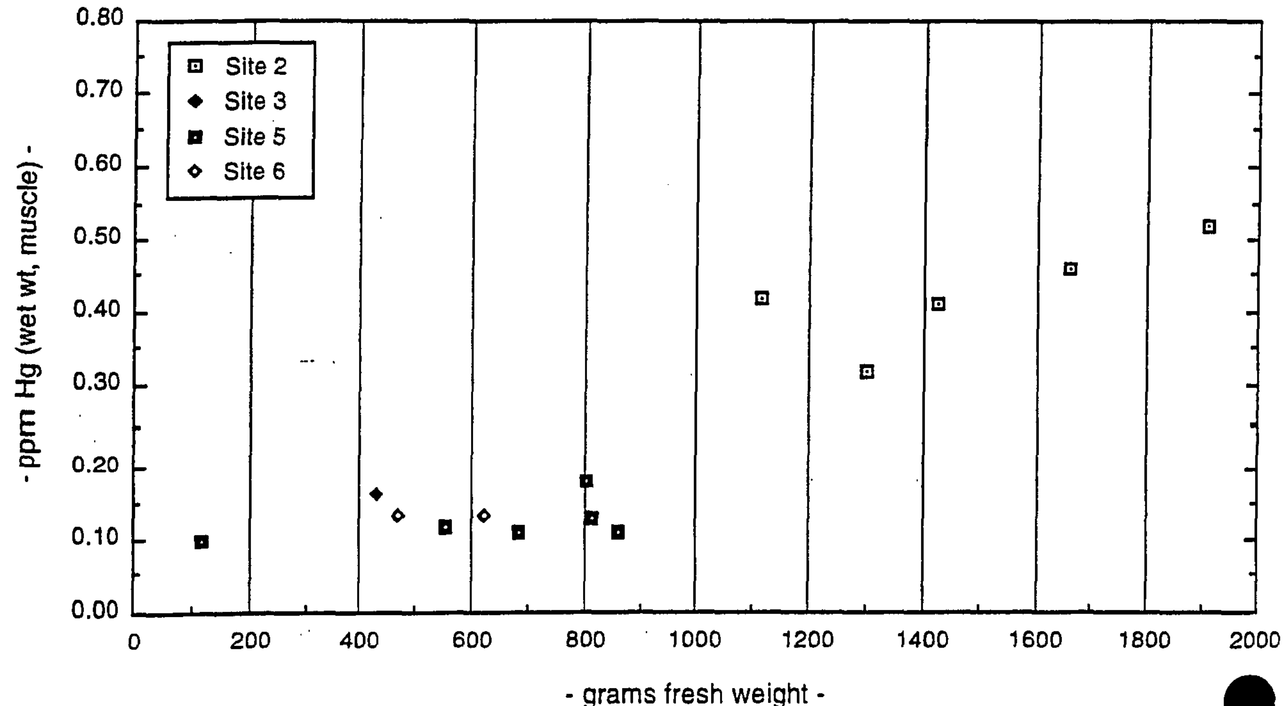


Fig. 4(e)
CARP

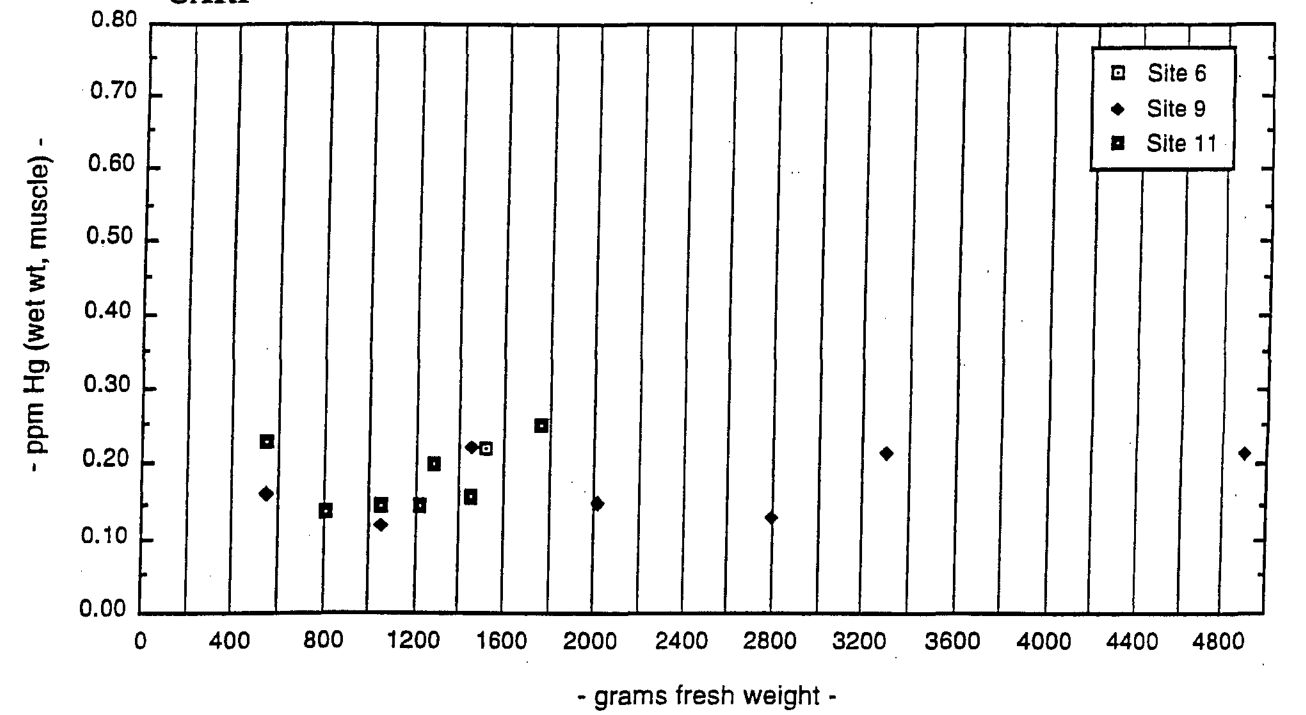


Fig. 4(f)
SUNFISH

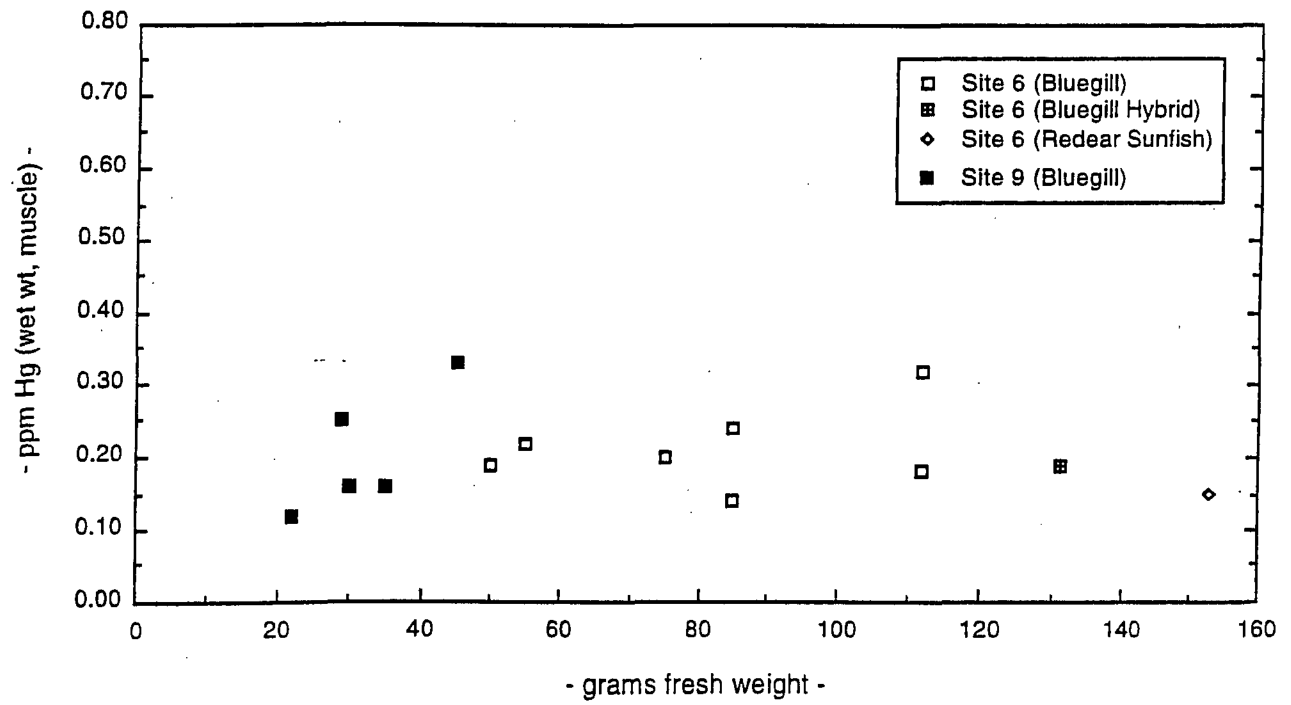


Fig. 4(g)
CATFISH

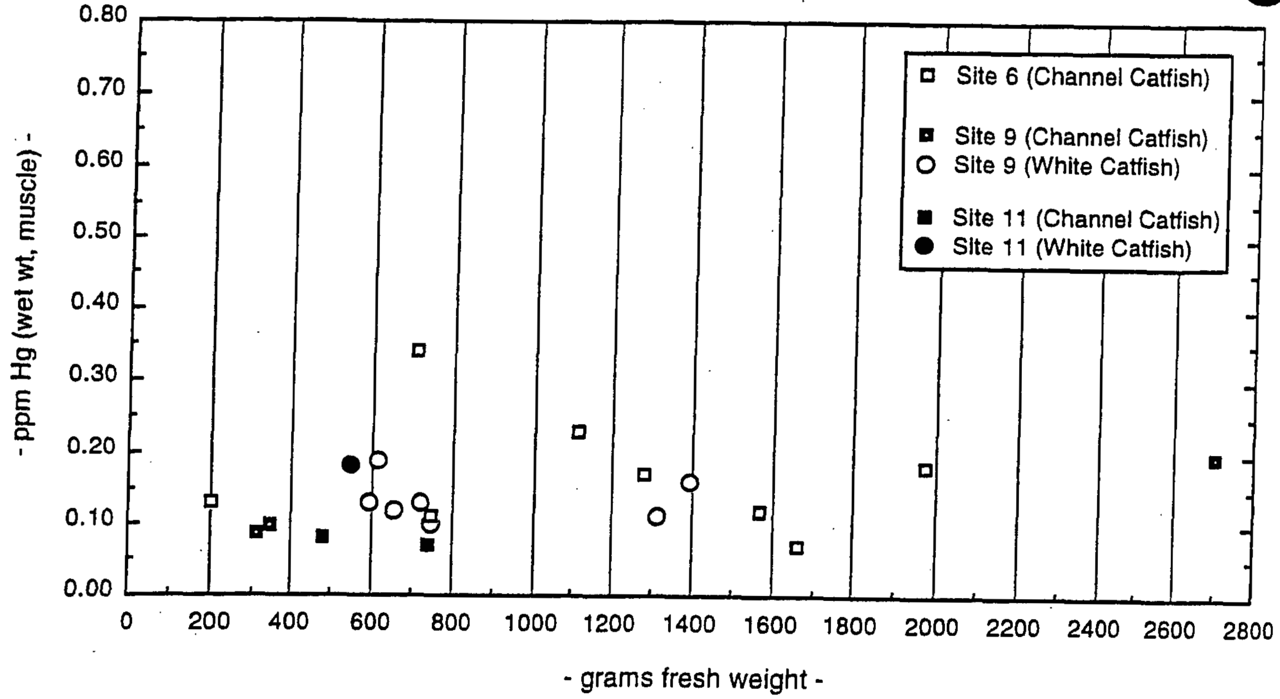


Fig. 4(h)
SQUAWFISH

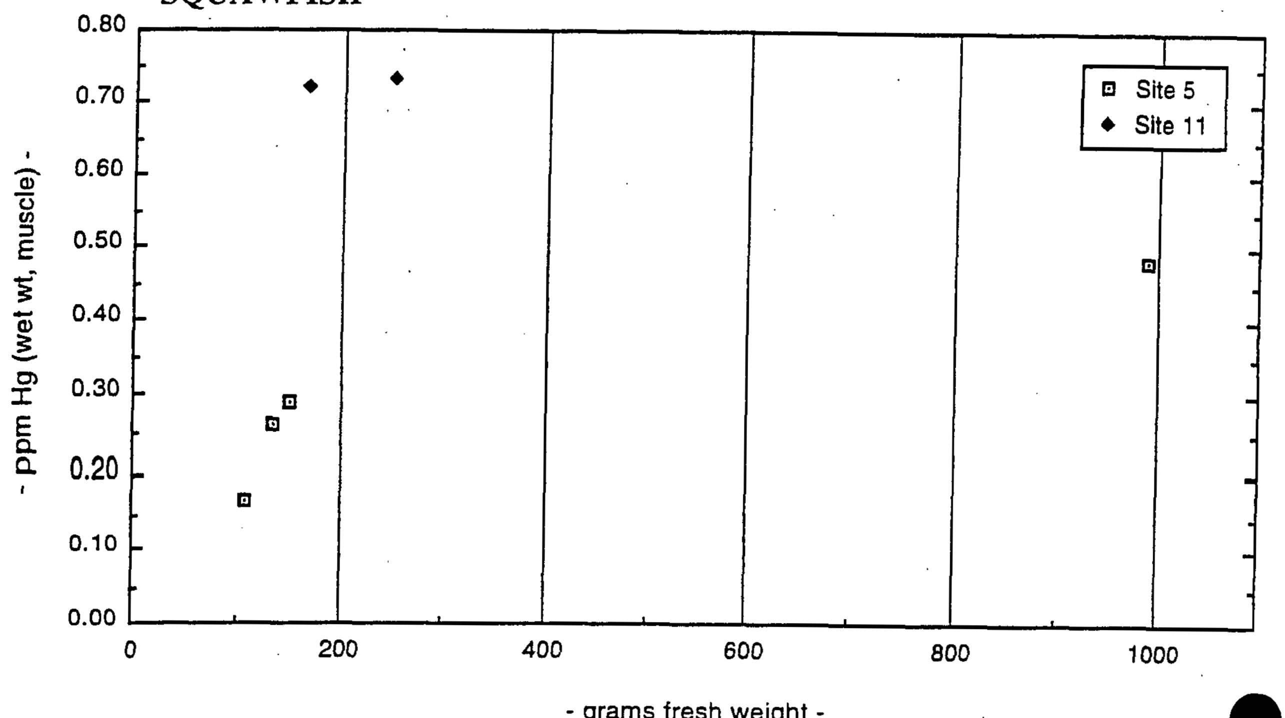


Fig. 4(i)
CRAPPIE

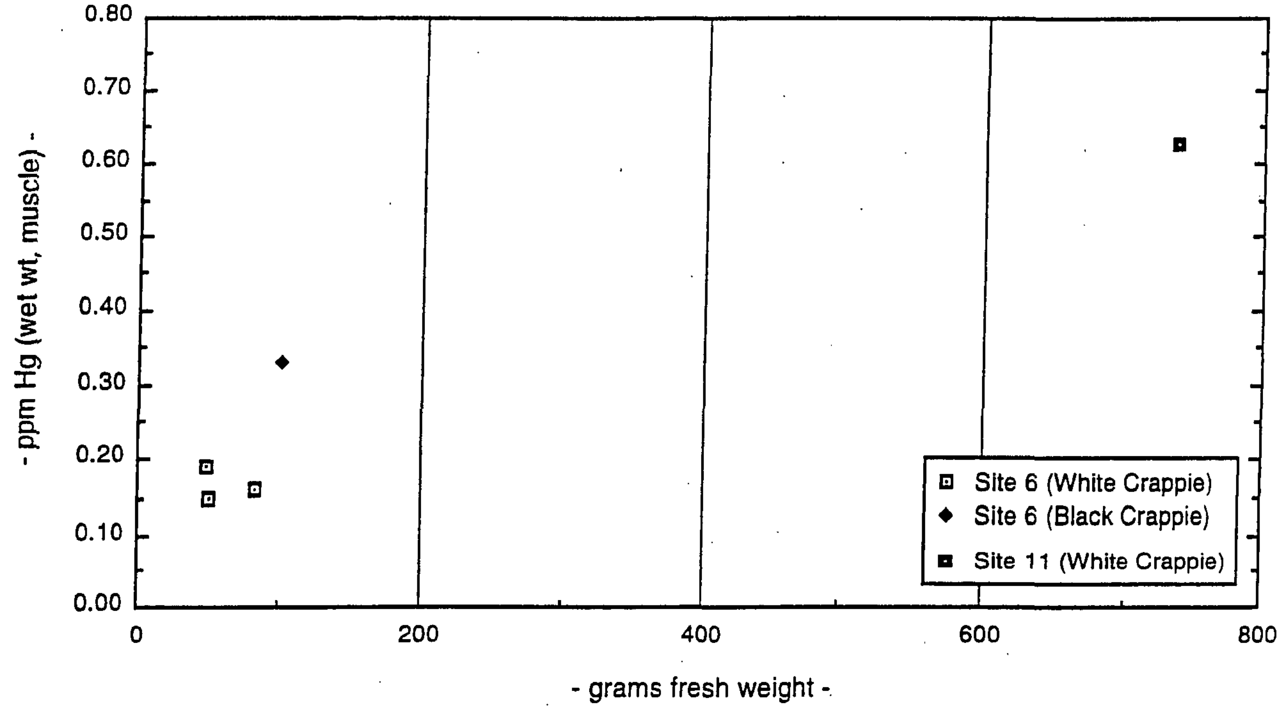
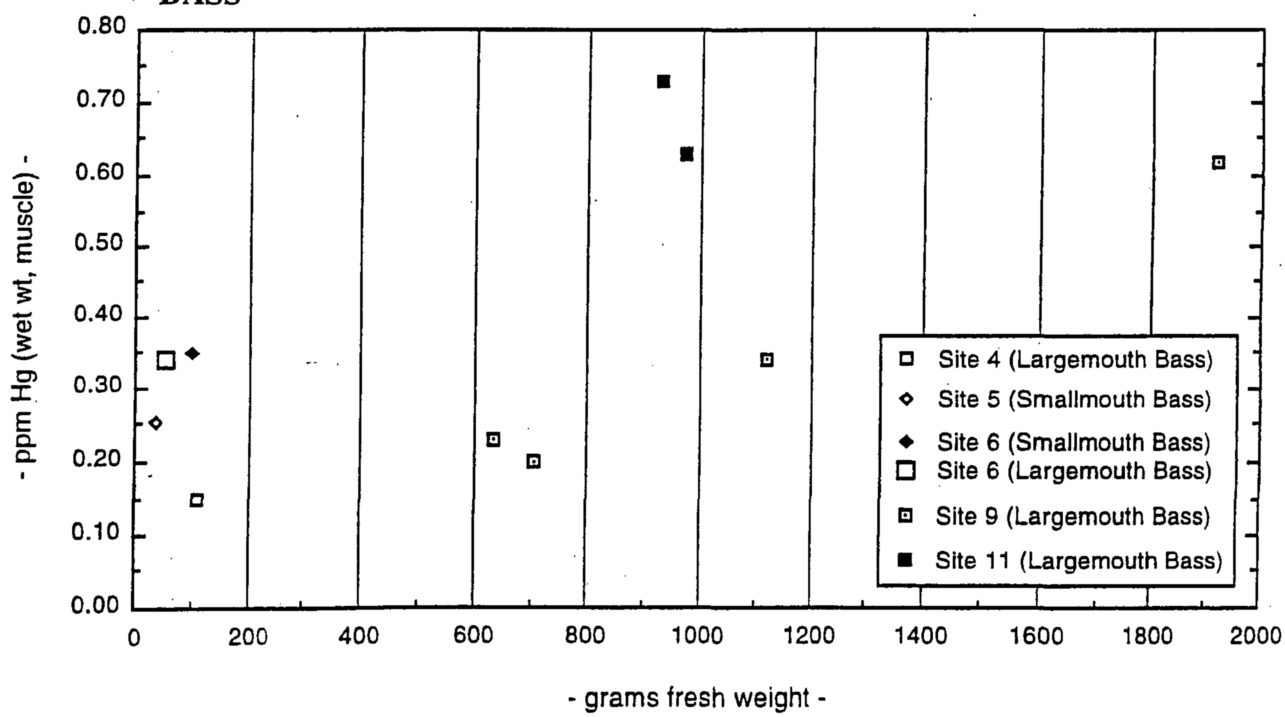


Fig. 4(j)
BASS



3.2 Small and Juvenile Fish

Twelve species of small or juvenile fish (≤15 g and 10 cm), together with bullfrog tadpoles, were collected for the project in 48 composite samples of multiple individuals. Whole fish, multi-individual compositing is a technique commonly used in other metals biomonitoring work in California (Hellawell 1986, Reuter *et al.* 1989, 1998, Bodega Research Associates 1998). Composites, within each species, were made of similar sized individuals. While these samples typically contain lower mercury concentrations than the larger fish muscle samples, they provide a more site-specific measure of relative localized mercury exposure and uptake. Because these fish and tadpoles are generally a year or less in age, the assumption can be made that they accumulated the majority of their mercury loads at or relatively near the site of capture. Data from composite small and juvenile whole fish and tadpole samples are presented in Table 4. The table is arranged so as to portray the relative distributions of the various species across the sampling sites. Just as seen for the larger fishes, these species include types found only in the upper reaches, others found in mid-reach sites, and others only in the lower sites. None of the species was found in sufficient numbers for analysis at all of the sites. However, relative to the question of potential UC Davis influences, five species were collected at sites both above and below the University and provide excellent additional information. Table 4 is arranged to facilitate mercury comparisons in several ways: (1) between sites, looking at all species/samples from each site together; (2) between species, both within individual sites and all sites combined; and most importantly (3) between sites, within individual species. In Figure 5, the small/juvenile fish data are plotted on a map of the region to demonstrate general, relative levels between sites.

In addition to providing biomonitoring information on relative mercury exposure/uptake between sites, the absolute mercury levels in these small fish are of interest from a wildlife consumption perspective. Just as the large fish fillet muscle data correspond to human health exposure, these small fish are primary prey of egrets, herons, and other species of wildlife. Whole fish mercury concentrations, as analyzed for these samples, provide the most ecologically relevant information.

The small fish and tadpole mercury data sets span a relatively small range of concentrations (0.02-0.23 ppm), with 46 of the 48 samples (96%) between 0.02 and 0.12 ppm. Juvenile squawfish taken just downstream of Lake Solano (Site 3) were relatively elevated at 0.17 ppm Hg. Concentrations in all four small fish species taken at the most downstream site (Site 11) were somewhat to highly elevated relative to their species data from other Putah Creek sites: juvenile bluegill--0.11 ppm vs 0.05-0.11 ppm at 6 other sites, Mississippi silverside--0.12 ppm vs 0.06-0.10 ppm at 5 other sites, red shiner--0.08 ppm vs 0.02-0.03 at 3 other sites, and mosquitofish—most anomalous at 0.23 ppm vs 0.03-0.08 ppm at 5 other sites.

The remaining 43 composite samples all contained mercury within the relatively narrow range of 0.02-0.12 ppm. Some of the lowest levels for a variety of species were found at Sites 7-10, located between a half mile upstream and 3 miles downstream of the UC Davis wastewater treatment plant outfall and the LEHR site. Higher mercury was seen upstream of these areas for logperch, bullfrog tadpoles, juvenile bluegill, and mosquitofish. Silversides were similar in both regions. The juvenile and small fish data indicate that the region adjacent to and within 3 miles downstream of the University had reduced levels of biological mercury exposure and uptake, relative to upstream sites. The data also indicate that enhanced exposure/uptake was associated with the furthest downstream site (Site 11) and, to a lesser extent, possibly at the site immediately below Lake Solano (Site 3).

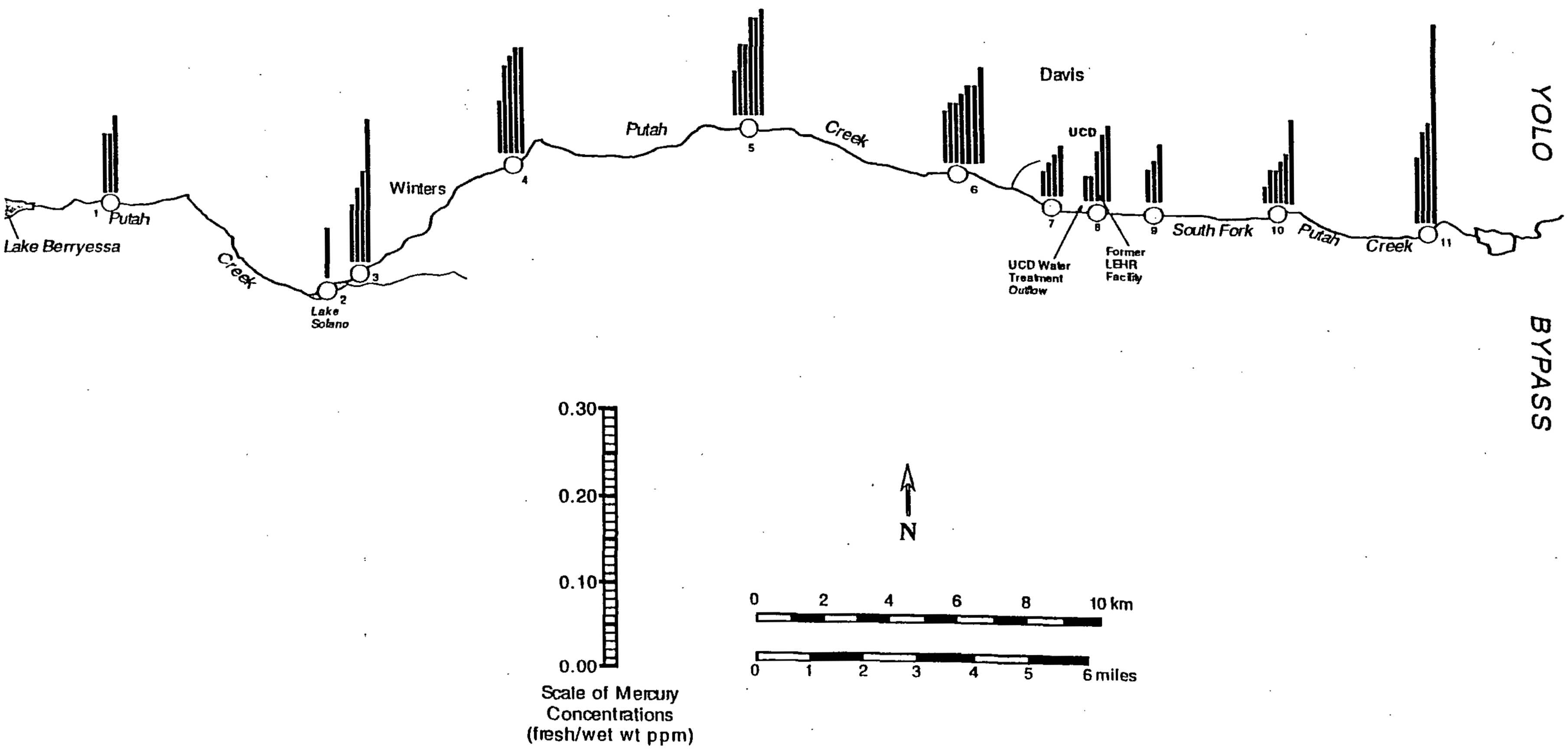
Table 4. Putah Creek Small and Juvenile Fish (+ bullfrog tadpoles) Mercury Data.
(Wet/fresh wt ppm Hg in multi-individual, homogenized, whole-body composites)

Site #	Site Description	Stickleback	Sculpin	Sac Sucker	Hitch	Squawfish	SM Bass	LM Bass	Logperch	BF Tadpole	Bluegill	Mosquitofish	Silverside	Red Shiner
1	Below Berryessa	0.07	0.07	0.09										
2	In Lake Solano	0.06												
3	Below L. Solano		0.09	0.07	0.11	0.17								
4	Below Winters			0.06	0.12		0.12	0.11	0.10					
5	At Russell Ranch					0.11		0.08	0.12	0.05	0.11	0.08		
6	At Pedrick Rd					0.11		0.09	0.08	0.06	0.09	0.07	0.07	
7	0.5 mi above UCD									0.04	0.05	0.03	0.06	
8	At LEHR/UCD								0.08		0.06	0.03	0.09	0.03
9	0.7 mi blw LEHR										0.05		0.07	0.03
10	At Mace Blvd								0.06	0.04	0.05	0.04	0.10	0.02
11	At Rd 106A										0.11	0.23	0.12	0.08

Stickleback: Three-spined Stickleback, *Gasterosteus aculeatus*
Sculpin: Riffle Sculpin, *Cottus gulosus*
Sac Sucker: Sacramento Sucker, *Catostomus occidentalis*, (young-of-year)
Hitch: Hitch, *Lavinia exilicauda*, (young-of-year)
Squawfish: Sacramento Squawfish, *Ptychocheilus grandis*, (young-of-year)
SM Bass: Smallmouth Bass, *Micropterus dolomieui*, (young-of-year)
LM Bass: Largemouth Bass, *Micropterus salmoides*, (young-of-year)
Logperch: Bigscale Logperch, *Percina macrolepida*
BF Tadpole: Bullfrog Tadpoles, *Rana catesbeiana*
Bluegill: Bluegill Sunfish, *Lepomis macrochirus*, (young-of-year)
Mosquitofish: Mosquitofish, *Gambusia affinis*
Silverside: Mississippi Siverside, *Menidia audens*
Red Shiner: Red Shiner, *Notropis lutrensis*

Figure 5. Lower Putah Creek Juvenile and Small Fish Composite Mercury

(each bar represents data for an individual species at each site)
(multi-individual, whole fish composites; data in fresh/wet weight ppm Hg)



3.3 Aquatic Insects

Aquatic insect samples were taken to supplement the adult fish and small/juvenile fish studies. Native in-stream aquatic insects have proven to be excellent monitors of mercury bioavailability in California streams and rivers (Slotton *et al.* 1995a, 1996, 1997a,b,c). These organisms are ideal indicators of highly localized conditions, as compared to adult fish which can and often do migrate extensively. The benthic insect species we collected in this work typically remain within a very limited area throughout their lives. They thus function as relatively static biological probes of the fraction of mercury in the system that is bioavailable. As the organisms sampled are typically a year or less in age, they also integrate mercury availability conditions specific to the year collected. Mercury data for the Putah Creek aquatic insect samples are presented in Table 5 and Figure 6. It is important to note that the aquatic insect data are given on a dry weight basis and are not directly comparable to the fresh/wet weight concentration units utilized for the other sample types. Multi-individual composites of each collected species were dried and powdered for uniformity. This was also done in order to bring the low mercury levels of these samples into a range well above detection (drying concentrates the samples 5-10 fold). The primary purpose of the insect collections was to provide an additional measure for inter-site comparisons of relative mercury exposure/uptake.

As found for both the adult and small/juvenile fishes, different portions of the creek supported different assemblages of macro-invertebrates. None were present at all stations and most were found in sufficient numbers for analysis at fewer than 50% of the stations. Additionally, typical riffle and debris habitats, where benthic aquatic insects aggregate and are most readily available for collection, were not present throughout the entire study region. In the downstream portions of the creek, adjacent to and downstream of the University, riffle habitat was essentially absent. Thus, only three samples of readily comparable organisms were available from the area downstream of the University. However, the aquatic insect data provide some useful information.

The data are arranged by trophic level of the organisms. The herbivore group was represented only by a very small species of Baetid mayfly, which was present at five of the sites in numbers sufficient for analysis. Mercury levels were uniformly very low, from below detection (<0.01 ppm) to 0.02 ppm in all of the samples. No trend was apparent. The sample taken from Site 11, six miles downstream of UC Davis, had mercury below 0.01 ppm.

Drift feeding omnivores included a sample of Simuliid blackfly larvae at Site 1 and Hydropsychid caddisfly larvae at seven of the sites. The blackfly sample, taken 1-2 miles below the Lake Berryessa outflow (Site 1), was relatively elevated at 0.20 ppm. However, no comparable samples were available from downstream sites. In contrast, Hydropsychid caddisflies were the most consistently available of all the aquatic insect samples, and this data set provides the best relative information among the insects for spatial variation in mercury exposure/uptake along the creek. Mercury was quite similar among all the caddisfly samples, ranging between 0.04 and 0.12 ppm. Highest concentrations were found at Sites 1, 3, and 5, located in the upper and middle sections of the creek. A caddisfly sample was obtained from three miles downstream of UC Davis near Mace Rd (Site 10). This sample, at 0.08 ppm, indicated no relative elevation. 0.08 ppm Hg was the mean level in caddisfly larvae from all seven sites where they were sampled.

"First order" (small prey) predators, typically represented by stonefly nymphs in headwater reaches, were not consistently available for flow-based kick-screen collection within the study region, primarily due to habitat changes throughout the stretch. Seven adequate composite samples were taken among five of the sites. These came from four different families: Perlodid stonefly nymphs (Site 1), Coenagrionid (Site 7) and Calopterygid (Sites 4, 5, and 7) damselfly nymphs, and Sialid alderflies which are small megalopterans (Sites 3 and 5). Damselfly mercury ranged from 0.04 to 0.09 ppm, with the highest levels, identical in both species at 0.09 ppm, at Site 7, upstream of the UC Davis water treatment outfall and the LEHR site. Small Perlodid stoneflies were collected only at the most upstream site (Site 1). These were apparently somewhat elevated at 0.16 ppm, though comparable samples were not present downstream. Sialid alderfly nymphs contained 0.08 ppm Hg at Site 3 below Lake Solano and exhibited an anomalously elevated level (0.27 ppm) at Russell Ranch (Site 5).

"Second order" (larger prey) predators, typically represented by hellgrammites in headwater reaches, consisted in this study of Tipulid cranefly larvae from Site 3 and Libellulid dragonfly nymphs at Sites 5, 6, 7, and 10. The Site 3 cranefly sample had 0.15 ppm mercury. Libellulid dragonfly nymphs were present both above the university inputs (Sites 5, 6, and 7) and three miles downstream at Site 10. Highest dragonfly mercury was found at Russell Ranch (Site 5, 0.15 ppm). Sites 6 and 7 had relatively lower levels of 0.07 and 0.09 ppm, and Site 10 below the University had the lowest level, at 0.04 ppm.

Similar, comparative data exist for aquatic insect mercury bioindicator organisms throughout California from our various projects, already cited. The levels summarized in Table 5 are not notably elevated for this region of California. Dramatically higher concentrations are typical closer to mining-related sources of mercury, both in the Coast Range and in the Sierra Nevada. As indicators, though, of relative levels of exposure or biological uptake between sites, these Putah Creek collections indicate no elevation in relation to potential University inputs.

Table 5. Putah Creek Aquatic Insect Mercury Data.
(DRY ppm Hg in multi-individual, homogenized, whole-body composites)

		HERBIVORES	DRIFT COLLECTORS		FIRST ORDER PREDATORS				SECOND ORDER PREDATORS	
Site #	Site Description	Baetidae	Simuliidae	Hydropsychidae	Small Perlodidae	Coenagrionidae	Calopterygidae	Sialidae	Libellulidae	Tipulidae
1	Below L. Berryessa		0.20	0.11	0.16					
3	Just Below L. Solano	0.02		0.12				0.08		0.15
4	Below Winters			0.06			0.04			
5	At Russell Ranch	BD*		0.11			0.06	0.27	0.15	
6	At Pedrick Rd	0.01		0.07					0.07	
7	0.5 mi above UCD	0.01		0.04		0.09	0.09		0.09	
10	At Mace Blvd			0.08					0.04	
11	At Rd 106A	BD*								

* BD = Below Detection

Baetidae: Mayfly nymphs (tiny species)

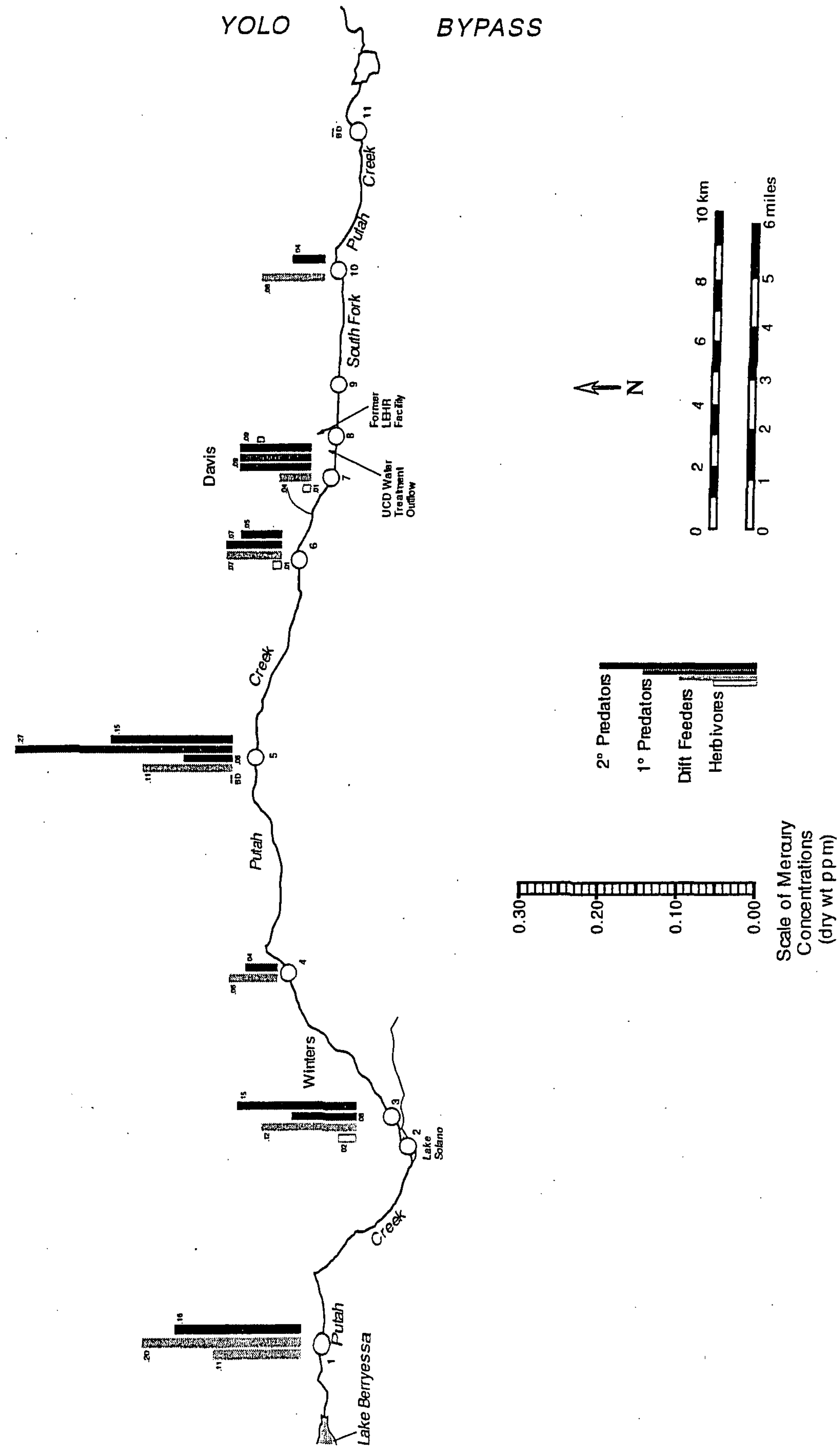
Simuliidae: Blackfly larvae
Hydropsychidae: Net spinning caddisfly larvae

Small Perlodidae: Stonefly nymphs (juveniles)
Coenagrionidae: Damselfly nymphs
Calopterygidae: Damselfly nymphs
Sialidae: Alderflyfly nymphs (small Megaloptera)

Libellulidae: Dragonfly nymphs
Tipulidae: Cranefly larvae

Figure 6. Lower Putah Creek Aquatic Insect Mercury

(each bar represents data for an individual species at each site, keyed to family)
(multi-individual, whole body composites; data in dry weight ppm Hg)



3.4 Crayfish

This Putah Creek mercury study was extended into the fall of 1998 in order to supplement the existing adult fish, small fish, and aquatic insect data bases with an intensive study of Putah Creek crayfish. Crayfish were of particular interest for a variety of reasons: (1) they exhibit strong site fidelity while providing mercury uptake and accumulation levels similar to adult fishes and (2) they represent important consumption endpoints for both humans and wildlife. Approval for this addition to the project was given only after the seasonal behavioral cycles of the crayfish made them relatively difficult to obtain (in late October 1998). However, it was possible, with many repeated days of sampling at each site, to obtain adequate, representative samples of adult crayfish throughout the study region between the Lake Berryessa outflow and the Yolo Bypass.

Crayfish tail muscle mercury data are presented in a variety of formats. Individual data appear in Table 6 and are plotted, by sampling site, in Figures 7 (a-j). Reduced crayfish data, including means of multiple individual analyses and 95% confidence intervals of the means, are shown in Tables 7a (arranged by sampling site) and 7b (arranged by species). Mean data are plotted against sampling location in Figure 8 and on a map of the region in Figure 9.

Adult crayfish within similar size ranges were collected from ten sites encompassing the entire study region. Three different species of crayfish were resident, all with similar body type and benthic feeding behavior. All were captured in identically baited traps. None were present at all of the sites, though two of the species were taken from sites upstream, adjacent to, and downstream of the university. Once again, the changing character of the creek habitat throughout the study region resulted in a partitioning between the resident species. The native species *Pacifasticus leniusculus* (signal crayfish) was the only species present at Sites 1-4 (Berryessa outflow to Highway 505 downstream of Winters). The introduced, red-colored Louisiana swamp crayfish (*Procambarus clarkii*) occurred at Sites 5-11 (Russell Ranch to the Yolo Bypass), dominating in the lower reaches of the creek. A second introduced species, *Orconectes virilis*, co-occurred with *Procambarus* and was most prevalent in the middle reaches of the creek (Sites 5-9). In Figure 10, the body proportion relationships of the three species are compared, using carapace length and body weight. *Pacifasticus* and *Orconectes* follow identical trends, while the slimmer *Procambarus* demonstrate somewhat lower weights relative to carapace length.

Native signal crayfish (*Pacifasticus*) exhibited relatively high and variable mercury levels at the most upstream site (Site 1, Berryessa outflow: mean = 0.34 ppm). Concentrations were less variable in the three downstream sites and exhibited steadily declining mean mercury levels (Site 2, Lake Solano: 0.23 ppm; Site 3: 0.20 ppm, Site 4, Hwy 505: 0.16 ppm). This was in spite of the fact that the mean sizes of the sampled individuals increased moving downstream. Mercury levels in individual *Pacifasticus* varied between 0.08 and 0.61 ppm. Signal crayfish were not present in the creek at Sites 5-11; thus, inter-site comparisons using this species can only be made among upstream Sites 1-4. We hypothesize that the elevated, variable concentrations from upstream Site 1 may indicate consumption by some of the *Pacifasticus* of highly mercury-elevated Sacramento suckers which make upstream spawning runs out of Lake Solano.

Louisiana swamp crayfish (*Procambarus*) contained mercury in a range considerably lower than that found upstream in samples of *Pacifasticus*. Individual *Procambarus* mercury ranged between 0.05 and 0.28 ppm, with site means ranging between 0.10 and 0.19 ppm. Within this relatively narrow range, highest levels were seen at Site 9 (0.7 miles downstream of UC Davis, 0.19 ppm), Site 10 (3 miles downstream of UC Davis, 0.16 ppm), and Site 6 (upstream of the University at Pedrick Rd, 0.15 ppm). The individuals taken at Sites 9 and 10 were, on average, considerably larger than *Procambarus* taken at other sites. Lowest mean levels were found at Site 5 (Russell Ranch, 0.10 ppm), Site 8 (directly adjacent to the LEHR site and downstream of the UC Davis wastewater treatment outfall, 0.12 ppm), and at the most downstream site (Site 11 at Rd 106A, 0.13 ppm). These data indicate no significant locational trend in mercury exposure/uptake between Sites 5 and 11.

The third species, *Orconectes*, was notable in containing considerably higher mercury concentrations than *Procambarus* at the sites where both species occurred. This was a consistent phenomenon, with *Orconectes* mercury typically 2-3 times greater than the levels seen in co-occurring *Procambarus*. The probable explanation is that these species, while both being bottom feeding omnivores with very similar body types and physiology, must to some extent partition the food resources at the sites where they overlap. The data suggest that *Orconectes* consume more high trophic level (animal) food on average, while the *Procambarus* diet may contain a substantial fraction of low trophic level (plant-based) food items. Mercury in individual *Orconectes* ranged between 0.18 and 0.52 ppm. Mean levels were highest and similar at Site 5 (Russell Ranch, 0.35 ppm), Site 6 (upstream of the University at Pedrick Rd, 0.32 ppm), and Site 9 (0.7 miles downstream of UC Davis, 0.33 ppm). Lowest *Orconectes* mercury was sampled at Site 8 (adjacent to the LEHR site and downstream of the UC Davis water treatment outfall, 0.22 ppm), and at the most downstream site (Site 11 at Rd 106A, 0.27 ppm). Similar to the *Procambarus* data, these relative concentrations indicate no significant locational trend in mercury exposure/uptake between Sites 5 and 11.

Table 6. Putah Creek Individual Crayfish Tail Muscle Mercury Data.

Site #	Site Description	Crayfish Species	Weight (g)	Carapace Length (mm)	Muscle Hg (wet wt ppm)
1	Below L. Berryessa	*Pacifasticus*	31	10.9	**0.11**
1	Below L. Berryessa	*Pacifasticus*	34	14.4	**0.45**
1	Below L. Berryessa	*Pacifasticus*	39	18.2	**0.44**
1	Below L. Berryessa	*Pacifasticus*	45	31.7	**0.14**
1	Below L. Berryessa	*Pacifasticus*	46	36.8	**0.35**
1	Below L. Berryessa	*Pacifasticus*	48	26.2	**0.61**
1	Below L. Berryessa	*Pacifasticus*	45	38.3	**0.33**
1	Below L. Berryessa	*Pacifasticus*	47	37.0	**0.24**
1	Below L. Berryessa	*Pacifasticus*	55	70.4	**0.51**
1	Below L. Berryessa	*Pacifasticus*	60	97.7	**0.22**
2	In Lake Solano	*Pacifasticus*	36	15.7	**0.18**
2	In Lake Solano	*Pacifasticus*	37	19.5	**0.23**
2	In Lake Solano	*Pacifasticus*	47	38.2	**0.20**
2	In Lake Solano	*Pacifasticus*	49	48.2	**0.26**
2	In Lake Solano	*Pacifasticus*	53	53.4	**0.27**
3	Just Below L. Solano	*Pacifasticus*	37	17.5	**0.12**
3	Just Below L. Solano	*Pacifasticus*	47	40.4	**0.16**
3	Just Below L. Solano	*Pacifasticus*	50	42.5	**0.13**
3	Just Below L. Solano	*Pacifasticus*	51	47.1	**0.16**
3	Just Below L. Solano	*Pacifasticus*	51	38.6	**0.18**
3	Just Below L. Solano	*Pacifasticus*	53	54.9	**0.29**
3	Just Below L. Solano	*Pacifasticus*	53	57.5	**0.23**
3	Just Below L. Solano	*Pacifasticus*	60	71.5	**0.34**
4	Below Winters	*Pacifasticus*	48	36.6	**0.11**
4	Below Winters	*Pacifasticus*	50	36.7	**0.10**
4	Below Winters	*Pacifasticus*	51	49.3	**0.13**
4	Below Winters	*Pacifasticus*	54	56.6	**0.08**
4	Below Winters	*Pacifasticus*	56	57.6	**0.28**
4	Below Winters	*Pacifasticus*	64	95.7	**0.21**
4	Below Winters	*Pacifasticus*	66	106.2	**0.17**
5	At Russell Ranch	*Procambarus*	30	5.0	**0.06**
5	At Russell Ranch	*Procambarus*	43	20.6	**0.10**
5	At Russell Ranch	*Procambarus*	51	33.4	**0.10**
5	At Russell Ranch	*Procambarus*	52	28.3	**0.14**
5	At Russell Ranch	*Orconectes*	39	20.5	**0.22**
5	At Russell Ranch	*Orconectes*	39	21.5	**0.32**
5	At Russell Ranch	*Orconectes*	42	25.2	**0.52**
5	At Russell Ranch	*Orconectes*	43	26.0	**0.22**
5	At Russell Ranch	*Orconectes*	44	28.0	**0.29**
5	At Russell Ranch	*Orconectes*	46	33.5	**0.49**
5	At Russell Ranch	*Orconectes*	45	35.1	**0.41**

(continued)

Table 6. Putah Creek Individual Crayfish Tail Muscle Mercury Data. *(continued)*

Site #	Site Description	Crayfish Species	Weight (g)	Carapace Length (mm)	Muscle Hg (wet wt ppm)
6	At Pedrick Rd	*Procambarus*	31	8.9	**0.05**
6	At Pedrick Rd	*Procambarus*	37	11.4	**0.06**
6	At Pedrick Rd	*Procambarus*	45	20.0	**0.12**
6	At Pedrick Rd	*Procambarus*	43	17.0	**0.13**
6	At Pedrick Rd	*Procambarus*	45	18.9	**0.28**
6	At Pedrick Rd	*Procambarus*	45	25.6	**0.12**
6	At Pedrick Rd	*Procambarus*	49	26.2	**0.22**
6	At Pedrick Rd	*Procambarus*	50	25.1	**0.17**
6	At Pedrick Rd	*Procambarus*	53	43.2	**0.17**
6	At Pedrick Rd	*Orconectes*	31	8.8	**0.18**
6	At Pedrick Rd	*Orconectes*	43	26.0	**0.45**
8	At LEHR/UCD	*Procambarus*	41	20.2	**0.10**
8	At LEHR/UCD	*Procambarus*	43	27.2	**0.10**
8	At LEHR/UCD	*Procambarus*	45	22.6	**0.10**
8	At LEHR/UCD	*Procambarus*	48	32.1	**0.14**
8	At LEHR/UCD	*Procambarus*	54	35.4	**0.10**
8	At LEHR/UCD	*Procambarus*	48	28.5	**0.18**
8	At LEHR/UCD	*Procambarus*	52	31.7	**0.14**
8	At LEHR/UCD	*Orconectes*	47	39.4	**0.26**
8	At LEHR/UCD	*Orconectes*	48	35.7	**0.19**
8	At LEHR/UCD	*Orconectes*	47	36.7	**0.22**
9	0.7 mi blw LEHR/UCD	*Procambarus*	47	26.7	**0.20**
9	0.7 mi blw LEHR/UCD	*Procambarus*	48	36.9	**0.15**
9	0.7 mi blw LEHR/UCD	*Procambarus*	50	39.5	**0.20**
9	0.7 mi blw LEHR/UCD	*Procambarus*	55	36.5	**0.19**
9	0.7 mi blw LEHR/UCD	*Orconectes*	48	39.3	**0.31**
9	0.7 mi blw LEHR/UCD	*Orconectes*	48	40.2	**0.36**
10	At Mace Blvd	*Procambarus*	46	24.8	**0.14**
10	At Mace Blvd	*Procambarus*	51	39.1	**0.14**
10	At Mace Blvd	*Procambarus*	48	29.8	**0.19**
10	At Mace Blvd	*Procambarus*	49	36.2	**0.17**
10	At Mace Blvd	*Procambarus*	52	40.7	**0.17**
11	At Rd 106A	*Procambarus*	33	9.1	**0.16**
11	At Rd 106A	*Procambarus*	35	10.8	**0.07**
11	At Rd 106A	*Procambarus*	40	14.5	**0.10**
11	At Rd 106A	*Procambarus*	47	25.3	**0.12**
11	At Rd 106A	*Procambarus*	49	27.5	**0.18**
11	At Rd 106A	*Procambarus*	56	43.2	**0.12**
11	At Rd 106A	*Orconectes*	42	24.7	**0.27**

Table 7. Putah Creek Crayfish Tail Muscle Mercury: Reduced Data.
(A) Sorted by Sampling Location

Site #	Site Description	Crayfish Species	n	Weight (g)	Length (mm)	Muscle Hg (wet wt ppm)	95% Confid. Int. of mean Hg (wet wt ppm)
				---------- (mean values ± std. deviation) ----------			
BY SITE							
1	Below L. Berryessa	*Pacifasticus*	10	45.0 ± 8.8	38.2 ± 26.8	**0.341** ± 0.162	0.225 - 0.457
2	In Lake Solano	*Pacifasticus*	5	44.4 ± 7.5	35.0 ± 16.9	**0.229** ± 0.038	0.182 - 0.276
3	Below L. Solano	*Pacifasticus*	8	50.3 ± 6.5	46.3 ± 15.9	**0.201** ± 0.076	0.137 - 0.265
4	Below Winters	*Pacifasticus*	7	55.6 ± 7.0	62.7 ± 27.6	**0.156** ± 0.070	0.092 - 0.220
5	At Russell Ranch	*Procambarus*	4	44.0 ± 10.2	21.8 ± 12.4	**0.101** ± 0.029	0.055 - 0.147
5	At Russell Ranch	*Orconectes*	7	42.6 ± 2.8	27.1 ± 5.6	**0.353** ± 0.123	0.240 - 0.467
6	At Pedrick Rd	*Procambarus*	9	44.2 ± 6.7	21.8 ± 10.1	**0.149** ± 0.073	0.093 - 0.205
6	At Pedrick Rd	*Orconectes*	2	37.0 ± 8.5	17.4 ± 12.2	**0.318** ± 0.191	(0.318)
8	At LEHR/UCD	*Procambarus*	7	47.3 ± 4.7	28.2 ± 5.4	**0.124** ± 0.032	0.094 - 0.153
8	At LEHR/UCD	*Orconectes*	3	47.3 ± 0.6	37.3 ± 1.9	**0.222** ± 0.037	0.130 - 0.313
9	0.7 mi blw LEHR/UCD	*Procambarus*	4	50.0 ± 3.6	34.9 ± 5.6	**0.186** ± 0.023	0.150 - 0.222
9	0.7 mi blw LEHR/UCD	*Orconectes*	2	48.0 ± 0.0	39.8 ± 0.6	**0.334** ± 0.038	(0.334)
10	At Mace Blvd	*Procambarus*	5	49.2 ± 2.4	34.1 ± 6.7	**0.160** ± 0.023	0.131 - 0.189
11	Below Rd 106A	*Procambarus*	6	43.3 ± 8.9	21.7 ± 12.9	**0.125** ± 0.041	0.082 - 0.168
11	Below Rd 106A	*Orconectes*	1	42.0 -	24.7 -	**0.270** -	(0.270)

(continued)

Table 7. Putah Creek Crayfish Tail Muscle Mercury: Reduced Data. ***(continued)***
(B) Sorted by Species

Site #	Site Description	Crayfish Species	n	Weight (g)	Length (mm)	Muscle Hg (wet wt ppm)	95% Confid. Int. of mean Hg (wet wt ppm)
				---------- *(mean values ± std. deviation)* ----------			
BY SPECIES							
1	Below L. Berryessa	*Pacifasticus*	10	45.0 ± 8.8	38.2 ± 26.8	**0.341** ± 0.162	0.225 - 0.457
2	In Lake Solano	*Pacifasticus*	5	44.4 ± 7.5	35.0 ± 16.9	**0.229** ± 0.038	0.182 - 0.276
3	Below L. Solano	*Pacifasticus*	8	50.3 ± 6.5	46.3 ± 15.9	**0.201** ± 0.076	0.137 - 0.265
4	Below Winters	*Pacifasticus*	7	55.6 ± 7.0	62.7 ± 27.6	**0.156** ± 0.070	0.092 - 0.220
5	At Russell Ranch	*Procambarus*	4	44.0 ± 10.2	21.8 ± 12.4	**0.101** ± 0.029	0.055 - 0.147
6	At Pedrick Rd	*Procambarus*	9	44.2 ± 6.7	21.8 ± 10.1	**0.149** ± 0.073	0.093 - 0.205
8	At LEHR/UCD	*Procambarus*	7	47.3 ± 4.7	28.2 ± 5.4	**0.124** ± 0.032	0.094 - 0.153
9	0.7 mi blw LEHR/UCD	*Procambarus*	4	50.0 ± 3.6	34.9 ± 5.6	**0.186** ± 0.023	0.150 - 0.222
10	At Mace Blvd	*Procambarus*	5	49.2 ± 2.4	34.1 ± 6.7	**0.160** ± 0.023	0.131 - 0.189
11	Below Rd 106A	*Procambarus*	6	43.3 ± 8.9	21.7 ± 12.9	**0.125** ± 0.041	0.082 - 0.168
5	At Russell Ranch	*Orconectes*	7	42.6 ± 2.8	27.1 ± 5.6	**0.353** ± 0.123	0.240 - 0.467
6	At Pedrick Rd	*Orconectes*	2	37.0 ± 8.5	17.4 ± 12.2	**0.318** ± 0.191	(0.318)
8	At LEHR/UCD	*Orconectes*	3	47.3 ± 0.6	37.3 ± 1.9	**0.222** ± 0.037	0.130 - 0.313
9	0.7 mi blw LEHR/UCD	*Orconectes*	2	48.0 ± 0.0	39.8 ± 0.6	**0.334** ± 0.038	(0.334)
11	Below Rd 106A	*Orconectes*	1	42.0 -	24.7 -	**0.270** -	(0.270)

Fig. 7(a) Crayfish
SITE 1: TROUT WATERS JUST BELOW LAKE BERRYESSA

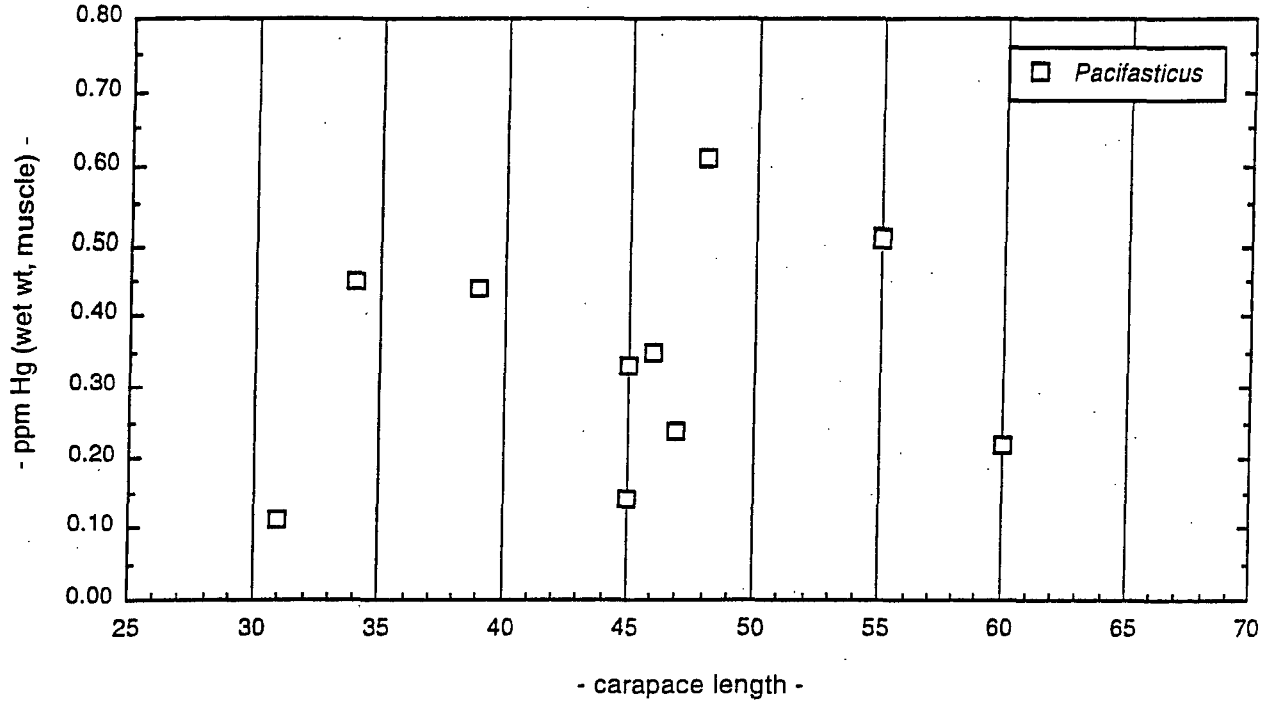


Fig. 7(b) Crayfish
SITE 2: IN LAKE SOLANO

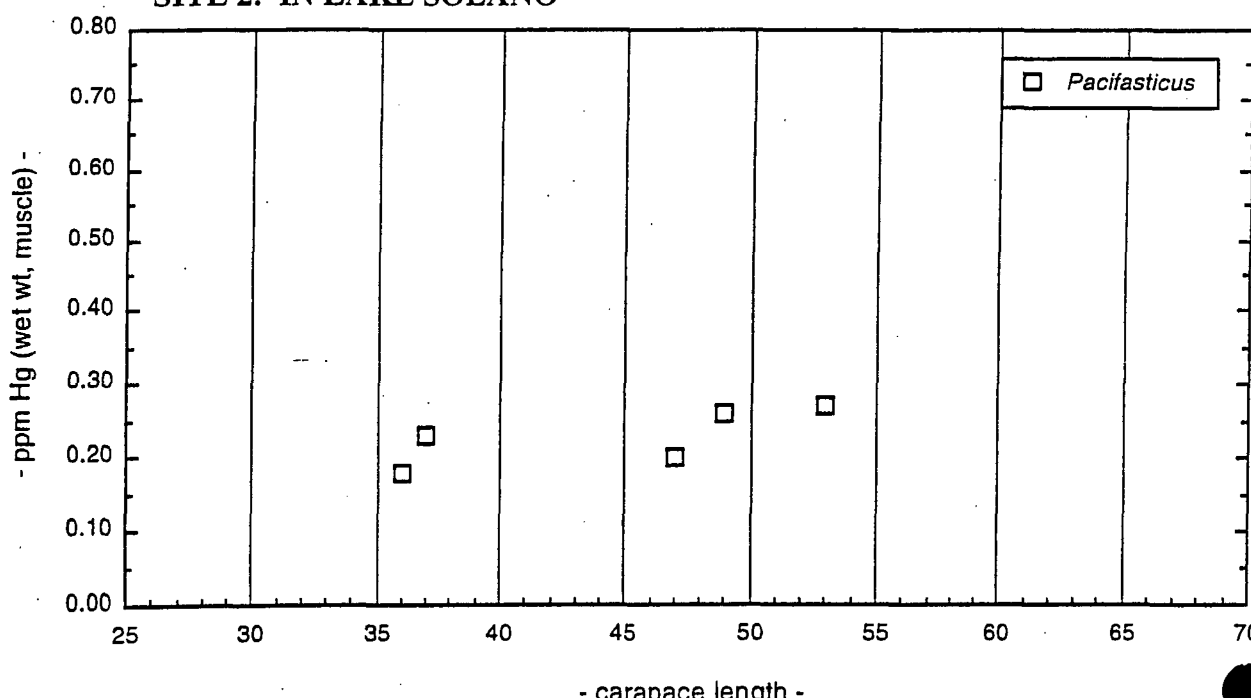


Fig. 7(c) Crayfish
SITE 3: JUST BELOW LAKE SOLANO

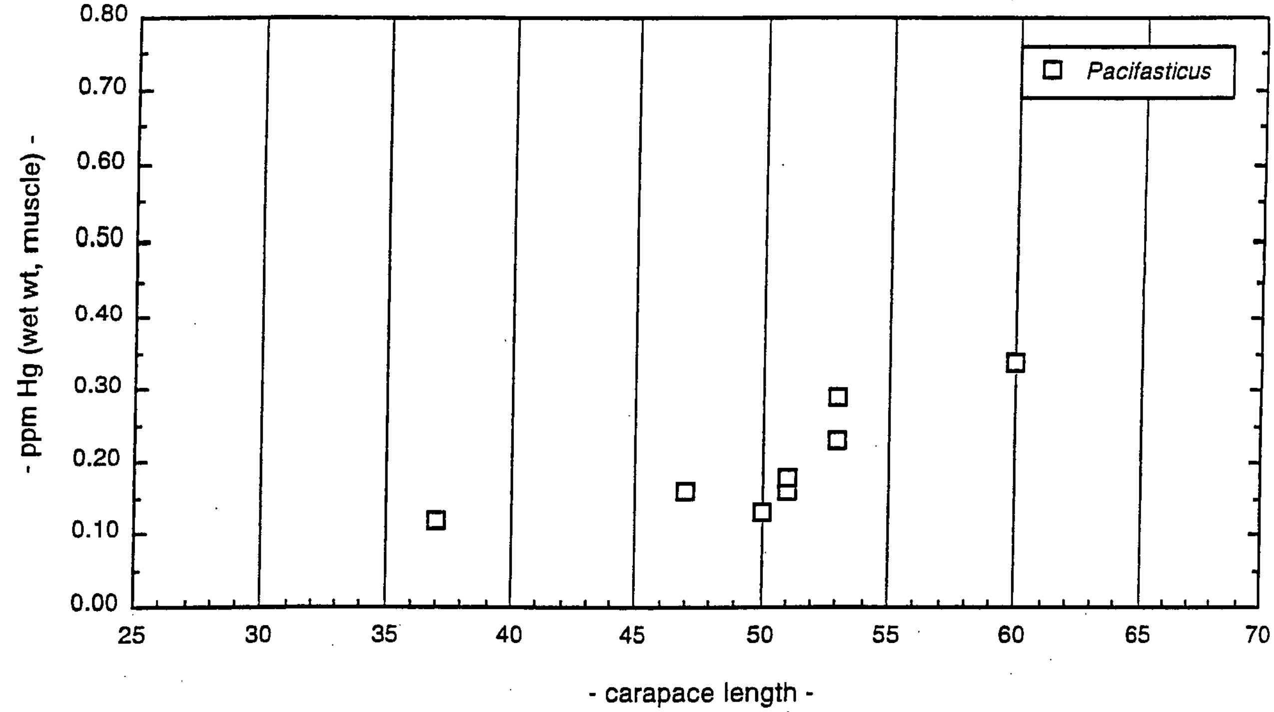


Fig. 7(d) Crayfish
SITE 4: BELOW WINTERS AT HIGHWAY 505

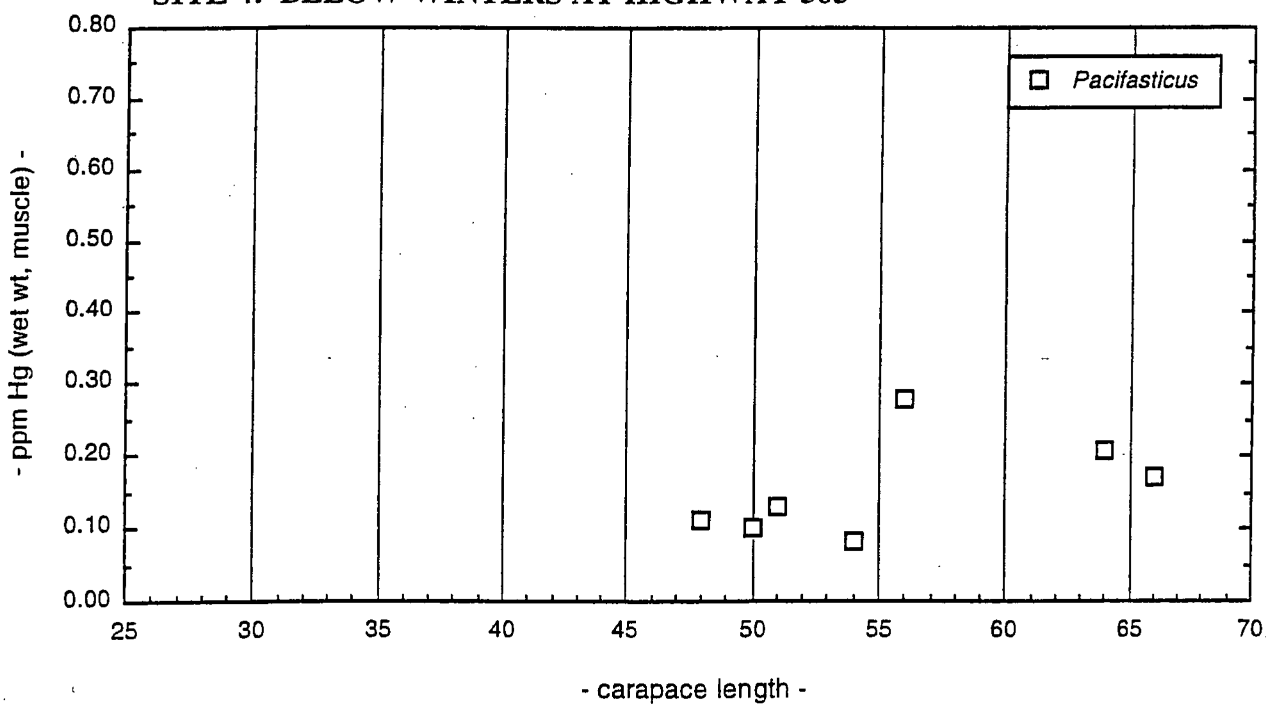


Fig. 7(e) Crayfish
SITE 5: AT RUSSELL RANCH

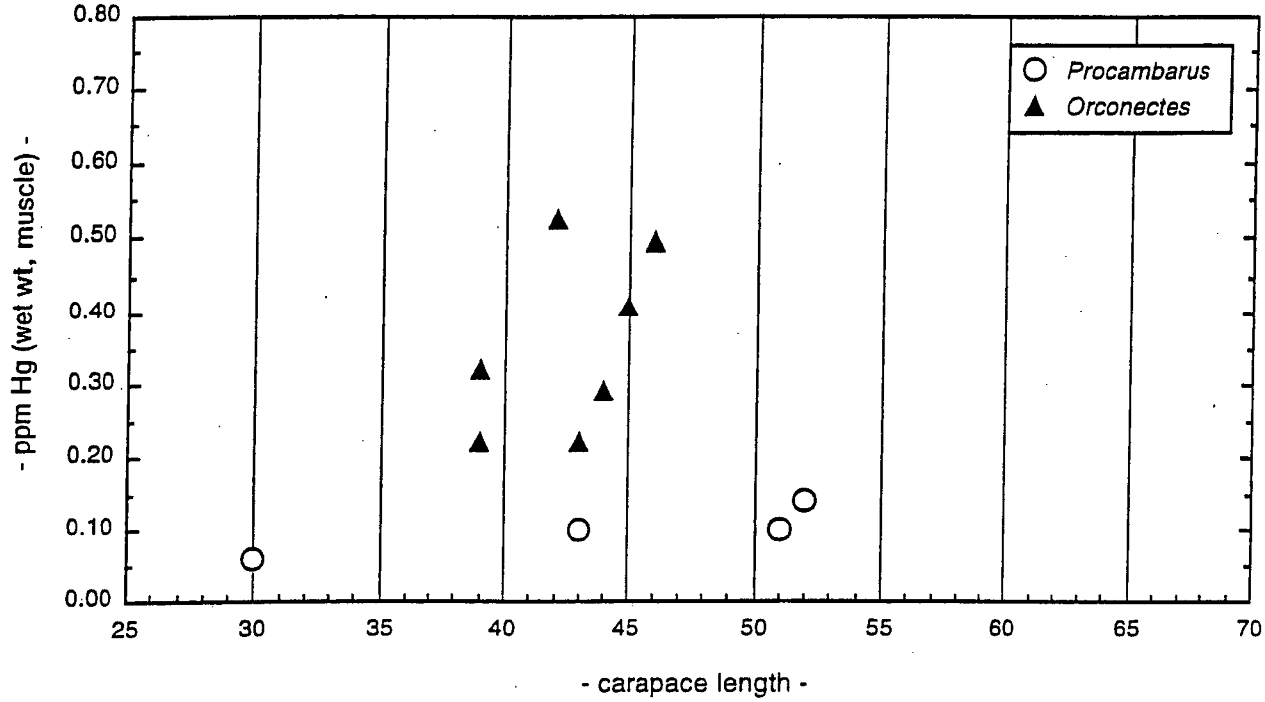


Fig. 7(f) Crayfish
SITE 6: ABOVE UC DAVIS AT PEDRICK ROAD

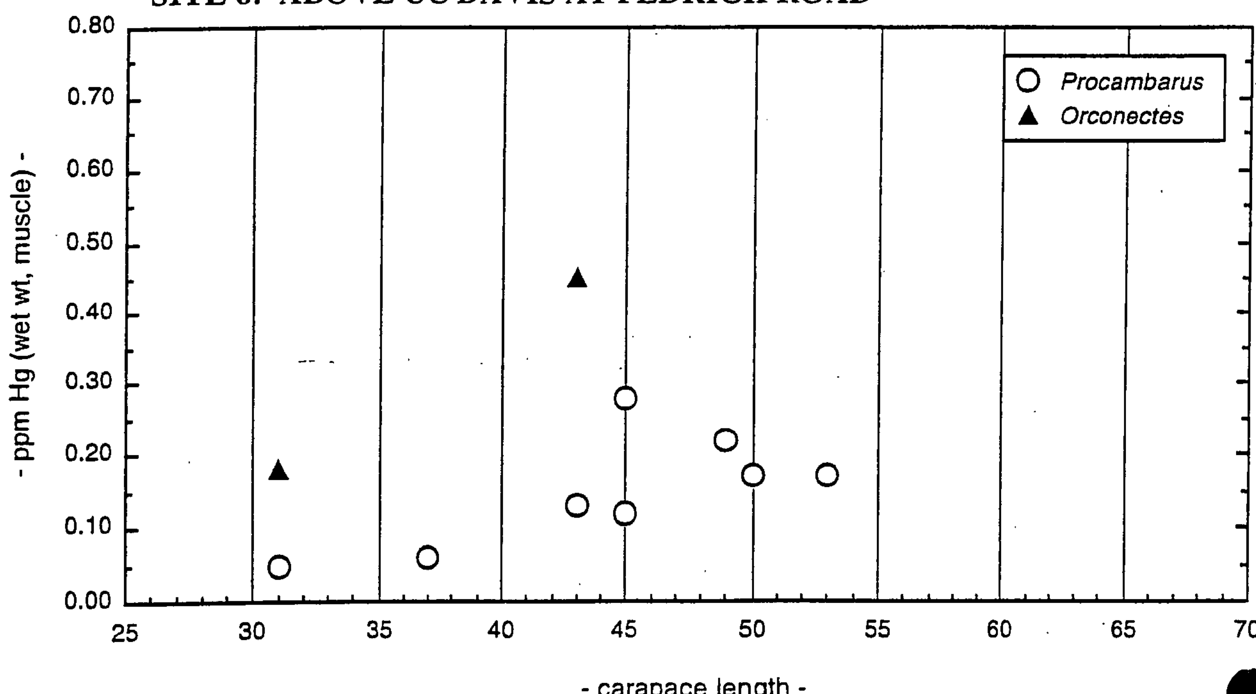


Fig. 7(g) Crayfish
SITE 8: ADJACENT TO LEHR SITE, BELOW OLD DAVIS RD

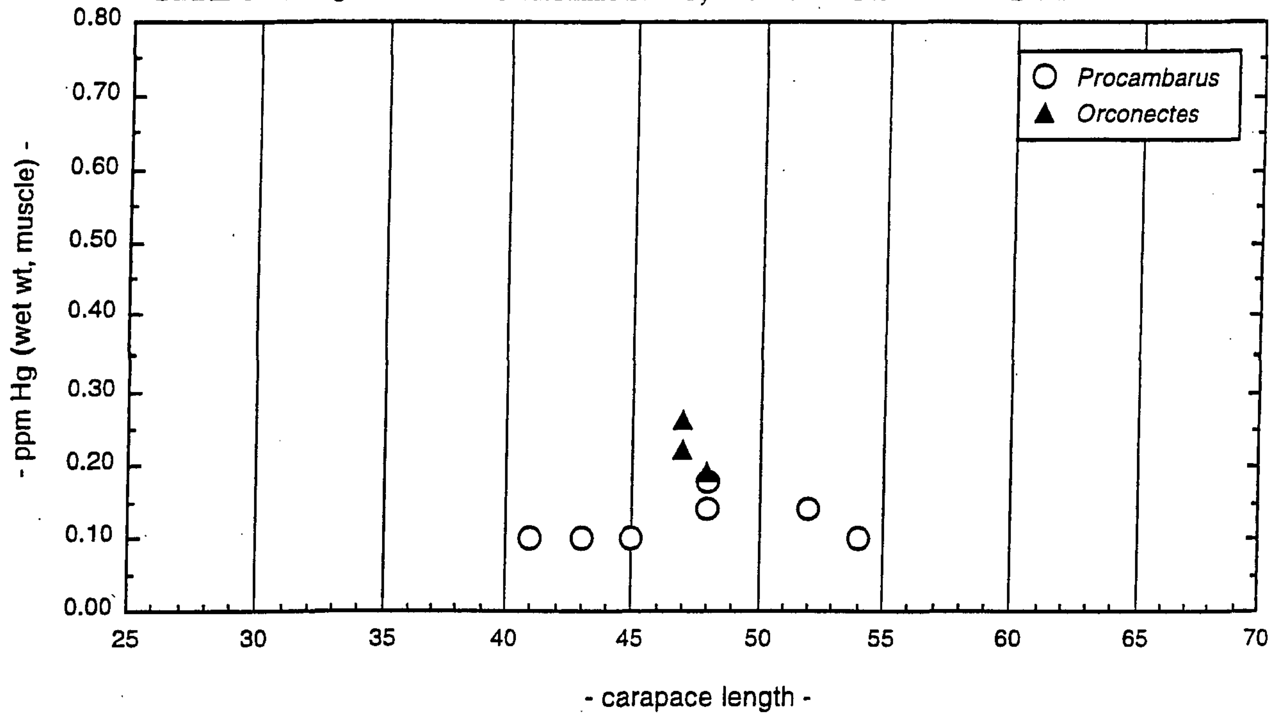


Fig. 7(h) Crayfish
SITE 9: 0.7 MILE DOWNSTREAM OF LEHR SITE

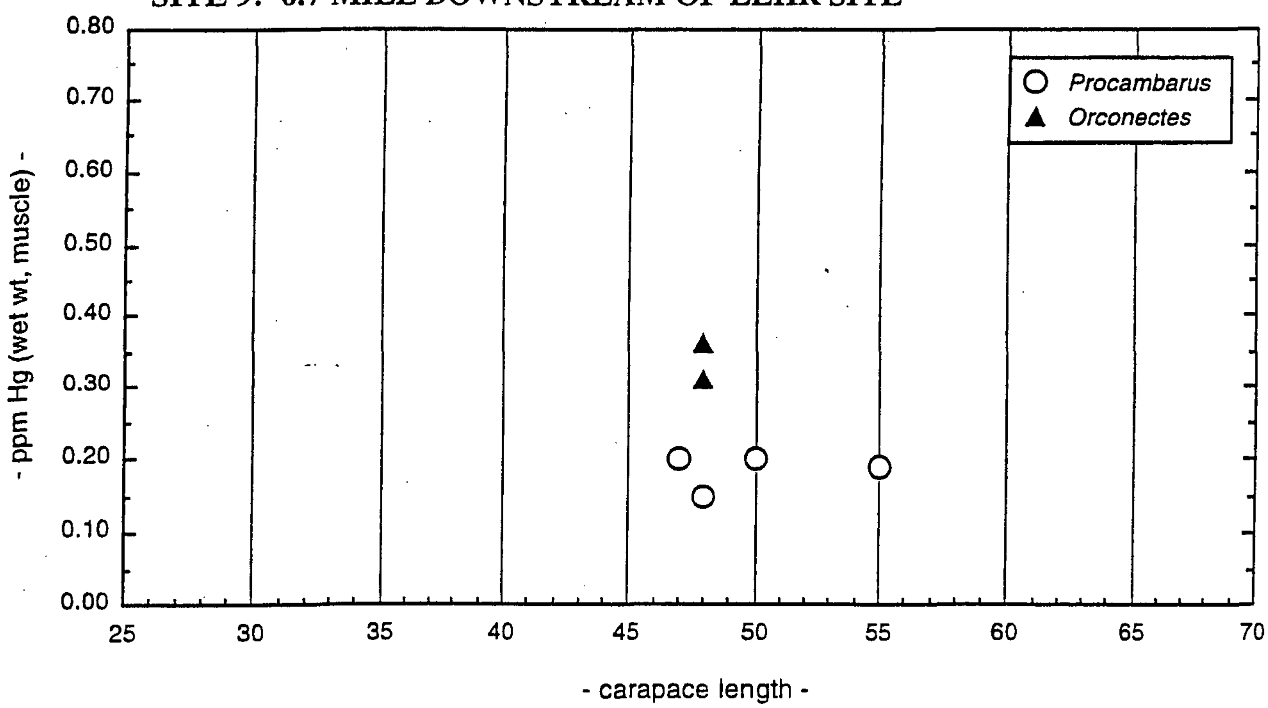


Fig. 7(i) Crayfish
SITE 10: ~3 MILES BELOW UC DAVIS AT MACE RD

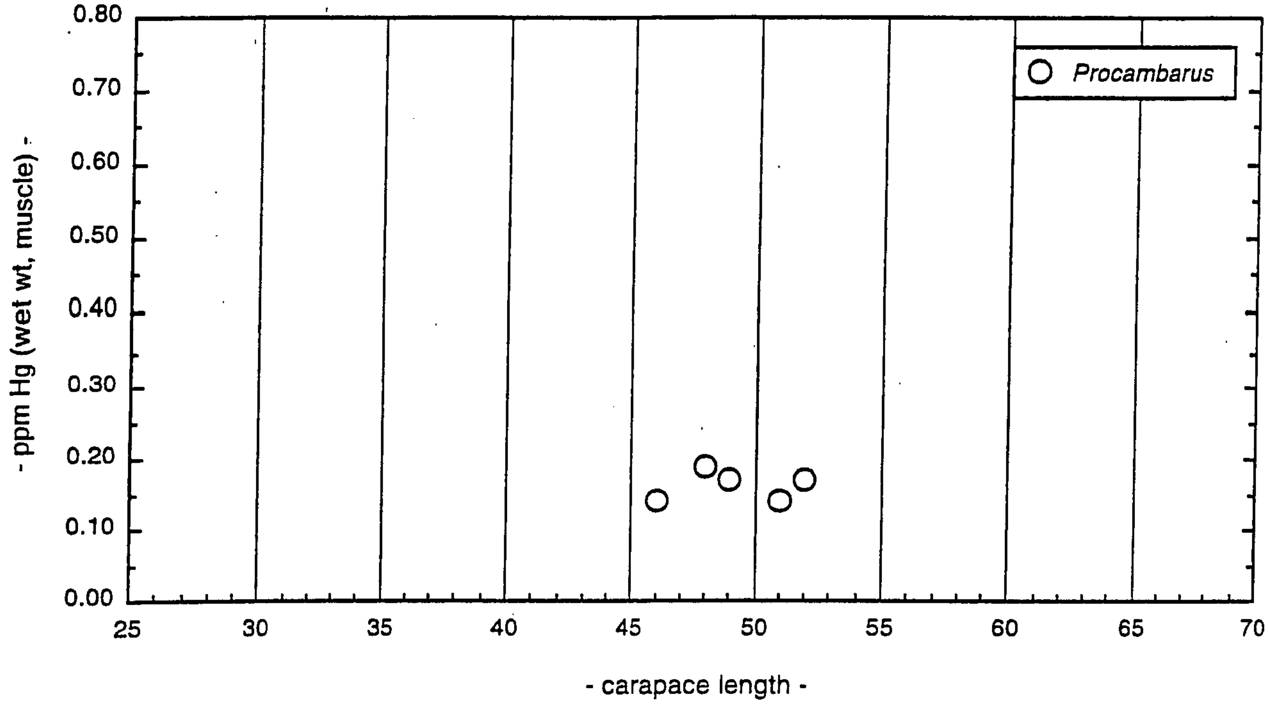


Fig. 7(j) Crayfish
SITE 11: AT AND BELOW ROAD 106A

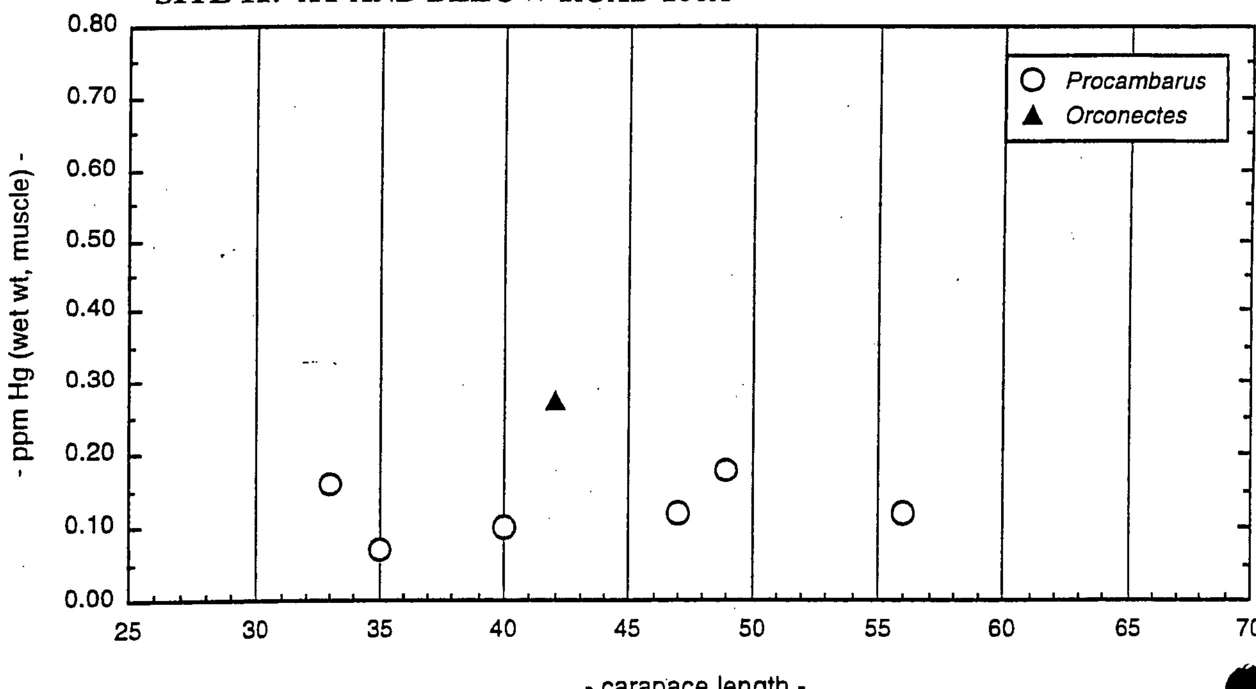


Fig. 8. Putah Creek Reduced (Mean) Crayfish Mercury Data Across the Range of Sampling Sites

(means ± 95% confidence intervals for multiple individual samples for each site/species)
(fresh/wet weight mercury concentrations in tail muscle)

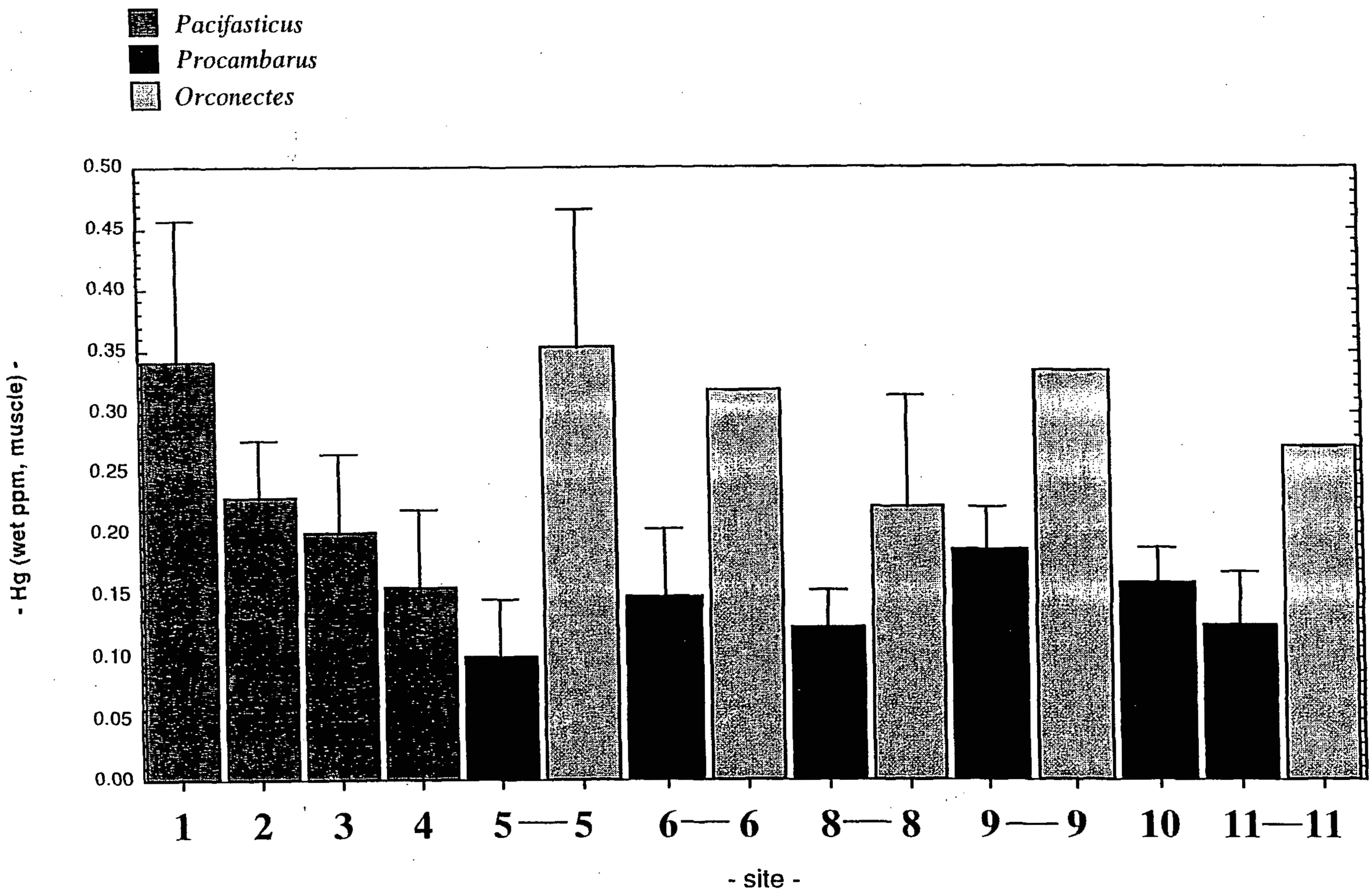


Figure 9. Lower Putah Creek Crayfish Tail Muscle Mercury

(each bar represents mean data for an individual species at each site)
(means of multiple individual samples; data in fresh/wet weight ppm Hg)

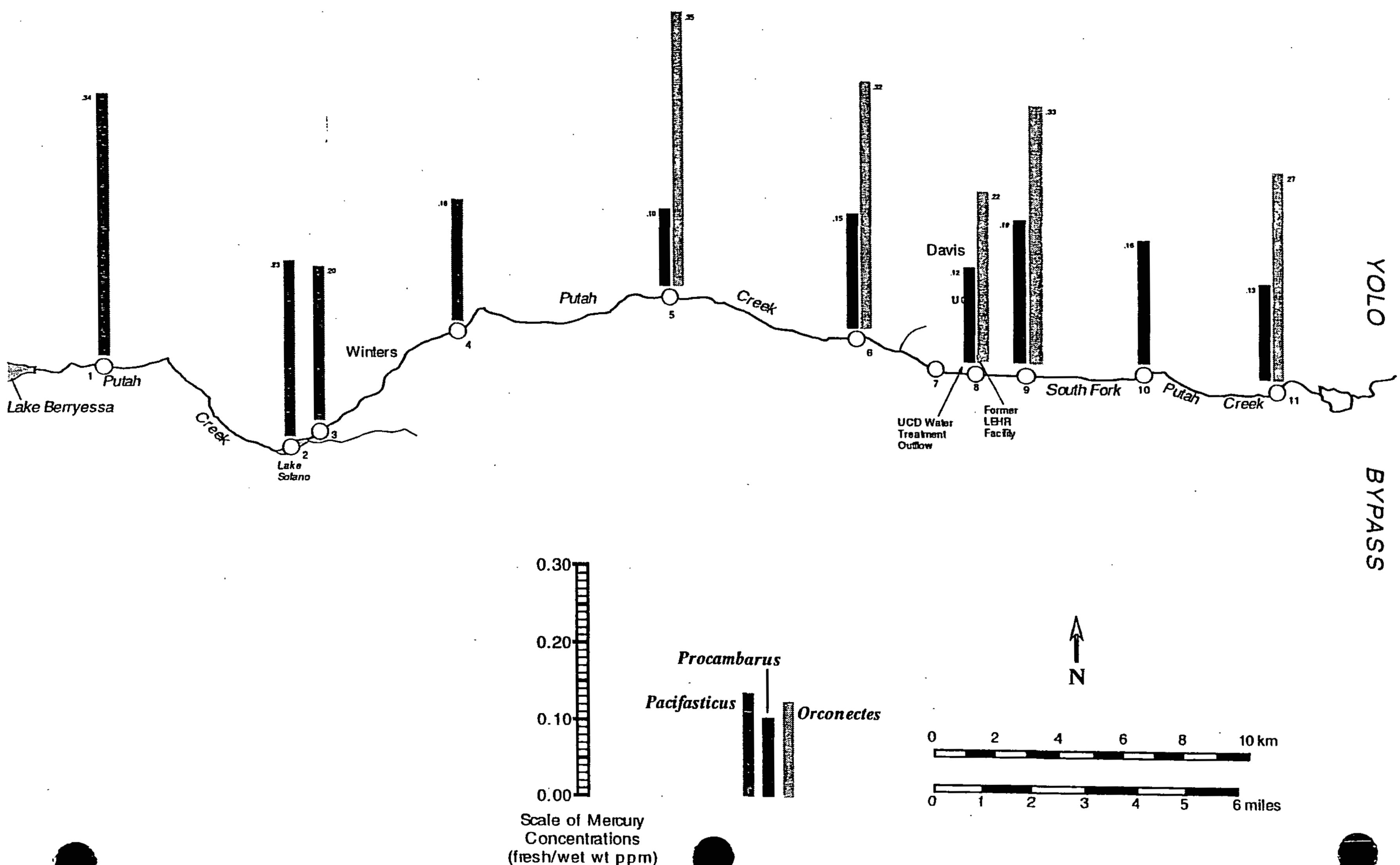
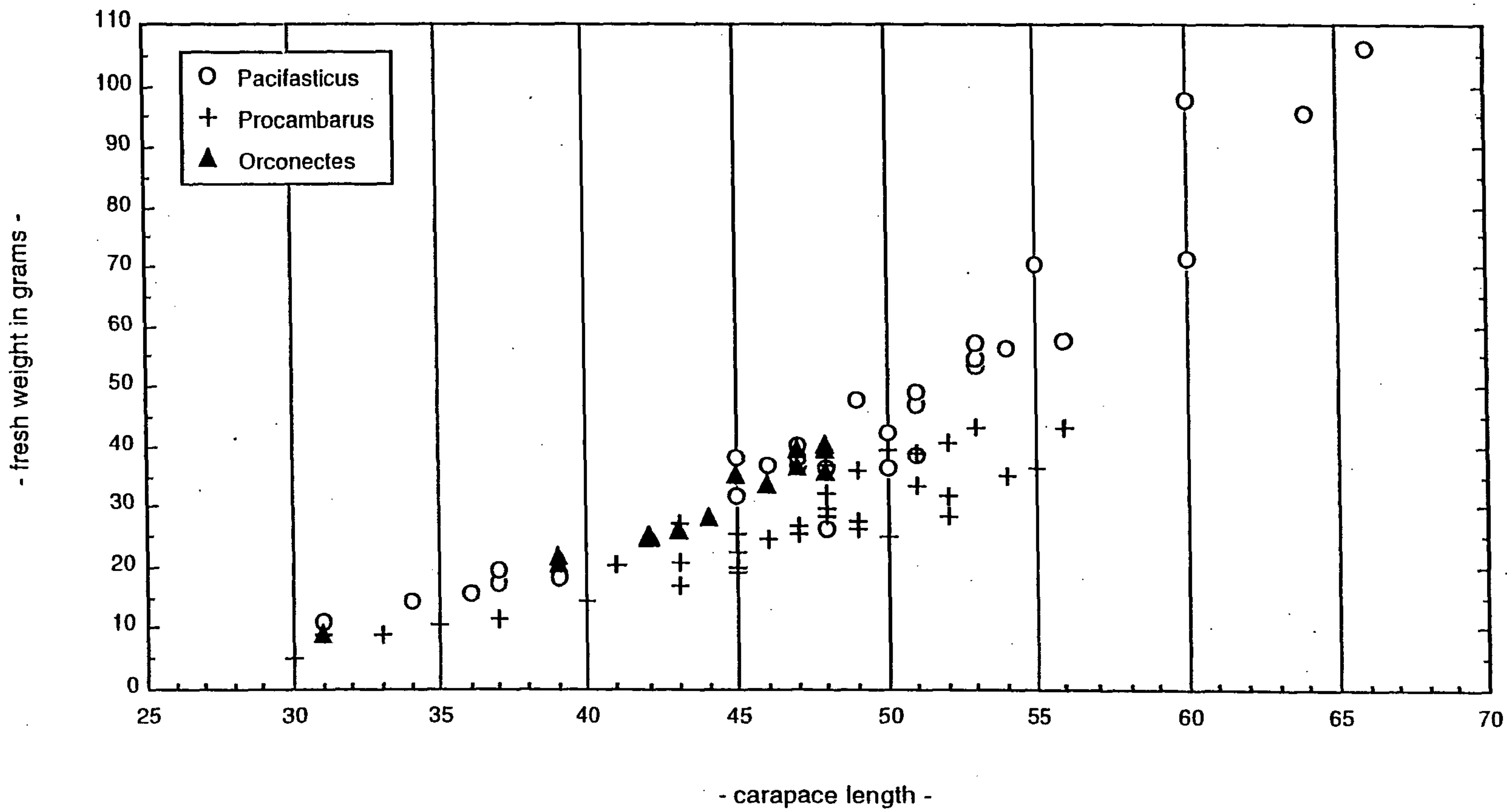


Fig. 10

Carapace Length : Body Weight Relations For The Three Putah Creek Crayfish Species



4. CONCLUSIONS

The data collected in this study provide new information on mercury concentrations in Putah Creek biota. Depending on the criterion used, many of the Putah Creek fish species contained mercury concentrations in edible muscle at levels of potential concern, with larger individuals of the top predatory species most highly contaminated. This supports the findings of previous work conducted by the ATSDR and is consistent with similar ranges of fish mercury concentrations found in other California aquatic systems with mining-related histories of bulk mercury contamination. The data further indicate that certain Putah Creek crayfish may represent a hazard for both human and wildlife consumption and that certain small or juvenile fish may represent a chronic hazard to fish-eating wildlife.

While it was not possible to obtain identical samples throughout the entire, varied stretch studied, numerous upstream/downstream comparative samples were obtained. Relatively elevated mercury exposure, uptake, and accumulation was indicated for certain biota in and around Lake Solano and in the extended pool region at the most downstream reach of the creek near the Yolo Bypass. We note that these are the two most extensive depositional regions along the lower creek, where flow is dramatically reduced in most seasons, organic material and mercury-containing sediment can most readily accumulate, low oxygen conditions develop, and a healthy population of mercury-methylating bacteria become established. Mercury was elevated, relative to the extended data sets, in Sacramento suckers and hitch within Lake Solano, in signal crayfish in and, particularly, upstream of Lake Solano, and in juvenile squawfish and trout immediately below. At the downstream site near the Yolo Bypass, highest overall fish levels were found and relatively elevated mercury occurred in several individual adult fish of different species and in all four of the small and juvenile fish composites, though (curiously) not in the crayfish.

With the exception of these two areas, similar ranges of accumulated mercury generally occurred among same species throughout the entire stretch of Putah Creek below Lake Berryessa. This included adult fish muscle, composite small/juvenile fish, aquatic insect composites, and crayfish tail muscle. Highest levels occurred in larger individuals of top predator species, wherever they were present. Neither the town of Winters, the agricultural fields, nor the UC Davis region of the creek were found to significantly alter biological mercury trends in any of the organisms sampled, including those which exhibit high levels of site fidelity. Where closely comparable data could be collected, the stretch of Putah Creek adjacent to the University and downstream to a distance of at least 3 miles frequently contained among the lowest relative levels. Though the most extensive pooled areas of the downstream creek occurred below this region at and near Site 11, considerable pooled stretches were also present between the UC Davis wastewater treatment outflow and Sites 8, 9, and 10. The relatively unchanged or lower mercury contents of bioindicator organisms from those sites indicate that this outflow does not have a major effect on mercury dynamics in the creek. It is possible that relatively enhanced levels of mercury methylation may occur at Site 11 downstream and that this may be partially related to the presence of surface-covering mats of water hyacinth plants there, which may promote local anoxic zones either in the water column or at the bottom when the plants die and sink. Nutrients from the University outflow may contribute somewhat to the hyacinth growth, though the entire creek below Lake Berryessa is high in nutrients.

Biotic mercury accumulations found in this Putah Creek study were similar to and somewhat lower than those found in research conducted on the lower portion of Cache Creek (Slotton *et al.* 1997c). Aquatic insect mercury concentrations from lower Putah Creek were considerably lower than levels seen in comparable organisms in the upstream watersheds of both Cache Creek (Reuter *et al.* 1996, 1998, Slotton *et al.* 1997b) and Putah Creek (study in progress). It is clear to us that the predominant source of bioavailable mercury in both watersheds can be traced to historic mercury mining and now-abandoned mercury mines. Cache Creek, which remains un-dammed below Clear Lake and Indian Valley Reservoir, is currently believed to be the single most significant conduit of mercury to the San Francisco Bay-Delta. A very intensive, multi-investigator research project is being developed at this time for the State, to study this phenomenon and the possibilities for cost-effective remediation of key mine-related sources (Stephenson *et al.* 1999).

While Lake Berryessa now lies between the lower portion of Putah Creek and upstream historic mercury mining zones, it is important to note that the dam and reservoir were not present throughout the period of active mining in the late 19th and early to mid 20th centuries. Figure 11 shows some of the more important mercury mines in the upper Putah watershed, including the Oat Hill Mine, second largest in all of California and largest in Northern California. Historic mercury production in the Putah Creek watershed was more than double that in the Cache Creek watershed (USDCMG 1997). Before Monticello Dam was built in the 1950s, Putah Creek undoubtedly constituted at least as great of a "mercury conduit" as present day Cache Creek. While the ongoing downstream transport of this material may have been greatly diminished by the dam and reservoir, remnant mercury must certainly be present within the stream bed and adjacent banks of lower Putah Creek. This material is re-exposed, transported, and re-distributed during high flow events. The results of this study are consistent with remnant, mining-derived mercury (together with some level of ongoing transfer through Lake Berryessa) constituting the primary source of ongoing mercury contamination in lower Putah Creek.

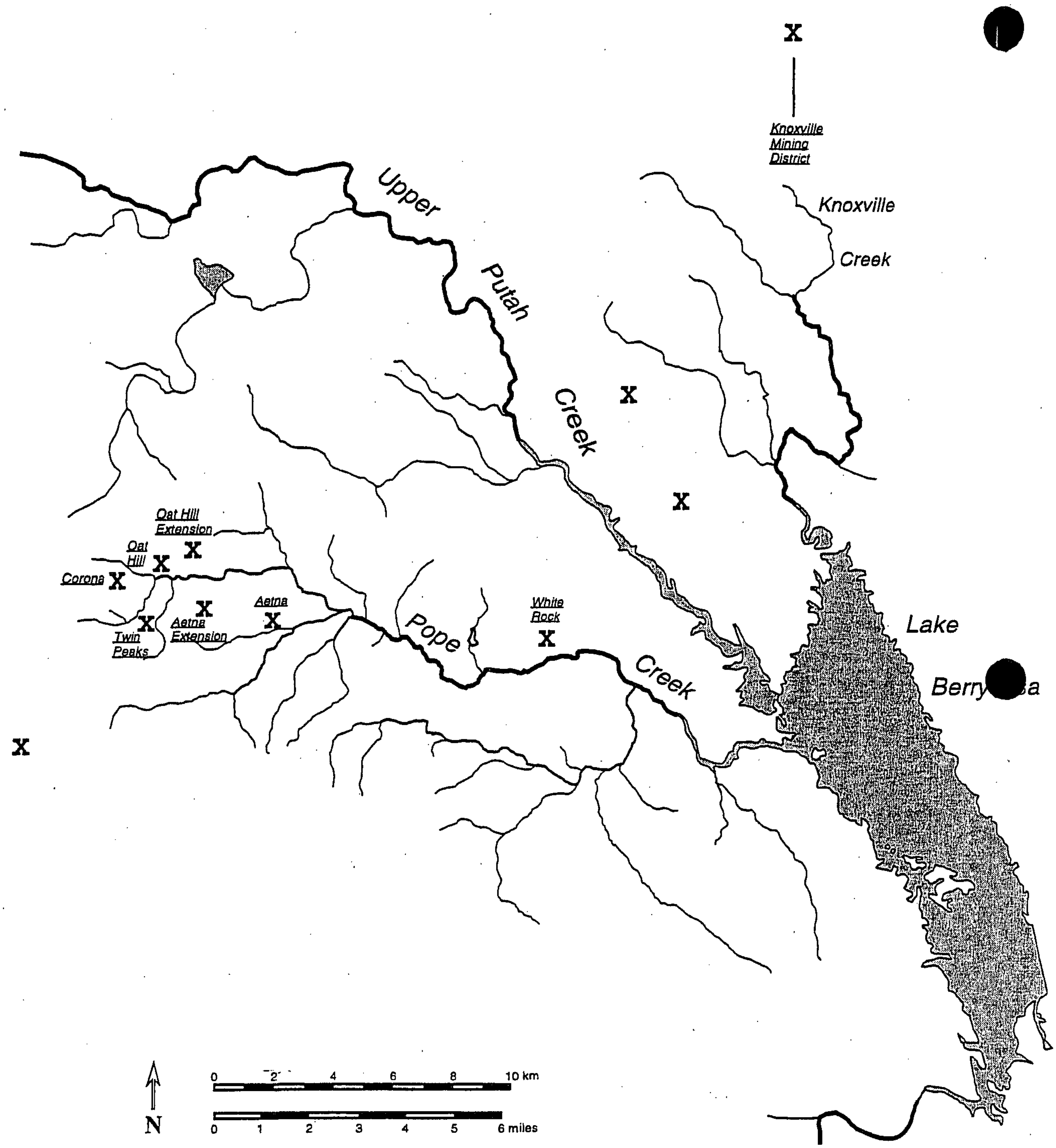


Fig. 11. Portions of the Upper Putah Creek Watershed, with Primary Abandoned Mercury Mines

5. LITERATURE CITED

ATSDR. 1997. Health consultation: Fish sampling in Putah Creek, 1996, Laboratory for Energy-Related Health Research, Davis, California. *Agency for Toxic Substances and Disease Registry (ATSDR) report.* April 1997.

ATSDR. 1998. Health consultation: Survey of fish in Putah Creek (Phase II), Laboratory for Energy-Related Health Research, Davis, California. *Agency for Toxic Substances and Disease Registry (ATSDR) report.* September 1998.

Bodega Research Associates. 1998. 1997-1998 Monitoring data for Hunting Creek and Knoxville Creek drainages, McLaughlin Mine Project, Lake and Napa Counties, California, 85 pp. *Report for Homestake Mining Company.* (Similar reports from 1987-1997).

Cal. Fish and Game. 1999. *1999 California Sportfishing Regulations.* California Department of Fish and Game.

EPRI. 1991. *Mercury In Temperate Lakes--1990 Annual Report.* Electric Power Research Institute, Palo Alto, California. 137 pp.

Forstner, U. and G.T.W. Wittman. 1981. *Metal Pollution In The Aquatic Environment*. Springer-Verlag, New York.

Gill, G.A. and K.W. Bruland. 1990. Mercury speciation in surface freshwater systems in California and other areas. *Environmental Science and Technology*, 24(9):1302-1400.

Hellawell, J.M. 1986. *Biological indicators of freshwater pollution and environmental management.* Elsevier Applied Science Publishers LTD, Essex, United Kingdom.

Huckabee, J.W., J.W. Elwood, & S.W. Hildebrand. 1979. Accumulation of mercury in freshwater biota. In *The Biogeochemistry of Mercury* (J.O. Nriagu, ed.). Elsevier/North-Holland Biomedical Press, New York. 277-302.

Hutchinson, T.C. and K.M. Meema (eds.). 1987. *Lead, Mercury, Cadmium and Arsenic in the Environment*. John Wiley & Sons Ltd. 336 pp.

Lee, G.F. 1997. Davis South Campus Superfund Oversight Committee (DSCSOC) Website: http://members.aol.com/dscsoc/dscsoc.htm. Website contains series of comments on lower Putah Creek water quality and associated studies from 1996 through the present.

Lee, G.F. 1998. Excessive mercury bioaccumulation in Putah Creek Fish. *Report for the Davis South Campus Superfund Oversight Committee (DSCSOC).* October 1998.

Light, T. 1994. A casual key to the crayfishes of California. *University of California at Davis report*, May 1994.

Lindberg, S., P.M. Stokes, and E. Goldberg. 1987. Group report: Mercury. Chapter 2 in *Lead, Mercury, Cadmium, and Arsenic in the Environment.* T.C. Hutchinson and K.M. Meema, eds. John Wiley and Sons Ltd, 17-33.

Moyle, P.B. 1976. *Inland fishes of California.* University of California Press, Berkeley, Los Angeles, London. 405 pp.

Moyle, P. B., M. P. Marchetti, J. Baldrige, and T. L. Taylor. 1998. Fish health and diversity: justifying flows for a California stream. *Fisheries* (Bethesda) 23(7):6-15.

NAREL. 1997. Concentrations of radionuclides and chemicals in fish, sediment, and water collected from the Putah Creek near the former Laboratory for Energy-Related Health Research, Davis, CA. *Report for the Agency for Toxic Substances and Disease Registry (ATSDR), prepared by the National Air and Radiation Environmental Laboratory (NAREL).* March 1997.

Reuter, J.E., D.G. Slotton, R.P. Axler, and C.R. Goldman. 1989. Analysis of the Long-Term Environmental Monitoring Program for Davis Creek Watershed Surface Waters--January 1, 1982 - June 30, 1989. *Report for Yolo County.* 268 pp.

Reuter, J.E., D.G. Slotton and C.R. Goldman. 1996. Evaluation of McLaughlin Gold Mine Project in Yolo County as Related to Surface Waters in the Davis Creek Watershed--July 1, 1995 - June 30, 1996. *Report for Yolo County.* 187 pp. (Similar reports from 1986-1988, 1990-1995).

Reuter, J.E., D.G. Slotton, S.M. Ayers, and C.R. Goldman. 1998. Environmental monitoring for mercury in water, sediment, and biota in Davis Creek and Davis Creek Reservoir. *Report for Yolo County.* 83 pp. (similar report from 1997).

Slotton, D.G. 1991. Mercury bioaccumulation in a newly impounded Northern California reservoir. *Doctoral dissertation, University of California, Davis.* 363 pp.

Slotton, D.G., S.M. Ayers, J.E. Reuter, and C.R. Goldman. 1995a. Gold mining impacts on food chain mercury in northwestern Sierra Nevada streams. *Technical Completion Report for the University of California Water Resources Center, Project W-816*, August 1995, 46 pp.

Slotton, D.G., J.E. Reuter, and C.R. Goldman. 1995b. Mercury uptake patterns of biota in a seasonally anoxic northern California reservoir. *Water, Air, and Soil Pollution*, 80:841-850.

Slotton, D.G., S.M. Ayers, and J.E. Reuter. 1996. Marsh Creek watershed 1995 mercury assessment project. *Final Report for Contra Costa County*, March 1996, 66 pp.

Slotton, D.G., S.M. Ayers, J.E. Reuter, and C.R. Goldman. 1997a. Sacramento River watershed mercury control planning project--UC Davis biotic component. *Final Report for the Sacramento Regional County Sanitation District*, March 1997, 74 pp.

Slotton, D.G., S.M. Ayers, J.E. Reuter, and C.R. Goldman. 1997b. Cache Creek watershed preliminary mercury assessment, using benthic macro-invertebrates. *Final Report for the Central Valley Regional Water Quality Control Board and the National Science Foundation*, June 1997, 36 pp.

Slotton, D.G., S.M. Ayers, and J.E. Reuter. 1997c. Mercury in lower Cache Creek biota: baseline assessment, Fall 1997. *Report prepared for Yolo County Planning Dept.*, December 1997, 28 pp.

Stephenson, M. and 16 other investigators. 1999. Assessment of Ecological and Human Health Impacts of Mercury in the Bay-Delta Watershed. *Designated action proposal submitted to CALFED Bay-Delta Program*, on behalf of 17 Principle Investigators at 13 different agencies and institutions, January 1999.

Suchanek, T.H., P.J. Richerson, L.A. Woodward, D.G. Slotton, L.J. Holts and C.E. Woodmansee 1993. Ecological Assessment of the Sulphur Bank Mercury Mine Superfund Site, Clear Lake, California: A survey and Evaluation of Mercury In: Sediment, Water, Plankton, Periphyton, Benthic Invertebrates and Fishes Within the Aquatic Ecosystem of Clear Lake, California. *Phase 1- Preliminary Lake Study Report.* Prepared for EPA-Region IX, Superfund Program. 113 pp., plus 2 attachments.

Suchanek, T.H., P.J. Richerson, L.J. Holts, B.A. Lamphere, C.E. Woodmansee, D.G. Slotton, E.J. Harner and L.A. Woodward 1995. Impacts of mercury on benthic invertebrate populations and communities within the aquatic ecosystem of Clear Lake, California. *Water, Air and Soil Pollution* 80:951-960.

Suchanek, T.H., P.J. Richerson, L.J. Mullen, L.L. Brister, J.C. Becker, A. Maxson, and D.G. Slotton. 1997. The role of the Sulphur Bank Mercury Mine site (and associated hydrogeological processes) in the dynamics of mercury transport and bioaccumulation within the Clear Lake aquatic ecosystem. *A report prepared for the USEPA, Region IX Superfund Program.* 479pp.

Suchanek, T.H., B.A. Lamphere, L.H. Mullen, C.E. Woodmansee, P.J. Richerson, D.G. Slotton, L.A. Woodward and E.J. Harner (1999). Mercury in lower trophic levels of the Clear Lake aquatic ecosystem, California. In: K. Scow (Ed.), Understanding Multiple Stresses on Ecosystems. Ann Arbor Press. (in press).

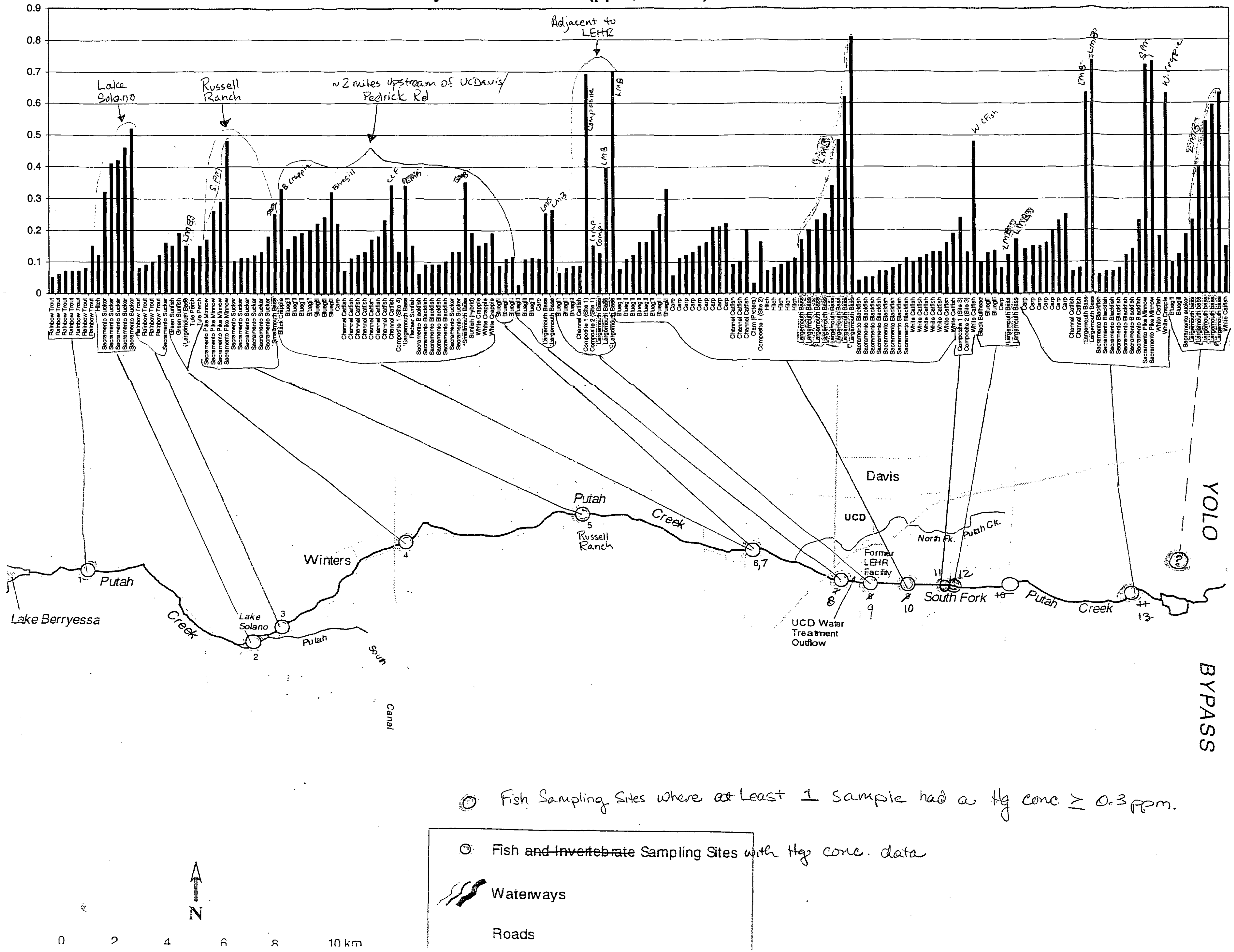
TSMP 1990. Toxic Substances Monitoring Program: Ten year summary report, 1978-1987. *State of California Water Resources Control Board publication* 90-1WQ, August 1990. Prepared by Del Rasmussen and Heidi Blethrow, Division of Water Quality.

TSMP 1997. Toxic Substances Monitoring Program: 1994-1995 Data Report. *State of California Water Resources Control Board / California Environmental Protection Agency publication*, October 1997. Prepared by Del Rasmussen, Division of Water Quality. Similar reports from 1991 (covering 19988-1989), 1992 (covering 1990), 1993 (covering 1991), and 1995 (covering 1992-1993).

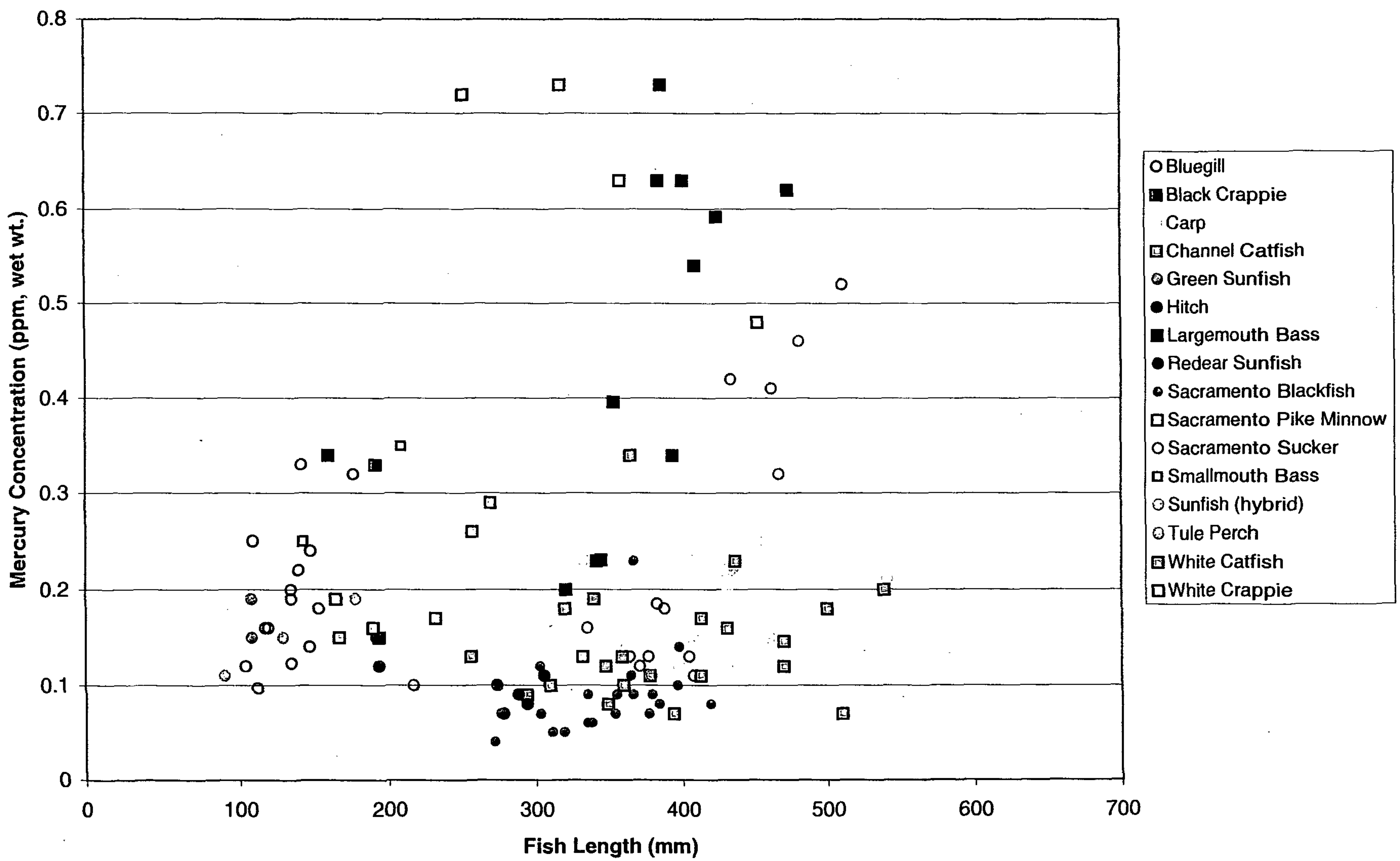
USDCMG. 1997. U.S. Department of Conservation, Mining, and Geology. California abandoned mines database; mercury, gold, and silver.

Wiener, J. G. 1995. Bioaccumulation of Mercury in Fish. *National Forum on Mercury in Fish, Proceedings.* EPA 823-R-95-002, (41-47).

Mercury Concentrations (ppm, wet wt.) in Putah Creek Fish



Mercury Concentrations in Putah Creek Fish



Mercury Concentrations in Fish
Calculations Needed to Determine Compliance with USEPA Criteria

Waterbody: Putah Creek

A. Comparison of Criterion to # of Samples (Individual and Composite)*	TL2 Fish	TL3 Fish	TL4 Fish	Trout	Bass (LM, SM & Str)	[Other Info]
# of Samples:	1	106	61	11	26	---
# of Samples with Hg > 0.3 µg/g:	0	7	21	0	14	---
% of Samples with Hg > 0.3 µg/g:	0%	7%	34%	0%	54%	---
USEPA Recommended Criterion (µg/g):	---	---	---	---	---	*0.3*

B. Comparison of Criterion to Hg Concentration Averages	TL2 Fish	TL3 Fish	TL4 Fish	Trout	Bass (LM, SM & Str)	[Other Info]
# of fish:	1	204	67	11	32	---
# of Samples:	1	106	61	11	26	
Average fish tissue mercury concentration (based on # of fish) (µg/g):	0.03	0.12	0.28	0.09	0.35	---
Average fish tissue mercury concentration (based on # of samples) (µg/g):	0.03	0.14	0.29	0.09	0.38	---
USEPA Recommended Criterion (µg/g):	---	---	---	---	---	*0.3*

C. Comparison of USEPA Reference Dose to Estimated Total Hg Intake from Waterbody Fish

C1. USEPA Default Consumption Rates Based on the 90th Percentile National Average of General Population	TL2 Fish	TL3 Fish	TL4 Fish	---	---	[Other Info]
USEPA default consumption rates (g/day) based on the 90th percentile national average of general population (total 17.5 g/day; 2 meals per month):	*3.8*	*8*	*5.7*	---	---	---
bwt (kg):	---	---	---	---	---	*70*
Estimated daily intake of MeHg from waterbody's fish,** using average Hg concentrations based on # of samples (µg/kg bwt-d):	0.0016	0.0162	0.0238	---	---	---
Estimated daily intake of MeHg from waterbody's fish,** using average Hg concentrations based on # of fish (µg/kg bwt-d):	0.0016	0.0140	0.0230	---	---	---
Assumed concurrent intake of MeHg from commercial (marine) fish (12.5 g/day) (µg/kg bwt d):	---	---	---	---	---	*0.027*
Estimated total Hg intake, using average Hg concentrations based on # of samples (µg/kg):	---	---	---	---	---	**0.069**
Estimated total Hg intake, using average Hg concentrations based on # of fish (µg/kg):	---	---	---	---	---	**0.066**
USEPA Reference Dose (safe daily intake level) (µg/kg bwt-d):	---	---	---	---	---	*0.1*

C2. USEPA Default Consumption Rate Assuming 50% TL3 and 50% TL4 Fish Are Eaten	TL2 Fish	TL3 Fish	TL4 Fish	---	---	[Other Info]
USEPA default consumption rates (g/day) based on the 90th percentile national average of general population (total 17.5 g/day; 2 meals per month; only TL3 and TL4 fish are eaten):	---	*8.75*	*8.75*	---	---	---
bwt (kg):	---	---	---	---	---	*70*
Estimated daily intake of MeHg from waterbody's fish,** using average Hg concentrations based on # of samples (µg/kg bwt-d):	---	0.0177	0.0365	---	---	---
Estimated daily intake of MeHg from waterbody's fish,** using average Hg concentrations based on # of fish (µg/kg bwt-d):	---	0.0153	0.0353	---	---	---
Assumed concurrent intake of MeHg from commercial (marine) fish (12.5 g/day) (µg/kg bwt d):	---	---	---	---	---	*0.027*
Estimated total Hg intake, using average Hg concentrations based on # of samples (µg/kg):	---	---	---	---	---	**0.081**
Estimated total Hg intake, using average Hg concentrations based on # of fish (µg/kg):	---	---	---	---	---	**0.078**
USEPA Reference Dose (safe daily intake level) (µg/kg bwt-d):	---	---	---	---	---	*0.1*

* Italicized numbers indicate "fixed" numbers; i.e., numbers that are the same for all waterbodies.

** If no TL2 data are available, assume average concentration of TL2 fish is same as TL3 fish.

Source	Date	Location	Location Description	Downstream Order	Species	Composite Description	TL	Size or Length (mm)	Weight (g)	# of Fish	Hg Conc (ppm, wet wt)	# of Fish * Conc	*Species Mean at Each Location*
UCDavis	1998	1	Putah Creek downsteam of Lake Berryessa.	1	Rainbow Trout		3	337	425	1	0.05	0.05	*0.079*
UCDavis	1998	1	Putah Creek downsteam of Lake Berryessa.	1	Rainbow Trout		3	245	205	1	0.06	0.06	
UCDavis	1998	1	Putah Creek downsteam of Lake Berryessa.	1	Rainbow Trout		3	192	82	1	0.07	0.07	
UCDavis	1998	1	Putah Creek downsteam of Lake Berryessa.	1	Rainbow Trout		3	225	159	1	0.07	0.07	
UCDavis	1998	1	Putah Creek downsteam of Lake Berryessa.	1	Rainbow Trout		3	259	215	1	0.07	0.07	
UCDavis	1998	1	Putah Creek downsteam of Lake Berryessa.	1	Rainbow Trout		3	348	505	1	0.08	0.08	
UCDavis	1998	1	Putah Creek downsteam of Lake Berryessa.	1	Rainbow Trout		3	383	580	1	0.15	0.15	
UCDavis	1998	2	In Lake Solano.	2	Hitch		3	194	95	1	0.12	0.12	*0.120*
UCDavis	1998	2	In Lake Solano.	2	Sacramento Sucker		3	467	1300	1	0.32	0.32	*0.426*
UCDavis	1998	2	In Lake Solano.	2	Sacramento Sucker		3	462	1425	1	0.41	0.41	
UCDavis	1998	2	In Lake Solano.	2	Sacramento Sucker		3	434	1115	1	0.42	0.42	
UCDavis	1998	2	In Lake Solano.	2	Sacramento Sucker		3	481	1660	1	0.46	0.46	
UCDavis	1998	2	In Lake Solano.	2	Sacramento Sucker		3	511	1910	1	0.52	0.52	
UCDavis	1998	3	Putah Creek downsteam of Lake Solano.	3	Rainbow Trout		3	193	105	1	0.08	0.08	*0.098*
UCDavis	1998	3	Putah Creek downsteam of Lake Solano.	3	Rainbow Trout		3	185	75	1	0.09	0.09	
UCDavis	1998	3	Putah Creek downsteam of Lake Solano.	3	Rainbow Trout		3	189	72	1	0.1	0.1	
UCDavis	1998	3	Putah Creek downsteam of Lake Solano.	3	Rainbow Trout		3	166	60	1	0.12	0.12	
UCDavis	1998	3	Putah Creek downsteam of Lake Solano.	3	Sacramento Sucker		3	335	430	1	0.16	0.16	*0.154*
UCDavis	1998	4	Putah Creek downstream of Winters.	4	Green Sunfish		3	108	25	1	0.15	0.15	*0.170*
UCDavis	1998	4	Putah Creek downstream of Winters.	4	Green Sunfish		3	108	23	1	0.19	0.19	
UCDavis	1998	4	Putah Creek downstream of Winters.	4	Largemouth Bass		4	194	110	1	0.15	0.15	*0.150*
UCDavis	1998	4	Putah Creek downstream of Winters.	4	Tule Perch		3	90	16	1	0.11	0.11	*0.130*
UCDavis	1998	4	Putah Creek downstream of Winters.	4	Tule Perch		3	129	42	1	0.15	0.15	
UCDavis	1998	5	Putah Creek at Russell Ranch	5	Sacramento Pike Minnow		4	232	107	1	0.17	0.17	*0.300*
UCDavis	1998	5	Putah Creek at Russell Ranch	5	Sacramento Pike Minnow		4	257	135	1	0.26	0.26	
UCDavis	1998	5	Putah Creek at Russell Ranch	5	Sacramento Pike Minnow		4	270	150	1	0.29	0.29	
UCDavis	1998	5	Putah Creek at Russell Ranch	5	Sacramento Pike Minnow		4	453	990	1	0.48	0.48	
UCDavis	1998	5	Putah Creek at Russell Ranch	5	Sacramento Sucker		3	217	115	1	0.1	0.1	*0.125*
UCDavis	1998	5	Putah Creek at Russell Ranch	5	Sacramento Sucker		3	379	680	1	0.11	0.11	
UCDavis	1998	5	Putah Creek at Russell Ranch	5	Sacramento Sucker		3	408	860	1	0.11	0.11	
UCDavis	1998	5	Putah Creek at Russell Ranch	5	Sacramento Sucker		3	371	550	1	0.12	0.12	
UCDavis	1998	5	Putah Creek at Russell Ranch	5	Sacramento Sucker		3	405	810	1	0.13	0.13	
UCDavis	1998	5	Putah Creek at Russell Ranch	5	Sacramento Sucker		3	388	800	1	0.18	0.18	
UCDavis	1998	5	Putah Creek at Russell Ranch	5	Smallmouth Bass		4	143	40	1	0.25	0.25	*0.250*
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (app	6	Black Crappie		4	192	103	1	0.33	0.33	*0.330*
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (app	6	Bluegill		3	147	85	1	0.14	0.14	*0.213*
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (app	6	Bluegill		3	153	112	1	0.18	0.18	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (app	6	Bluegill		3	135	50	1	0.19	0.19	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (app	6	Bluegill		3	135	75	1	0.2	0.2	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (app	6	Bluegill		3	140	55	1	0.22	0.22	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (app	6	Bluegill		3	148	85	1	0.24	0.24	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (app	6	Bluegill		3	177	112	1	0.32	0.32	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (app	6	Carp		3	435	1520	1	0.22	0.22	*0.220*
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (app	6	Channel Catfish		4	510	1660	1	0.07	0.07	*0.169*
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (app	6	Channel Catfish		4	378	750	1	0.11	0.11	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (app	6	Channel Catfish		4	470	1570	1	0.12	0.12	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (app	6	Channel Catfish		4	256	205	1	0.13	0.13	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (app	6	Channel Catfish		4	413	1280	1	0.17	0.17	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (app	6	Channel Catfish		4	500	1970	1	0.18	0.18	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (app	6	Channel Catfish		4	437	1110	1	0.23	0.23	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (app	6	Channel Catfish		4	365	710	1	0.34	0.34	
ATSDR1	1996	4	Approximately 3.3 miles upsteam of LEHR	6	Composite 1 (Site 4)	Bluegill (78), Green Sunfish (13), Largemouth Bass (3), Crayfish (8), White Catfish (1)	3-4		3035	103	0.13	13.39	*0.130*
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (app	6	Largemouth Bass		4	160	52	1	0.34	0.34	*0.340*
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (app	6	Redear Sunfish		3	192	153	1	0.15	0.15	*0.150*
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (app	6	Sacramento Blackfish		3	335	580	1	0.06	0.06	*0.086*
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (app	6	Sacramento Blackfish		3	335	630	1	0.09	0.09	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (app	6	Sacramento Blackfish		3	366	700	1	0.09	0.09	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (app	6	Sacramento Blackfish		3	379	920	1	0.09	0.09	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (app	6	Sacramento Blackfish		3	397	1000	1	0.1	0.1	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (app	6	Sacramento Sucker		3	377	470	1	0.13	0.13	*0.130*
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (app	6	Sacramento Sucker		3	364	625	1	0.13	0.13	

Source	Date	Study Location	Location Description	Downstream Order	Species	Composite Description	TL	Size or Length (mm)	Weight (g)	# of Fish	Hg Conc (ppm, wet wt)	# of Fish * Conc	*Species Mean at Each Location*
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (app	6	Smallmouth Bass		4	209	100	1	0.35	0.35	*0.350*
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (app	6	Sunfish (hybrid)		3	178	131	1	0.19	0.19	*0.190*
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (app	6	White Crappie		4	167	50	1	0.15	0.15	*0.167*
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (app	6	White Crappie		4	190	83	1	0.16	0.16	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (app	6	White Crappie		4	165	48	1	0.19	0.19	
ATSDR2	1997	4	Upstream of LEHR site, west of Davis at Pedrick	7	Bluegill		3	Large		1	0.0863	0.0863	*0.104*
ATSDR2	1997	4	Upstream of LEHR site, west of Davis at Pedrick	7	Bluegill		3	Small		2	0.108	0.216	
ATSDR2	1997	4	Upstream of LEHR site, west of Davis at Pedrick	7	Bluegill		3	Medium		1	0.115	0.115	
ATSDR2	1997	5	Between sites #1 and 4#, at the APO picnic grou	8	Bluegill		3	Large		2	0.0237	0.0474	*0.105*
ATSDR2	1997	5	Between sites #1 and 4#, at the APO picnic grou	8	Bluegill		3	Small		27	0.106	2.862	
ATSDR2	1997	5	Between sites #1 and 4#, at the APO picnic grou	8	Bluegill		3	Medium		29	0.11	3.19	
ATSDR2	1997	5	Between sites #1 and 4#, at the APO picnic grou	8	Carp		3	Large		1	0.108	0.108	*0.108*
ATSDR2	1997	5	Between sites #1 and 4#, at the APO picnic grou	8	Largemouth Bass		4	Medium		1	0.252	0.252	*0.260*
ATSDR2	1997	5	Between sites #1 and 4#, at the APO picnic grou	8	Largemouth Bass		4	Small		3	0.263	0.789	
ATSDR2	1997	1	Downstream of Old Davis Road and adjacent to	9	Bluegill		3	Small		13	0.0633	0.8229	*0.071*
ATSDR2	1997	1	Downstream of Old Davis Road and adjacent to	9	Bluegill		3	Medium		6	0.0792	0.4752	
ATSDR2	1997	1	Downstream of Old Davis Road and adjacent to	9	Bluegill		3	Large		4	0.0853	0.3412	
ATSDR2	1997	1	Downstream of Old Davis Road and adjacent to	9	Channel Catfish		4	N/A		1	0.0855	0.0855	*0.086*
ATSDR1	1996	1	Adjacent to LEHR	9	Composite 1 (Site 1)	Black Crappie (2), Bluegill (1), Largemouth Bass (2)	3-4		1747	5	0.69	3.45	*0.279*
ATSDR1	1996	1	Adjacent to LEHR	9	Composite 2 (Site 1)	Crayfish (10), Black Bullhead (4), White Catfish (2)	3-4		3020	16	0.15	2.4	
ATSDR2	1997	1	Downstream of Old Davis Road and adjacent to	9	Largemouth Bass		4	Small		2	0.127	0.254	*0.337*
ATSDR2	1997	1	Downstream of Old Davis Road and adjacent to	9	Largemouth Bass		4	Medium		1	0.395	0.395	
ATSDR2	1997	1	Downstream of Old Davis Road and adjacent to	9	Largemouth Bass		4	Large		1	0.699	0.699	
ATSDR2	1997	2	One mile downsteam of Old Davis Road and 0.6	10	Bluegill		3	Small		6	0.0749	0.4494	*0.135*
ATSDR2	1997	2	One mile downsteam of Old Davis Road and 0.6	10	Bluegill		3	Medium		4	0.107	0.428	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	Bluegill		3	104	22	1	0.12	0.12	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	Bluegill		3	117	30	1	0.16	0.16	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	Bluegill		3	119	35	1	0.16	0.16	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	Bluegill		3	Large		2	0.195	0.39	
ATSDR2	1997	2	One mile downsteam of Old Davis Road and 0.6	10	Bluegill		3	109	29	1	0.25	0.25	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	Bluegill		3	142	45	1	0.33	0.33	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	Carp		3	Small		1	0.0565	0.0565	*0.152*
ATSDR2	1997	2	One mile downsteam of Old Davis Road and 0.6	10	Carp		3	Large		1	0.111	0.111	
ATSDR2	1997	2	One mile downsteam of Old Davis Road and 0.6	10	Carp		3	398	1060	1	0.12	0.12	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	Carp		3	525	2800	1	0.13	0.13	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	Carp		3	460	2025	1	0.15	0.15	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	Carp		3	311	555	1	0.16	0.16	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	Carp		3	541	3300	1	0.21	0.21	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	Carp		3	620	4900	1	0.21	0.21	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	Carp		3	429	1450	1	0.22	0.22	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	Channel Catfish		4	294	310	1	0.09	0.09	*0.130*
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	Channel Catfish		4	310	340	1	0.1	0.1	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	Channel Catfish		4	539	2700	1	0.2	0.2	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	Clam (Protera)		2			1	0.03	0.03	*0.030*
ATSDR1	1996	2	Approximately 1.2 miles downsteam of LEHR	10	Composite 1 (Site 2)	Carp (1), Black Bullhead (1)	3		1776	2	0.16	0.32	*0.160*
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	Hitch		3	278	315	1	0.07	0.07	*0.090*
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	Hitch		3	294	355	1	0.08	0.08	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	Hitch		3	288	345	1	0.09	0.09	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	Hitch		3	274	305	1	0.1	0.1	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	Hitch		3	306	360	1	0.11	0.11	
ATSDR2	1997	2	One mile downsteam of Old Davis Road and 0.6	10	Largemouth Bass		4	Small		2	0.168	0.336	*0.363*
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	Largemouth Bass		4	321	705	1	0.2	0.2	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	Largemouth Bass		4	342	635	1	0.23	0.23	
ATSDR1	1996	2	Approximately 1.2 miles downsteam of LEHR	10	Largemouth Bass	Largemouth Bass (1)	4		650	1	0.25	0.25	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	Largemouth Bass		4	394	1120	1	0.34	0.34	
ATSDR2	1997	2	One mile downsteam of Old Davis Road and 0.6	10	Largemouth Bass		4	Medium		1	0.485	0.485	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	Largemouth Bass		4	474	1920	1	0.62	0.62	
ATSDR2	1997	2	One mile downsteam of Old Davis Road and 0.6	10	Largemouth Bass		4	Large		1	0.808	0.808	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	Sacramento Blackfish		3	272	290	1	0.04	0.04	*0.070*
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	Sacramento Blackfish		3	311	430	1	0.05	0.05	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	Sacramento Blackfish		3	319	505	1	0.05	0.05	

Source	Date	Study Location	Location Description	Downstream Order	Species	Composite Description	TL	Size or Length (mm)	Weight (g)	# of Fish	Hg Conc (ppm, wet wt)	# of Fish * Conc	Species Mean at Each Location
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	Sacramento Blackfish		3	354	685	1	0.07	0.07	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	Sacramento Blackfish		3	377	790	1	0.07	0.07	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	Sacramento Blackfish		3	419	1140	1	0.08	0.08	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	Sacramento Blackfish		3	355	555	1	0.09	0.09	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	Sacramento Blackfish		3	365	820	1	0.11	0.11	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	White Catfish		4	360	745	1	0.1	0.1	*0.134*
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	White Catfish		4	413	1310	1	0.11	0.11	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	White Catfish		4	348	655	1	0.12	0.12	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	White Catfish		4	332	595	1	0.13	0.13	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	White Catfish		4	359	720	1	0.13	0.13	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	White Catfish		4	431	1390	1	0.16	0.16	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (	10	White Catfish		4	340	610	1	0.19	0.19	
ATSDR1	1996	3	Approximately 2.4 miles downsteam of LEHR	11	Composite 1 (Site 3)	Black Crappie (2), Largemouth Bass (1)	3-4		1598	3	0.24	0.72	*0.155*
ATSDR1	1996	3	Approximately 2.4 miles downsteam of LEHR	11	Composite 2 (Site 3)	Crayfish (9), Carp (1)	3-4		1985	10	0.13	1.3	
ATSDR1	1996	3	Approximately 2.4 miles downsteam of LEHR	11	White Catfish	White Catfish (1)	4		2624	1	0.48	0.48	*0.480*
ATSDR2	1997	3	Above Mace Boulevard, about 3 miles downstre	12	Black Bullhead		3	N/A		1	0.0994	0.0994	*0.099*
ATSDR2	1997	3	Above Mace Boulevard, about 3 miles downstre	12	Bluegill		3	Large		1	0.127	0.127	*0.133*
ATSDR2	1997	3	Above Mace Boulevard, about 3 miles downstre	12	Bluegill		3	Small		3	0.135	0.405	
ATSDR2	1997	3	Above Mace Boulevard, about 3 miles downstre	12	Carp		3	Large		1	0.0802	0.0802	*0.080*
ATSDR2	1997	3	Above Mace Boulevard, about 3 miles downstre	12	Largemouth Bass		4	Small		2	0.123	0.246	*0.147*
ATSDR2	1997	3	Above Mace Boulevard, about 3 miles downstre	12	Largemouth Bass		4	Medium		2	0.171	0.342	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 mil	13	Carp		3	362	805	1	0.14	0.14	*0.183*
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 mil	13	Carp		3	411	1040	1	0.15	0.15	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 mil	13	Carp		3	402	1210	1	0.15	0.15	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 mil	13	Carp		3	427	1440	1	0.16	0.16	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 mil	13	Carp		3	432	1280	1	0.2	0.2	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 mil	13	Carp		3	333	535	1	0.23	0.23	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 mil	13	Carp		3	457	1750	1	0.25	0.25	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 mil	13	Channel Catfish		4	394	740	1	0.07	0.07	*0.075*
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 mil	13	Channel Catfish		4	349	480	1	0.08	0.08	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 mil	13	Largemouth Bass		4	385	970	1	0.63	0.63	*0.680*
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 mil	13	Largemouth Bass		4	387	930	1	0.73	0.73	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 mil	13	Sacramento Blackfish		3	338	505	1	0.06	0.06	*0.110*
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 mil	13	Sacramento Blackfish		3	276	285	1	0.07	0.07	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 mil	13	Sacramento Blackfish		3	303	385	1	0.07	0.07	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 mil	13	Sacramento Blackfish		3	384	315	1	0.08	0.08	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 mil	13	Sacramento Blackfish		3	303	355	1	0.12	0.12	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 mil	13	Sacramento Blackfish		3	398	840	1	0.14	0.14	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 mil	13	Sacramento Blackfish		3	367	600	1	0.23	0.23	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 mil	13	Sacramento Pike Minnow		4	252	165	1	0.72	0.72	*0.725*
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 mil	13	Sacramento Pike Minnow		4	318	250	1	0.73	0.73	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 mil	13	White Catfish		4	320	545	1	0.18	0.18	*0.180*
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 mil	13	White Crappie		4	359	735	1	0.63	0.63	*0.630*
SRWP	1999		Putah Creek	14?	Bluegill		3	112		5	0.097	0.485	*0.110*
SRWP	1999		Putah Creek	14?	Bluegill		3	135		5	0.123	0.615	
SRWP	1999		Putah Creek	14?	Sacramento sucker		3	383		4	0.185	0.74	*0.185*
SRWP	1999		Putah Creek	14?	Largemouth bass		4	345		1	0.231	0.231	*0.478*
SRWP	1999		Putah Creek	14?	Largemouth bass		4	354		1	0.396	0.396	
SRWP	1999		Putah Creek	14?	Largemouth bass		4	410		1	0.54	0.54	
SRWP	1999		Putah Creek	14?	Largemouth bass		4	425		1	0.592	0.592	
SRWP	1999		Putah Creek	14?	Largemouth bass		4	402		1	0.63	0.63	
SRWP	1999		Putah Creek	14?	White Catfish		4	470		1	0.146	0.146	*0.146*

	Average	# of Fish
TL2:	0.03	1
TL3:	0.12	204
TL4:	0.28	67
Misc. Composites:	0.22	15

Source	Date	Study Location	Location Description	Downstream Order	Species	Composite Description	TL	Size or Length (mm)	Weight (g)	# of Fish	Hg Conc (ppm, wet wt)	# of Fish * Conc	*Species Mean at Each Location*
											Trout:	0.09	11
											Bass:	0.35	32

Source	Date	Location	Location Description	Downstream Order	Species	Composite Description	TL	Size or Length (mm)	Weight (g)	# of Fish	Hg Conc (ppm, wet wt)	# of Fish * Conc	Species Mean
Trophic Level 2													
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	Clam (Protera)		2			1	0.03	0.03	*0.030*
Trophic Level 3													
ATSDR2	1997	3	Above Mace Boulevard, about 3 miles downstream of Old Davis Road and 2.5 miles downsteam of storm drain on	12	Black Bullhead		3	N/A		1	0.0994	0.0994	*0.099*
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 4)	6	Bluegill		3	147	85	1	0.14	0.14	*0.110*
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 4)	6	Bluegill		3	153	112	1	0.18	0.18	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 4)	6	Bluegill		3	135	50	1	0.19	0.19	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 4)	6	Bluegill		3	135	75	1	0.2	0.2	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 4)	6	Bluegill		3	140	55	1	0.22	0.22	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 4)	6	Bluegill		3	148	85	1	0.24	0.24	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 4)	6	Bluegill		3	177	112	1	0.32	0.32	
ATSDR2	1997	4	Upstream of LEHR site, west of Davis at Pedrick Road crossing (downstream of Site 4 in ATSDR1).	7	Bluegill		3	Large		1	0.0863	0.0863	
ATSDR2	1997	4	Upstream of LEHR site, west of Davis at Pedrick Road crossing (downstream of Site 4 in ATSDR1).	7	Bluegill		3	Small		2	0.108	0.216	
ATSDR2	1997	4	Upstream of LEHR site, west of Davis at Pedrick Road crossing (downstream of Site 4 in ATSDR1).	7	Bluegill		3	Medium		1	0.115	0.115	
ATSDR2	1997	5	Between sites #1 and 4#, at the APO picnic grounds (where Arden Way meets Putah Creek).	8	Bluegill		3	Large		2	0.0237	0.0474	
ATSDR2	1997	5	Between sites #1 and 4#, at the APO picnic grounds (where Arden Way meets Putah Creek).	8	Bluegill		3	Small		27	0.106	2.862	
ATSDR2	1997	5	Between sites #1 and 4#, at the APO picnic grounds (where Arden Way meets Putah Creek).	8	Bluegill		3	Medium		29	0.11	3.19	
ATSDR2	1997	1	Downstream of Old Davis Road and adjacent to LEHR site.	9	Bluegill		3	Small		13	0.0633	0.8229	
ATSDR2	1997	1	Downstream of Old Davis Road and adjacent to LEHR site.	9	Bluegill		3	Medium		6	0.0792	0.4752	
ATSDR2	1997	1	Downstream of Old Davis Road and adjacent to LEHR site.	9	Bluegill		3	Large		4	0.0853	0.3412	
ATSDR2	1997	2	One mile downsteam of Old Davis Road and 0.6 miles downstream of storm drain on eastern edge of LEHR site	10	Bluegill		3	Small		6	0.0749	0.4494	
ATSDR2	1997	2	One mile downsteam of Old Davis Road and 0.6 miles downstream of storm drain on eastern edge of LEHR site	10	Bluegill		3	Medium		4	0.107	0.428	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	Bluegill		3	104	22	1	0.12	0.12	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	Bluegill		3	117	30	1	0.16	0.16	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	Bluegill		3	119	35	1	0.16	0.16	
ATSDR2	1997	2	One mile downsteam of Old Davis Road and 0.6 miles downstream of storm drain on eastern edge of LEHR site	10	Bluegill		3	Large		2	0.195	0.39	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	Bluegill		3	109	29	1	0.25	0.25	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	Bluegill		3	142	45	1	0.33	0.33	
ATSDR2	1997	3	Above Mace Boulevard, about 3 miles downstream of Old Davis Road and 2.5 miles downsteam of storm drain on	12	Bluegill		3	Large		1	0.127	0.127	
ATSDR2	1997	3	Above Mace Boulevard, about 3 miles downstream of Old Davis Road and 2.5 miles downsteam of storm drain on	12	Bluegill		3	Small		3	0.135	0.405	
SRWP	1999		Putah Creek	14?	Bluegill		3	135		5	0.123	0.615	
SRWP	1999		Putah Creek	14?	Bluegill		3	112		5	0.097	0.485	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 4)	6	Carp		3	435	1520	1	0.22	0.22	*0.161*
ATSDR2	1997	5	Between sites #1 and 4#, at the APO picnic grounds (where Arden Way meets Putah Creek).	8	Carp		3	Large		1	0.108	0.108	
ATSDR2	1997	2	One mile downsteam of Old Davis Road and 0.6 miles downstream of storm drain on eastern edge of LEHR site	10	Carp		3	Small		1	0.0565	0.0565	
ATSDR2	1997	2	One mile downsteam of Old Davis Road and 0.6 miles downstream of storm drain on eastern edge of LEHR site	10	Carp		3	Large		1	0.111	0.111	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	Carp		3	398	1060	1	0.12	0.12	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	Carp		3	525	2800	1	0.13	0.13	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	Carp		3	460	2025	1	0.15	0.15	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	Carp		3	311	555	1	0.16	0.16	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	Carp		3	541	3300	1	0.21	0.21	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	Carp		3	620	4900	1	0.21	0.21	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	Carp		3	429	1450	1	0.22	0.22	
ATSDR2	1997	3	Above Mace Boulevard, about 3 miles downstream of Old Davis Road and 2.5 miles downsteam of storm drain on	12	Carp		3	Large		1	0.0802	0.0802	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 miles downsteamof LEHR).	13	Carp		3	362	805	1	0.14	0.14	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 miles downsteamof LEHR).	13	Carp		3	411	1040	1	0.15	0.15	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 miles downsteamof LEHR).	13	Carp		3	402	1210	1	0.15	0.15	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 miles downsteamof LEHR).	13	Carp		3	427	1440	1	0.16	0.16	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 miles downsteamof LEHR).	13	Carp		3	432	1280	1	0.2	0.2	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 miles downsteamof LEHR).	13	Carp		3	333	535	1	0.23	0.23	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 miles downsteamof LEHR).	13	Carp		3	457	1750	1	0.25	0.25	
UCDavis	1998	4	Putah Creek downstream of Winters.	4	Green Sunfish		3	108	25	1	0.15	0.15	*0.170*
UCDavis	1998	4	Putah Creek downstream of Winters.	4	Green Sunfish		3	108	23	1	0.19	0.19	
UCDavis	1998	2	In Lake Solano.	2	Hitch		3	194	95	1	0.12	0.12	*0.095*
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	Hitch		3	278	315	1	0.07	0.07	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	Hitch		3	294	355	1	0.08	0.08	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	Hitch		3	288	345	1	0.09	0.09	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	Hitch		3	274	305	1	0.1	0.1	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	Hitch		3	306	360	1	0.11	0.11	
UCDavis	1998	1	Putah Creek downsteam of Lake Berryessa.	1	Rainbow Trout		3	337	425	1	0.05	0.05	*0.085*
UCDavis	1998	1	Putah Creek downsteam of Lake Berryessa.	1	Rainbow Trout		3	245	205	1	0.06	0.06	
UCDavis	1998	1	Putah Creek downsteam of Lake Berryessa.	1	Rainbow Trout		3	192	82	1	0.07	0.07	
UCDavis	1998	1	Putah Creek downsteam of Lake Berryessa.	1	Rainbow Trout		3	225	159	1	0.07	0.07	
UCDavis	1998	1	Putah Creek downsteam of Lake Berryessa.	1	Rainbow Trout		3	259	215	1	0.07	0.07	
UCDavis	1998	1	Putah Creek downsteam of Lake Berryessa.	1	Rainbow Trout		3	348	505	1	0.08	0.08	
UCDavis	1998	1	Putah Creek downsteam of Lake Berryessa.	1	Rainbow Trout		3	383	580	1	0.15	0.15	
UCDavis	1998	3	Putah Creek downsteam of Lake Solano.	3	Rainbow Trout		3	193	105	1	0.08	0.08	
UCDavis	1998	3	Putah Creek downsteam of Lake Solano.	3	Rainbow Trout		3	185	75	1	0.09	0.09	
UCDavis	1998	3	Putah Creek downsteam of Lake Solano.	3	Rainbow Trout		3	189	72	1	0.1	0.1	
UCDavis	1998	3	Putah Creek downsteam of Lake Solano.	3	Rainbow Trout		3	166	60	1	0.12	0.12	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 4)	6	Redear Sunfish		3	192	153	1	0.15	0.15	*0.150*
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 4)	6	Sacramento Blackfish		3	335	580	1	0.06	0.06	*0.088*
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 4)	6	Sacramento Blackfish		3	335	630	1	0.09	0.09	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 4)	6	Sacramento Blackfish		3	366	700	1	0.09	0.09	

Source	Date	Location	Location Description	Downstream Order	Species	Composite Description	TL	Size or Length (mm)	Weight (g)	# of Fish	Hg Conc (ppm, wet wt)	# of Fish * Conc	Species Mean
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 4)	6	Sacramento Blackfish		3	379	920	1	0.09	0.09	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 4)	6	Sacramento Blackfish		3	397	1000	1	0.1	0.1	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	Sacramento Blackfish		3	272	290	1	0.04	0.04	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	Sacramento Blackfish		3	311	430	1	0.05	0.05	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	Sacramento Blackfish		3	319	505	1	0.05	0.05	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	Sacramento Blackfish		3	354	685	1	0.07	0.07	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	Sacramento Blackfish		3	377	790	1	0.07	0.07	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	Sacramento Blackfish		3	419	1140	1	0.08	0.08	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	Sacramento Blackfish		3	355	555	1	0.09	0.09	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	Sacramento Blackfish		3	365	820	1	0.11	0.11	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 miles downsteamof LEHR).	13	Sacramento Blackfish		3	338	505	1	0.06	0.06	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 miles downsteamof LEHR).	13	Sacramento Blackfish		3	276	285	1	0.07	0.07	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 miles downsteamof LEHR).	13	Sacramento Blackfish		3	303	385	1	0.07	0.07	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 miles downsteamof LEHR).	13	Sacramento Blackfish		3	384	315	1	0.08	0.08	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 miles downsteamof LEHR).	13	Sacramento Blackfish		3	303	355	1	0.12	0.12	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 miles downsteamof LEHR).	13	Sacramento Blackfish		3	398	840	1	0.14	0.14	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 miles downsteamof LEHR).	13	Sacramento Blackfish		3	367	600	1	0.23	0.23	
UCDavis	1998	2	In Lake Solano.	2	Sacramento Sucker		3	467	1300	1	0.32	0.32	*0.224*
UCDavis	1998	2	In Lake Solano.	2	Sacramento Sucker		3	462	1425	1	0.41	0.41	
UCDavis	1998	2	In Lake Solano.	2	Sacramento Sucker		3	434	1115	1	0.42	0.42	
UCDavis	1998	2	In Lake Solano.	2	Sacramento Sucker		3	481	1660	1	0.46	0.46	
UCDavis	1998	2	In Lake Solano.	2	Sacramento Sucker		3	511	1910	1	0.52	0.52	
UCDavis	1998	3	Putah Creek downsteam of Lake Solano.	3	Sacramento Sucker		3	335	430	1	0.16	0.16	
UCDavis	1998	5	Putah Creek at Russell Ranch	5	Sacramento Sucker		3	217	115	1	0.1	0.1	
UCDavis	1998	5	Putah Creek at Russell Ranch	5	Sacramento Sucker		3	379	680	1	0.11	0.11	
UCDavis	1998	5	Putah Creek at Russell Ranch	5	Sacramento Sucker		3	408	860	1	0.11	0.11	
UCDavis	1998	5	Putah Creek at Russell Ranch	5	Sacramento Sucker		3	371	550	1	0.12	0.12	
UCDavis	1998	5	Putah Creek at Russell Ranch	5	Sacramento Sucker		3	405	810	1	0.13	0.13	
UCDavis	1998	5	Putah Creek at Russell Ranch	5	Sacramento Sucker		3	388	800	1	0.18	0.18	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 4)	6	Sacramento Sucker		3	377	470	1	0.13	0.13	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 4)	6	Sacramento Sucker		3	364	625	1	0.13	0.13	
SRWP	1999		Putah Creek	14?	Sacramento sucker		3	383		4	0.185	0.74	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 4)	6	Sunfish (hybrid)		3	178	131	1	0.19	0.19	*0.190*
UCDavis	1998	4	Putah Creek downstream of Winters.	4	Tule Perch		3	90	16	1	0.11	0.11	*0.130*
UCDavis	1998	4	Putah Creek downstream of Winters.	4	Tule Perch		3	129	42	1	0.15	0.15	
Trophic Level 4													
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 4)	6	Black Crappie		4	192	103	1	0.33	0.33	*0.330*
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 4)	6	Channel Catfish		4	510	1660	1	0.07	0.07	*0.141*
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 4)	6	Channel Catfish		4	378	750	1	0.11	0.11	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 4)	6	Channel Catfish		4	470	1570	1	0.12	0.12	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 4)	6	Channel Catfish		4	256	205	1	0.13	0.13	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 4)	6	Channel Catfish		4	413	1280	1	0.17	0.17	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 4)	6	Channel Catfish		4	500	1970	1	0.18	0.18	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 4)	6	Channel Catfish		4	437	1110	1	0.23	0.23	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 4)	6	Channel Catfish		4	365	710	1	0.34	0.34	
ATSDR2	1997	1	Downstream of Old Davis Road and adjacent to LEHR site.	9	Channel Catfish		4	N/A		1	0.0855	0.0855	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	Channel Catfish		4	294	310	1	0.09	0.09	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	Channel Catfish		4	310	340	1	0.1	0.1	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	Channel Catfish		4	539	2700	1	0.2	0.2	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 miles downsteamof LEHR).	13	Channel Catfish		4	394	740	1	0.07	0.07	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 miles downsteamof LEHR).	13	Channel Catfish		4	349	480	1	0.08	0.08	
UCDavis	1998	4	Putah Creek downstream of Winters.	4	Largemouth Bass		4	194	110	1	0.15	0.15	*0.350*
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 4)	6	Largemouth Bass		4	160	52	1	0.34	0.34	
ATSDR2	1997	5	Between sites #1 and 4#, at the APO picnic grounds (where Arden Way meets Putah Creek).	8	Largemouth Bass		4	Medium		1	0.252	0.252	
ATSDR2	1997	5	Between sites #1 and 4#, at the APO picnic grounds (where Arden Way meets Putah Creek).	8	Largemouth Bass		4	Small		3	0.263	0.789	
ATSDR2	1997	1	Downstream of Old Davis Road and adjacent to LEHR site.	9	Largemouth Bass		4	Small		2	0.127	0.254	
ATSDR2	1997	1	Downstream of Old Davis Road and adjacent to LEHR site.	9	Largemouth Bass		4	Medium		1	0.395	0.395	
ATSDR2	1997	1	Downstream of Old Davis Road and adjacent to LEHR site.	9	Largemouth Bass		4	Large		1	0.699	0.699	
ATSDR2	1997	2	One mile downsteam of Old Davis Road and 0.6 miles downstream of storm drain on eastern edge of LEHR site	10	Largemouth Bass		4	Small		2	0.168	0.336	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	Largemouth Bass		4	321	705	1	0.2	0.2	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	Largemouth Bass		4	342	635	1	0.23	0.23	
ATSDR1	1996	2	Approximately 1.2 miles downsteam of LEHR	10	Largemouth Bass	Largemouth Bass (1)	4		650	1	0.25	0.25	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	Largemouth Bass		4	394	1120	1	0.34	0.34	
ATSDR2	1997	2	One mile downsteam of Old Davis Road and 0.6 miles downstream of storm drain on eastern edge of LEHR site	10	Largemouth Bass		4	Medium		1	0.485	0.485	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	Largemouth Bass		4	474	1920	1	0.62	0.62	
ATSDR2	1997	2	One mile downsteam of Old Davis Road and 0.6 miles downstream of storm drain on eastern edge of LEHR site	10	Largemouth Bass		4	Large		1	0.808	0.808	
ATSDR2	1997	3	Above Mace Boulevard, about 3 miles downstream of Old Davis Road and 2.5 miles downsteam of storm drain on	12	Largemouth Bass		4	Small		2	0.123	0.246	
ATSDR2	1997	3	Above Mace Boulevard, about 3 miles downstream of Old Davis Road and 2.5 miles downsteam of storm drain on	12	Largemouth Bass		4	Medium		2	0.171	0.342	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 miles downsteamof LEHR).	13	Largemouth Bass		4	385	970	1	0.63	0.63	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 miles downsteamof LEHR).	13	Largemouth Bass		4	387	930	1	0.73	0.73	
SRWP	1999		Putah Creek	14?	Largemouth bass		4	402		1	0.63	0.63	
SRWP	1999		Putah Creek	14?	Largemouth bass		4	425		1	0.592	0.592	
SRWP	1999		Putah Creek	14?	Largemouth bass		4	410		1	0.54	0.54	
SRWP	1999		Putah Creek	14?	Largemouth bass		4	354		1	0.396	0.396	

Source	Date	Location	Location Description	Downstream Order	Species	Composite Description	TL	Size or Length (mm)	Weight (g)	# of Fish	Hg Conc (ppm, wet wt)	# of Fish * Conc	*Species Mean*
SRWP	1999		Putah Creek	14?	Largemouth bass		4	345		1	0.231	0.231	
UCDavis	1998	5	Putah Creek at Russell Ranch	5	Sacramento Pike Minnow		4	232	107	1	0.17	0.17	*0.442*
UCDavis	1998	5	Putah Creek at Russell Ranch	5	Sacramento Pike Minnow		4	257	135	1	0.26	0.26	
UCDavis	1998	5	Putah Creek at Russell Ranch	5	Sacramento Pike Minnow		4	270	150	1	0.29	0.29	
UCDavis	1998	5	Putah Creek at Russell Ranch	5	Sacramento Pike Minnow		4	453	990	1	0.48	0.48	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 miles downsteamof LEHR).	13	Sacramento Pike Minnow		4	252	165	1	0.72	0.72	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 miles downsteamof LEHR).	13	Sacramento Pike Minnow		4	318	250	1	0.73	0.73	
UCDavis	1998	5	Putah Creek at Russell Ranch	5	Smallmouth Bass		4	143	40	1	0.25	0.25	*0.300*
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 4)	6	Smallmouth Bass		4	209	100	1	0.35	0.35	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	White Catfish		4	360	745	1	0.1	0.1	*0.175*
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	White Catfish		4	413	1310	1	0.11	0.11	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	White Catfish		4	348	655	1	0.12	0.12	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	White Catfish		4	332	595	1	0.13	0.13	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	White Catfish		4	359	720	1	0.13	0.13	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	White Catfish		4	431	1390	1	0.16	0.16	
UCDavis	1998	9	Putah Creek 0.7 miles downsteam of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 2)	10	White Catfish		4	340	610	1	0.19	0.19	
ATSDR1	1996	3	Approximately 2.4 miles downsteam of LEHR	11	White Catfish	White Catfish (1)	4		2624	1	0.48	0.48	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 miles downsteamof LEHR).	13	White Catfish		4	320	545	1	0.18	0.18	
SRWP	1999		Putah Creek	14?	White Catfish		4	470		1	0.146	0.146	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 4)	6	White Crappie		4	167	50	1	0.15	0.15	*0.283*
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 4)	6	White Crappie		4	190	83	1	0.16	0.16	
UCDavis	1998	6	Putah Creek 2 miles upstream of UCDavis (approximately same location as ATSDR1 and ATSDR2 Site 4)	6	White Crappie		4	165	48	1	0.19	0.19	
UCDavis	1998	11	Putah Creek at Road 106A (approximately 7 miles downsteamof LEHR).	13	White Crappie		4	359	735	1	0.63	0.63	
ATSDR1	1996	2	Approximately 1.2 miles downsteam of LEHR	10	Composite 1 (Site 2)	Carp (1), Black Bullhead (1)	3		1776	2	0.16	0.32	*0.160*
ATSDR1	1996	1	Adjacent to LEHR	9	Composite 1 (Site 1)	Black Crappie (2), Bluegill (1), Largemouth Bass (2)	3-4		1747	5	0.69	3.45	*0.690*
ATSDR1	1996	3	Approximately 2.4 miles downsteam of LEHR	11	Composite 1 (Site 3)	Black Crappie (2), Largemouth Bass (1)	3-4		1598	3	0.24	0.72	*0.240*
ATSDR1	1996	4	Approximately 3.3 miles upsteam of LEHR	6	Composite 1 (Site 4)	Bluegill (78), Green Sunfish (13), Largemouth Bass (3), Crayfish (8), White Catfish (1)	3-4		3035	103	0.13	13.39	*0.130*
ATSDR1	1996	1	Adjacent to LEHR	9	Composite 2 (Site 1)	Crayfish (10), Black Bullhead (4), White Catfish (2)	3-4		3020	16	0.15	2.4	*0.150*
ATSDR1	1996	3	Approximately 2.4 miles downsteam of LEHR	11	Composite 2 (Site 3)	Crayfish (9), Carp (1)	3-4		1985	10	0.13	1.3	*0.130*

HEALTH CONSULTATION

R30-C

FISH SAMPLING IN PUTAH CREEK, 1996

Laboratory for Energy-Related Health Research
Davis, California

CERCLIS NO. CA2890190000

April 4, 1997

Prepared by

Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Federal Facilities Assessment Branch
Energy Section

BACKGROUND

The Agency for Toxic Substances and Disease Registry (ATSDR) is mandated by Congress under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) to conduct public health assessments at all sites listed or proposed for listing on the National Priorities List (NPL, or Superfund list). The Laboratory for Energy-Related Health Research (LEHR) in Davis, California, was listed on the NPL in May 1994.

ATSDR staff first visited the LEHR site in July 1995. As a result of that visit and after reviewing documents pertaining to the site, we issued a site summary report in December 1995. In that report, we recommended that the fish in Putah Creek, adjacent to the LEHR site, be sampled to ensure that people who eat the fish from the creek are not being exposed to unsafe levels of contamination. As a followup to this recommendation, ATSDR asked the Environmental Protection Agency's (EPA's) National Air and Radiation Environmental Laboratory (NAREL) to assist us by collecting and analyzing fish from Putah Creek near the LEHR site. NAREL completed the fish screening survey in September 1996, and this report contains a summary of the results of that study.

EPA NAREL staff asked EPA Region IX scientists to help with this fish survey. EPA Region IX scientists collected a total of 141 fish and crayfish from four locations along Putah Creek in a two week period during August and September 1996. They also collected water and sediment samples from the creek at the same four locations. They packaged the samples and sent them to the NAREL in Montgomery, Alabama, for analysis. NAREL scientists filleted the fish and removed the crayfish tails and, in some cases, combined them to have enough sample for analysis [1].

We have attached the data from the laboratory analyses of fish, water, and sediment collected from Putah Creek to the end of this report. ATSDR scientists and NAREL scientists reviewed the NAREL data [2]. ATSDR offers the following conclusions and recommendations:

CONCLUSIONS

1. Mercury and lead concentrations in some fish collected from Putah Creek pose a public health hazard.

2. Based on the samples that EPA Region IX collected in August and September 1996, neither the water nor the sediment in Putah Creek directly poses a public health hazard.

3. Radionuclides, organic pesticides, polychlorinated biphenyls (PCBs), and metals other than mercury and lead were not present in the fish, water, or sediment collected from Putah Creek in concentrations that pose a public health hazard.

RECOMMENDATIONS

1. Conduct an additional fish study to define the concentration of mercury and lead in different fish species within selected length ranges.

2. Until further data are available, post a general fish advisory for areas of Putah Creek near the former LEHR site; elevated concentrations of mercury and lead in the collected fish justify the advisory.

DISCUSSION

Mercury and lead in fish and crayfish collected from Putah Creek were present at levels that pose a public health hazard. The fish and crayfish that contain elevated levels of mercury or lead were collected at the location (Site #1) nearest the LEHR site. The high concentrations of mercury (0.69 milligrams of mercury per kilogram of wet fish [mg Hg/kg-wet fish]) and lead (1.06 milligrams lead per kilogram of wet fish [mg Pb/kg-wet fish]) were measured in two separate composites of fish fillets (or fish fillets and crayfish tails); each composite was made up of three different species of fish (six species in all). Composite 1 at Site #1 had approximately four times the mercury concentration of Composite 2, and Composite 2 had approximately four times the lead concentration of Composite 1. These data suggest that the bioconcentration of mercury and lead may vary by species of fish. In addition, because these samples are composites, these data reflect *average* concentrations. This means that one or two fish species may have much higher levels of mercury or lead than the maximum levels reported, and other species may have little or no mercury or lead.

ATSDR scientists note that the highest concentrations of mercury and lead reported by NAREL in these samples are higher than concentrations that may be considered toxic to people who would eat these fish frequently. The actual hazard to people depends on how often the people eat the contaminated fish and how much of the fish they eat. Because we do not know how much fish people actually eat from Putah Creek, we based our evaluation on estimated average fish consumption rates for the general U.S. population [3, 4].

Our conclusions and recommendations are based on a limited amount of data because we combined many fish into composite samples to have sufficient sample sizes to perform all the analyses we had planned.

We found that contamination is not at levels that pose a health hazard in the water or sediment. However, lead was in all the sediment samples, and mercury was in those sediment samples from Site #1--the same location where the fish with the highest concentration of mercury were collected.

Mercury and lead are especially toxic to fetuses, infants, and children. Both mercury and lead affect the central nervous system; both methylmercury (the most prevalent form of mercury found in fish) and lead are able to cross the placental and blood-brain barriers in children and cause permanent brain damage. Early signs of mercury poisoning are often nonspecific, e.g., malaise, blurred vision, or hearing loss; higher blood levels of mercury will cause kidney damage. Effects of lead poisoning in children are similar to those of mercury poisoning: impaired neurological development, lower IQ scores, and hearing loss. At significantly elevated blood levels, lead can interfere with normal cell metabolism and induce anemia [5, 6].

We recommend additional fish sampling to differentiate mercury and lead contamination across different species and sizes of fish in Putah Creek. Fish size or length is a surrogate for fish age. Since the fish can bioconcentrate the contaminants (mercury and lead), we expect the older fish will have the highest concentrations of contaminants. Additional fish sampling can clarify whether people who catch fish in Putah Creek should limit their consumption of those fish to certain species and size. Unlike the initial screening survey, which investigated many different contaminants and required large sample weights for the large number of different analytes, the next fishing survey should have to address mercury and lead contamination only. The laboratory analyses for mercury and lead require only small amounts (50 grams wet weight, total) of fish.

For questions or comments, please contact Dr. William H. Taylor, Health Assessor, Agency for Toxic Substances and Disease Registry, Mailstop E-56, Atlanta, Georgia 30333, 404-639-6035.

ATSDR is performing a public health assessment on the LEHR Site. The ATSDR public health assessment is scheduled for release in 1998.

PREPARERS OF REPORT

William H. Taylor, PhD
Health Assessor
Federal Facilities Assessment Branch
ATSDR

Clinton Cox, PhD, CIH, PE
NAREL

REVIEWERS OF REPORT

Burt J. Cooper
Chief, Energy Section
Federal Facilities Assessment Branch
ATSDR

Sandra G. Isaacs
Chief, Federal Facilities Assessment Branch
ATSDR

J. Scott Telofski, PE
NAREL

Vicki D. Lloyd
NAREL

WRITER-EDITOR

Ronald E. Hatcher
Program Evaluation, Records and Information Services Branch
ATSDR

REFERENCES

1. Environmental Protection Agency, National Air and Radiation Environmental Laboratory. Sampling and analysis guidelines for fish, sediment, and water samples from the Putah Creek adjacent to the former Laboratory for Energy-Related Health Research, Davis, CA. 1997 Aug 24.

2. Environmental Protection Agency, National Air and Radiation Environmental Laboratory. Concentrations of selected radionuclides and chemicals in fish, sediment, and water collected from the Putah Creek near the former Laboratory for Energy-Related Health Research, Davis, CA. 1997 Mar 31.

3. Environmental Protection Agency. Guidance for assessing chemical contamination data for use in fish advisories, volume 1, fish sampling and analysis, second edition; 1995 Sep. Report No.:EPA 823-R-95-007,

4. U.S. Department of Agriculture. Food and nutrient intakes by individuals in the United States, 1 day, 1987-1988, nationwide food consumption survey; 1993 Sep. Report No.: 87-I-1.

5. Agency for Toxic Substances and Disease Registry. Toxicological profile for mercury (update). Atlanta: US Department of Health and Human Services, Public Health Service, 1994.

6. Agency for Toxic Substances and Disease Registry. Toxicological profile for lead (update). Atlanta: US Department of Health and Human Services, Public Health Service, 1993.

DATA TABLES FROM ATSDR / EPA NAREL FISH SAMPLING SURVEY, PUTAH CREEK, DAVIS CALIFORNIA, AUGUST-SEPTEMBER 1996

Table 1. Sampling Locations in Putah Creek Adjacent to the LEHR Site, Aug 27-Sep 12, 1996

Sampling Locations for Fish, Sediment, and Water		
Sampling Location	Latitude	Longitude
1	N 38° 31' 2.0"	W 121° 45' 22.1"
2	N 38° 31' 1.6"	W 121° 43' 58.0"
3	N 38° 31' 0.7"	W 121° 42' 46.8"
4 (background)	N 38° 31' 34.4"	W 121° 48' 42.9"

Figure 1.

Putah Creek
Sampling Locations

Table 2. Fish Collected from Putah Creek near the Former LEHR Facility, Aug 27-Sep 12, 1996

Location	Fish Species (#)	Whole Wet Weight (g)	Fillet Wet Weight (g)
1	Black Crappie (2)	489	168
	Bluegill (1)	136	37
	Large Mouth Bass (2)	1122	421
	Composite 1 (5)	1747	626
	Crayfish (10)	413	38
	Black Bullhead (4)	1115	209
	White Catfish (2)	1492	262
	Composite 2 (16)	3020	509
2	Carp (1)	1564	367
	Black Bullhead (1)	212	46
	Composite (2)	1776	413
	Large Month Bass (1)	650	188
3	Black Crappie (2)	364	92
	Large Mouth Bass (1)	1234	362
	Composite 1 (3)	1598	454
	Crayfish (9)	289	26
	Carp (1)	1696	495
	Composite 2 (10)	1985	521
	White Catfish (1)	2624	670
4(background)	Bluegill (78)	1906	394
	Green Sunfish (13)	627	127
	Large Month Bass (3)	192	45
	Crayfish (8)	221	42
	White Catfish (1)	89	12
	Composite (103)	3035	620

Table 3. Radiological Results for Water Collected from Putah Creek near the Former LEHR Facility

Analyte	Site #1 LEHR96.05001/X (pCi/L)		Site #2 LEHR96.05000/X (pCi/L)		Site #3 LEHR96.05005 (pCi/L)	Site #4 LEHR96.04998 (pCi/L)
Gross Alpha	2.57±1.93	3.18±2.19	5.71±2.75	NA	4.57±2.54	1.76±1.73
Gross Beta	3.63±2.20	5.29±2.46	4.41±2.39	NA	6.87±2.67	2.76±2.22
U-238	0.2709±0.0699	NA	0.3430±0.0798	0.3819±0.0813	0.3737±0.0698	0.2737±0.0678
U-234	0.6306±0.1101	NA	0.5139±0.0984	0.6414±0.1075	0.6465±0.0937	0.6238±0.1055
Th-230	0.0414±0.0289	NA	0.0624±0.0340	0.0456±0.0326	0.0480±0.0267	0.0411±0.0282
Ra-226 (γ)	≤77.5	≤74.3	≤78.0	NA	≤79.2	≤85.6
Ra-226	0.26±0.03	0.22±0.05	0.07±0.01	NA	0.09±0.02	0.11±0.02
U-235	0.0463±0.0310	ND	0.0423±0.0309	0.0209±0.0221	0.0835±0.0350	0.0599±0.0361
Th-227	0.0095±0.0291	NA	0.0090±0.0275	0.0639±0.0635	0.0123±0.0214	0.0364±0.0364
Th-232	0.0238±0.0238	NA	0.0101±0.0156	0.0118±0.0182	0.0455±0.0268	0.0103±0.0158
Ra-228 (γ)	≤17.0	≤17.1	≤16.8	NA	≤16.2	≤24.0
Ra-228	2.9±1.0	1.0±1.0	0.35±0.75	NA	-0.12±0.78	0.88±0.73
Th-228	0.0202±0.0680	NA	0.0240±0.0651	0.0284±0.0718	0.0231±0.0555	-0.0330±0.0518
Tl-208	ND	ND	1.67±3.06	NA	ND	ND
Pu-238	0.0072±0.0131	NA	0.0286±0.0317	-0.0077±0.0292	0.0640±0.0564	0.0263±0.0358
Pu-239/240	-0.0012±0.0024	NA	0.00136±0.0090	0.0124±0.0164	0.0021±0.0137	0.0000±0.0101
K-40	≤51.6	≤54.9	≤51.6	NA	≤51.9	33.2±62.8
C-14	-80±82	-72±82	-96±81	NA	-77±82	NA
Ba-140	≤99.9	≤101	≤96.2	NA	≤99.0	≤161
Co-60	≤5.84	≤5.28	≤6.43	NA	≤5.62	≤8.44
Cs-137	≤4.52	≤4.31	≤4.16	NA	≤4.48	≤6.58
I-131	≤79.7	≤79.0	≤79.4	NA	≤80.2	≤101
Sr-89	-3.01±4.76	NA	3.78±4.80	NA	2.08±4.80	1.90±4.41*
Sr-90	0.571±0.717	NA	-0.400±0.755	NA	0.0112±0.757	-0.134±0.667*

(γ) -- measured by gamma spectrometry with a corresponding radiochemical analysis. ND -- not detected.
NA -- not analyzed. X -- designates a replicate analysis.
* Replicate analysis: Sr-89, 7.47±4.96 pCi/L; Sr-90, -0.750±0.740 pCi/L.
"Less than value" is equal to the Minimum Detectable Concentration (MDC).

Table 4. Inorganic Results For Water Collected From Putah Creek Near The Former LEHR Facility

Analyte	CAS Number	Site #1 LEHR96.05001[X] (µg/L or ppb)		Site #2 LEHR96.05000 (µg/L or ppb)	Site #3 LEHR96.05005 (µg/L or ppb)	Site #4 LEHR96.04998 (µg/L or ppb)
Antimony	7440-36-0	2.48[B]	4.43[B]	2.24[B]	2.52[B]	1.94[B]
Arsenic	7440-38-2	3.08[B]	2.03[B]	2.29[B]	3.08[B]	1.31[B]
Barium	7440-39-3	190.0[B]	260.0[B]	530.0[B]	570.0[B]	400.0[B]
Cadmium	7440-43-9	≤0.36	≤0.36	≤0.36	≤0.36	≤0.36
Chromium	7440-47-3	60.0[B]	60.0[B]	30.0[B]	50.0[B]	30.0[B]
Cobalt	7440-48-4	≤2.5	≤2.5	≤2.5	2.6[B]	≤2.5
Lead	7439-92-1	3.02	1.57[B]	≤1.26	1.52[B]	≤1.26
Mercury	7439-97-6	≤0.05	≤0.05	≤0.05	≤0.05	≤0.05
Nickel	7440-02-0	7.1[B]	8.07[B]	≤5.5	17.8[B]	≤5.5
Selenium	7782-49-2	≤1.07	≤1.07	≤1.07	≤1.07	≤1.07
Silver	7440-22-4	≤0.18	≤0.18	≤0.18	≤0.18	0.21[B]
Thallium	7440-28-0	≤0.80	≤0.80	2.01[B]	≤0.80	≤0.80
Vanadium	7440-62-2	7.8[B]	7.5[B]	7.2[B]	12.5[B]	6.1[B]
Zinc	7440-66-6	70.0	80.0	60.0	70.0	60.0

[B] The value is less than the Reporting Limit but greater than or equal to the Instrument Detection Limit (IDL).
[X] The values in the second column are from a replicate analysis.

Table 5. Organic Results For Water Collected From Putah Creek Near The Former LEHR Facility

Analyte	CAS Number	Site #1 LEHR96.05001 (μg/L or ppb)	Site #2 LEHR96.05000 (μg/L or ppb)	Site #3 LEHR96.05005 (μg/L or ppb)	Site #4 LEHR96.04997 (μg/L or ppb)
Chlordane (Total)	57-74-9	≤0.05	≤0.05	≤0.05	≤0.05
4,4"-DDT	50-29-3	≤0.10	≤0.10	≤0.10	≤0.10
Dicofol	115-32-2	≤0.20	≤0.20	≤0.20	≤0.20
Dieldrin	60-57-1	≤0.10	≤0.10	≤0.10	≤0.10
Endosulfan I	959-98-8	≤0.05	≤0.05	≤0.05	≤0.05
Endosulfan II	33213-65-9	≤0.10	≤0.10	≤0.10	≤0.10
Endrin	72-20-8	≤0.10	≤0.10	≤0.10	≤0.10
Heptachlor Epoxide	1024-57-3	≤0.05	≤0.05	≤0.05	≤0.05
Hexachlorobenzene	118-74-1	≤0.05	≤0.05	≤0.05	≤0.05
Lindane	58-89-9	≤0.05	≤0.05	≤0.05	≤0.05
Toxaphene	8001-35-2	≤5.0	≤5.0	≤5.0	≤5.0
Aroclor 1016	12674-11-2	≤1.0	≤1.0	≤1.0	≤1.0
Aroclor 1221	11104-28-2	≤2.0	≤2.0	≤2.0	≤2.0
Aroclor 1232	11141-16-5	≤1.0	≤1.0	≤1.0	≤1.0
Aroclor 1242	53469-21-9	≤1.0	≤1.0	≤1.0	≤1.0
Aroclor 1248	12672-29-6	≤1.0	≤1.0	≤1.0	≤1.0
Aroclor 1254	11097-69-1	≤1.0	≤1.0	≤1.0	≤1.0
Aroclor 1260	11096-82-5	≤1.0	≤1.0	≤1.0	≤1.0

Note: The "less than value" is the Reporting Limit, i.e., analyte was analyzed for but not detected.

Table 6. Radiological Results for Sediment Collected from Putah Creek near the Former LEHR Facility

Analyte	Site #1 LEHR96.05002/X (pCi/g-dry)		Site #2 LEHR96.05003 (pCi/g-dry)	Site #3 LEHR96.05004 (pCi/g-dry)	Site #4 LEHR96.04999/X (pCi/g-dry)	
Gross Alpha	7.17±5.25	5.91±5.01	8.00±5.21	10.2±5.70	7.42±5.53	NA
Gross Beta	14.8±3.31	13.4±3.16	17.1±3.38	12.6±3.06	12.4±3.19	NA
U-238	0.343±0.0779	0.435±0.0904	0.631±0.102	0.459±0.0727	0.523±0.0971	NA
Th-234	ND	NA	0.399±0.150	ND	ND	ND
U-234	0.555±0.101	0.544±0.101	0.627±0.100	0.565±0.0810	0.431±0.088	NA
Th-230	0.369±0.0707	0.387±0.0682	0.576±0.0843	0.488±0.0753	0.549±0.0863	NA
Ra-226 (γ)	0.698±0.145	NA	1.30±0.223	0.860±0.207	1.06±0.216	1.24±0.201
Ra-226	0.43±0.04	0.41±0.03	0.92±0.04	0.59±0.03	0.71±0.04	NA
Pb-214	0.314±0.0158	NA	0.481±0.0214	0.385±0.0198	0.484±0.0219	0.561±0.0209
Bi-214	0.286±0.0169	NA	0.458±0.0230	0.369±0.0212	0.445±0.0238	0.518±0.0219
U-235	0.0285±0.0275	0.0684±0.0400	0.0806±0.0400	0.0483±0.0250	0.0698±0.0392	0.0755±0.0122
U-235 (γ)	ND	NA	0.0799±0.0134	ND	ND	ND
Th-227	0.0183±0.0254	0.0414±0.0308	0.0256±0.0248	0.0207±0.0207	0.0502±0.0366	NA
Ra-223	ND	NA	0.0681±0.0448	ND	ND	ND
Th-232	0.290±0.0624	0.326±0.0624	0.587±0.0851	0.545±0.0795	0.477±0.0802	NA
Ra-228 (γ)	0.296±0.0210	NA	0.594±0.0316	0.420±0.0296	0.483±0.0313	0.532±0.0295
Ra-228	1.1±0.56	0.99±0.52	1.7±0.54	0.94±0.56	0.99±0.65	NA
Th-228	0.314±0.0654	0.332±0.0638	0.676±0.0919	0.414±0.0699	0.510±0.0831	NA
Ra-224	0.223±0.155	NA	0.470±0.218	0.276±0.219	0.477±0.230	0.578±0.207
Pb-212	0.304±0.0165	NA	0.675±0.0236	0.432±0.0202	0.562±0.0230	0.574±0.0217
Bi-212	0.349±0.0901	NA	0.627±0.126	0.488±0.105	0.591±0.121	0.501±0.117
Tl-208	0.113±0.00936	NA	0.216±0.0127	0.154±0.0117	0.173±0.0128	0.199±0.0127
Pu-238	-0.00486±0.0335	-0.00272±0.0265	0.00475±0.0369	0.0000±0.0075	0.0224±0.0416	NA
Pu-239/240	0.0227±0.0215	0.00818±0.0147	0.00317±0.0098	0.00606±0.0084	0.00203±0.0132	NA
K-40	8.35±0.193	NA	13.7±0.271	9.83±0.253	9.87±0.266	9.92±0.239
Cs-137	0.0140±0.0057	NA	≤0.0167	0.0245±0.0079	≤0.0186	≤0.0179
Ba-140	≤0.308	NA	≤0.360	≤0.337	≤0.405	≤3.64
Co-60	≤0.0171	NA	≤0.0211	≤0.0194	≤0.0224	≤0.0201

Analyte	Site #1 LEHR96.05002/X (pCi/g-dry)		Site #2 LEHR96.05003 (pCi/g-dry)	Site #3 LEHR96.05004 (pCi/g-dry)	Site #4 LEHR96.04999/X (pCi/g-dry)	
I-131	≤0.250	NA	≤0.292	≤0.246	≤0.330	≤11.6
Sr-89	6.38±4.78'	NA	1.29±3.76	1.70±4.14	0.673±4.01	2.35±3.84
Sr-90	-0.662±0.659	NA	-0.128±0.561	-0.329±0.656	0.0351±0.612	0.187±0.561

"Less than value" is equal to the Minimum Detectable Concentration (MDC). γ – measured by gamma spectrometry. ND - not detected.
NA - not analyzed. + – less than MDC. X - designates replicate analysis.

Table 7. Inorganic Results for Sediment Collected from Putah Creek near the Former LEHR Facility

Analyte	CAS Number	Site #1 LEHR96.05002[X] (mg/kg or ppm)		Site #2 LEHR96.05003 (mg/kg or ppm)	Site #3 LEHR96.05004 (mg/kg or ppm)	Site #4 LEHR96.04999[X] (mg/kg or ppm)	
Antimony	7440-36-0	0.64[B]	0.54[B]	1.11[B]	0.92[B]	1.36	NA
Arsenic	7440-38-2	6.19	NA	10.12	5.92	12.09	12.35
Barium	7440-39-3	≤49.36	57.22[B]	98.05[B]	82.77[B]	127.01[B]	NA
Cadmium	7440-43-9	≤0.09	NA	≤0.09	≤0.10	0.48	0.19[B]
Chromium	7440-47-3	239.94	292.32	89.79	220.18	173.32	NA
Cobalt	7440-48-4	20.9	20.91	15.0	16.2	21.3	NA
Lead	7439-92-1	7.22	NA	9.93	9.06	9.27	9.52
Mercury	7439-97-6	0.15	0.18	≤0.03	≤0.03	≤0.03	NA
Nickel	7440-02-0	248	247.69	65.1	175	177	NA
Selenium	7782-49-2	0.29[B]	NA	0.31[B]	0.37[B]	0.40[B]	0.33[B]
Silver	7440-22-4	0.42	NA	0.07[B]	0.25[B]	0.11[B]	0.05[B]
Thallium	7440-28-0	≤0.21	NA	0.23[B]	≤0.22	0.22[B]	0.22[B]
Vanadium	7440-62-2	42.00	42.02	56.9	43.1	59.3	NA
Zinc	7440-66-6	102.45	150.32	162.04	116.99	105.32	NA

[B] The value is less than the Reporting Limit but greater than or equal to the Instrument Detection Limit (IDL).

[X] The values in the second column are from a replicate analysis. NA – not analyzed.

Table 8. Organic Results for Sediment Collected from Putah Creek near the Former LEHR Facility

Analyte	CAS Number	Site #1 LEHR96.05002 (μg/kg or ppb)	Site #2 LEHR96.05003 (μg/kg or ppb)	Site #3 LEHR96.05004 (μg/kg or ppb)	Site #4 LEHR96.04999 (μg/kg or ppb)
Chlordane (Total)	57-74-9	≤2.2	≤2.2	≤2.3	≤2.2
4,4"-DDT	50-29-3	≤4.3	≤4.2	≤4.5	≤4.4
Dicofol	115-32-2	≤8.6	≤8.4	≤9.0	≤8.7
Dieldrin	60-57-1	≤4.3	≤4.2	≤4.5	≤2.2
Endosulfan I	959-98-8	≤2.2	≤2.2	≤2.3	≤2.2
Endosulfan II	33213-65-9	≤4.3	≤4.2	≤4.5	≤4.4
Endrin	72-20-8	≤4.3	≤4.2	≤4.5	≤4.4
Heptachlor Epoxide	1024-57-3	≤2.2	≤2.2	≤2.3	≤2.2
Hexachlorobenzene	118-74-1	≤2.2	≤2.2	≤2.3	≤2.2
Lindane	58-89-9	≤2.2	≤2.2	≤2.3	≤2.2
Toxaphene	8001-35-2	≤220	≤220	≤230	≤220
Aroclor 1016	12674-11-2	≤43	≤42	≤45	≤43
Aroclor 1221	11104-28-2	≤86	≤84	≤92	≤88
Aroclor 1232	11141-16-5	≤43	≤42	≤45	≤43
Aroclor 1242	53469-21-9	≤43	≤42	≤45	≤43
Aroclor 1248	12672-29-6	≤43	≤42	≤45	≤43
Aroclor 1254	11097-69-1	≤43	≤42	≤45	≤43
Aroclor 1260	11096-82-5	≤43	≤42	≤45	≤43

Note: The "less than value" is the Reporting Limit, i.e., analyte was analyzed for but not detected.

Table 9. Radiological Results for Fish Collected from Putah Creek near the Former LEHR Facility

Analyte	Site #1, Comp 1/Comp 1/Comp 2 LEHR96.05987/7X/8 (pCi/g-wet)			Site #2, Comp/LMB LEHR96.05989/73 (pCi/g-wet)		Site #3, Comp 1, Comp 2, WCF LEHR96.05990/91/81 (pCi/g-wet)			Site #4, Comp LEHR96.05992 (pCi/g-wet)
Gross Alpha	0.0933±0.0792	NA	0.0917±0.0859	0.00825±0.0547	NA	0.000±0.0580	-0.00285±0.0403	0.0207±0.0408	0.0476±0.0732
Gross Beta	3.36±0.142	NA	3.13±0.143	3.12±0.135	NA	3.44±0.149	3.13±0.135	3.29±0.128	3.14±0.165
U-238	0.000524±0.000349	NA	0.00122±0.000521	0.000646±0.000421	0.000540±0.000473	0.000863±0.000490	0.000876±0.000471	0.000102±0.000187	0.00131±0.000528
Th-234	ND	ND	ND	ND	ND	ND	ND	ND	ND
U-234	0.000475±0.000353	NA	0.00110±0.000500	0.000855±0.000475	0.000731±0.000546	0.00177±0.000639	0.00170±0.000636	0.000408±.0.000314	0.00150±0.000570
Th-230	0.000099±0.000114	NA	0.00177±0.000554	0.000812±0.000334	0.000222±0.000216	0.000711±0.000379	0.000562±0.000308	0.000546±0.000368	0.00113±0.000674
Ra-226 (γ)	≤0.0907	≤0.0891	≤0.198	≤0.181	≤0.279	≤0.354	≤0.108	≤0.0799	≤0.0910
Ra-226	0.03±0.01	NA	0.03±0.01	0.07±0.01	0.03±0.01	-0.01±0.01	0.01±0.01	0.04±0.01*	0.02±0.01
Pb-214	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bi-214	ND	ND	ND	ND	ND	ND	ND	ND	ND
U-235	ND	ND	ND	ND	ND	ND	ND	ND	ND
U-235 (γ)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Th-227	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ra-223	ND	ND	ND	ND	ND	ND	ND	ND	ND
Th-232	0.000154±0.000149	NA	0.00475±0.000907	0.00410±0.000753	0.000±0.000110	0.000152±0.000211	0.000288±0.000217	-0.0000494±0.000262	0.000354±0.000391
Ra-228 (γ)	≤0.0203	≤0.0317	≤0.0506	≤0.0469	≤0.0619	≤0.0685	≤0.0340	≤0.0289	≤0.0223
Ra-228	0.18±0.15	NA	0.07±0.15	0.06±0.13	0.10±0.18	0.19±0.18	0.16±0.17	0.40±0.20	0.20±0.19
Th-228	-0.00195±0.000263	NA	0.00348±0.00102	0.00351±0.000902	-0.00290±0.000538	-0.000510±0.000633	0.000679±0.000414	-0.000368±0.000639	0.000607±0.00121
Ra-224	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pb-212	ND	ND	ND	ND	ND	0.0209±0.0216	ND	ND	ND
Bi-212	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tl-208	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pu-238	-0.000387±0.000415	0.0000362±0.000114	-0.000169±0.000313	0.0000107±0.000126	NA	0.0000516±0.000103	0.000387±0.000485	0.000192±0.000339	0.000215±0.000625
Pu-239/240	0.000±0.000141	0.0000362±0.000114	0.0000563±0.000172	0.0000321±0.0000641	NA	0.0000861±0.000150	0.0000738±0.000165	0.000±0.000	-0.0000537±0.0000760
K-40	3.11±0.101	3.04±0.147	2.54±0.224	2.84±0.174	3.41±0.229	2.94±0.211	2.99±0.166	3.01±0.137	2.62±0.0948
C-14	4.9±1.8	NA	5.4±1.7	3.9±1.9	2.4±2.1	3.6±2.8	4.8±1.6	3.8±1.6*	20±14
Cs-137	≤0.00538	≤0.00739	≤0.0157	≤0.0132	≤0.0175	≤0.0192	≤0.00929	≤0.00657	≤0.00571
Ba-140	≤0.251	≤0.594	≤0.565	≤1.13	≤0.268	≤0.861	≤0.356	≤0.0907	≤0.398
Co-60	≤0.00665	≤0.0100	≤0.0129	≤0.0151	≤0.0221	≤0.0248	≤0.0131	≤0.0106	≤0.00802
Hg-203	0.0137±0.00431	0.0109±0.0054	ND	ND	ND	ND	ND	ND	ND
I-131	≤0.298	≤0.989	≤0.711	≤2.45	≤0.188	≤1.08	≤0.387	≤0.0550	≤0.575
Sr-89	0.0824±0.0691'	0.0561±0.0954	-0.00365±0.0625	-0.0208±0.0477	NA	0.0369±0.0664	-0.0123±0.0634	0.000216±0.0537	-0.0537±0.113
Sr-90	-0.00903±0.00954	-0.00366±0.0133	0.00217±0.0103	0.00618±0.00686	NA	-0.00717±0.0111	0.00417±0.0107	0.00300±0.00882	0.0139±0.0163

γ -- measured by gamma spectrometry with a corresponding radiochemical analysis. ND -- not detected. NA -- not analyzed. + -- less than Minimum Detectable Concentration (MDC). X -- designates a replicate analysis.

*-- Replicate analysis, C-14, 15±1.8; Ra-226, 0.03±0.01; Ra-228, 0.64±0.28. "Less than value" is equal to the MDC.

Table 10. Inorganic Results for Fish Collected from Putah Creek near the Former LEHR Facility

Analyte	CAS Number	Site #1, Comp 1/2 LEHR96.05987/8 (mg/kg-wet or ppm-wet)		Site #2, LMB/Comp LEHR96.05973/89 (mg/kg-wet or ppm-wet)		Site #3, WCF/WCF/Comp 1/Comp 2 LEHR96.05981/81[X]/90/91 (mg/kg-wet or ppm-wet)				Site #4, Comp LEHR96.05992 (mg/kg-wet or ppm-wet)
Antimony	7440-36-0	0.38[B]	0.49[B]	0.70	0.44[B]	0.75	0.52	0.53	0.41[B]	0.84
Arsenic	7440-38-2	≤0.06	≤0.06	≤0.06	≤0.06	≤0.06	≤0.06	≤0.06	0.11[B]	≤0.06
Barium	7440-39-3	≤12.0	≤12.0	≤12.0	≤12.0	≤12.0	≤12.0	≤12.0	≤12.0	≤12.0
Cadmium	7440-43-9	≤0.02	≤0.02	≤0.02	≤0.02	≤0.02	≤0.02	≤0.02	≤0.02	≤0.02
Chromium	7440-47-3	≤9.10	≤9.10	≤9.10	≤9.10	≤9.10	≤9.10	≤9.10	≤9.10	≤9.10
Cobalt	7440-48-4	≤0.25	≤0.25	≤0.45	≤0.25	≤0.25	≤0.25	≤0.25	0.29[B]	≤0.25
Lead	7439-92-1	0.28[B]	1.06	0.20[B]	0.17[B]	0.17[B]	≤0.08	0.24[B]	0.19[B]	≤0.08
Mercury	7439-97-6	0.69	0.15	0.25	0.16	0.48	0.46	0.24	0.13	0.13
Nickel	7440-02-0	≤0.55	0.90[B]	≤0.55	≤0.55	≤0.55	≤0.55	≤0.55	≤0.55	≤0.55
Selenium	7782-49-2	0.27[B]	≤0.08	0.25[B]	0.25[B]	≤0.08	≤0.08	0.23[B]	0.36[B]	0.33[B]
Silver	7440-22-4	0.04[B]	0.03[B]	0.65	0.02[B]	0.03[B]	0.03[B]	0.01[B]	0.01[B]	0.01[B]
Thallium	7440-28-0	≤0.06	≤0.06	≤0.06	≤0.06	0.12[B]	0.10[B]	≤0.06	≤0.06	≤0.06
Vanadium	7440-62-2	≤0.17	≤0.17	≤0.17	≤0.17	≤0.17	≤0.17	≤0.17	≤0.17	≤0.17
Zinc	7440-66-6	9.80	8.70	12.0	13.4	6.10	11.6	8.70	15.3	17.60

[B] The value is less than the Reporting Limit but greater than or equal to the Instrument Detection Limit (IDL).

[x] The values in the second column are from a replicate analysis.

Table 11. Organic Results for Fish Collected from Putah Creek near the Former LEHR Facility

Analyte	CAS Number	Site #1, Comp 1/2 LEHR96.05987/8 (µg/kg-wet or ppb-wet)		Site #2, LMB/Comp LEHR96.05973/89 (µg/kg-wet or ppb-wet)		Site #3, WCF/ Comp 1/Comp 2 LEHR96.05981/90/91 (µg/kg-wet or ppb-wet)			Site #4, Comp LEHR96.05992 (µg/kg-wet or ppb-wet)
Chlordane (Total)	57-74-9	≤5.1	≤5.1	≤5.1	≤5.1	≤5.1	≤5.1	≤5.1	≤5.1
4,4"-DDT	50-29-3	≤10.0	≤10.0	≤10.0	≤10.0	≤20.0	≤10.0	≤10.0	≤10.0
Dicofol	115-32-2	≤10.0	≤10.0	≤10.0	≤10.0	≤10.0	≤10.0	≤10.0	≤10.0
Dieldrin	60-57-1	≤10.0	≤10.0	≤10.0	≤10.0	≤10.0	≤10.0	≤10.0	≤10.0
Endosulfan I	959-98-8	≤5.0	≤5.0	≤5.0	≤5.0	≤5.1	≤5.0	≤5.0	≤5.0
Endosulfan II	33213-65-9	≤10.0	≤10.0	≤10.0	≤10.0	≤10.0	≤10.0	≤10.0	≤10.0
Endrin	72-20-8	≤10.0	≤10.0	≤10.0	≤10.0	≤10.0	≤10.0	≤10.0	≤10.0
Heptachlor Epoxide	1024-57-3	≤5.1	≤5.1	≤5.1	≤5.1	≤5.1	≤5.1	≤5.1	≤5.1
Hexachlorobenzene	118-74-1	≤5.1	≤5.1	≤5.1	≤5.1	≤5.1	≤5.1	≤5.1	≤5.1
Lindane	58-89-9	≤5.1	≤5.1	≤5.1	≤5.1	≤5.1	≤5.1	≤5.1	≤5.1
Toxaphene	8001-35-2	≤510	≤510	≤510	≤510	≤510	≤510	≤510	≤510
Aroclor 1016	12674-11-2	≤100	≤100	≤100	≤100	≤100	≤100	≤100	≤100
Aroclor 1221	11104-28-2	≤200	≤200	≤200	≤200	≤200	≤200	≤200	≤200
Aroclor 1232	11141-16-5	≤100	≤100	≤100	≤100	≤100	≤100	≤100	≤100
Aroclor 1242	53469-21-9	≤100	≤100	≤100	≤100	≤100	≤100	≤100	≤100
Aroclor 1248	12672-29-6	≤100	≤100	≤100	≤100	≤100	≤100	≤100	≤100
Aroclor 1254	11097-69-1	≤100	≤100	≤100	≤100	≤100	≤100	≤100	≤100
Aroclor 1260	11096-82-5	≤100	≤100	≤100	≤100	≤100	≤100	≤100	≤100

HEALTH CONSULTATION

R 30 - E

SURVEY OF FISH IN PUTAH CREEK
(PHASE II)

Laboratory for Energy-Related Health Research
Davis, California

CERCLIS NO. CA2890190000

September 16, 1998

Prepared by

Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Federal Facilities Assessment Branch
Energy Section

PURPOSE

The purpose of this health consultation is to report the results from an ATSDR fish survey of the fish in Putah Creek in 1997, and report our conclusions and public health recommendations from that survey. The survey was conducted to better define the concentrations of mercury and lead in different fish species in Putah Creek.

BACKGROUND

This report is the second health consultation issued by the Agency for Toxic Substances and Disease Registry (ATSDR) which addresses fish in Putah Creek near the Laboratory for Energy-Related Health Research (LEHR) Superfund site on the University of California at Davis (UCD) campus, in Davis, California.

ATSDR recommended in a Site Summary report in December 1995 that fish in Putah Creek should be sampled and analyzed for hazardous substances, because people were eating fish from Putah Creek and there had been no previous analyses of the fish [1]. The U.S. Environmental Protection Agency (EPA) Region IX collected fish and crayfish, water, and sediment samples from four locations along the creek, and the EPA National Air and Radiation Environmental Laboratory (NAREL) analyzed the samples for ATSDR. ATSDR released a health consultation in April 1997 describing the results of the first fish survey [2].

The most important conclusion in the first health consultation was that mercury and lead concentrations in some fish collected from Putah Creek pose a public health hazard to people who eat the fish. However, NAREL composited many of the fish and crayfish before analyzing them because the laboratory required certain sample volumes to do all the analyses planned (18 pesticides and other organic chemicals, 14 metals, gross alpha, gross beta, and gamma spectrometry). Compositing the fish was appropriate for an initial screening survey of this kind.

Because mercury and lead were elevated in composite fish samples, ATSDR recommended in the first health consultation that an additional fish study be conducted to better define the concentrations of mercury and lead in different fish species. EPA agreed to assist ATSDR again, to collect a second round of fish and crayfish from Putah Creek. This health consultation reports the results of those efforts.

EPA Region IX collected a total of 152 fish and crayfish, plus water and sediment samples, at five locations along Putah Creek in October and November 1997. EPA staff were assisted by staff from Thomas R. Payne & Associates, Inc. (TRPA). TRPA is an independent contractor conducting fisheries monitoring on lower Putah Creek for the Solano County Water Agency. TRPA has sampled fish in Putah Creek for six years. Their staff shared their fishing expertise and their knowledge of Putah Creek with EPA staff for this ATSDR program. EPA Region IX scientists packaged the samples and sent them to the NAREL in

Montgomery, Alabama, for analysis. NAREL scientists homogenized the whole fish or crayfish. Composite samples of two or more fish were prepared of some of the fish, of a single species and size range from a single location.

We have attached the data from the laboratory analyses of fish, water, and sediment collected from Putah Creek to the end of this report. ATSDR scientists and NAREL scientists reviewed the NAREL data. ATSDR offers the following results, conclusions, recommendations, and follow-up public health actions based on these data.

RESULTS

1. All largemouth bass samples contained mercury. The mercury concentrations in the samples ranged from 0.11 milligrams of mercury per kilogram of fish (mg/kg-fish) to 0.81 mg/kg-fish. The largemouth bass contained the highest levels of mercury that were found in this survey.

2. The highest levels of lead were found in crayfish. All crayfish samples contained lead. The lead concentrations in the samples ranged from 0.15 mg/kg-fish to 1.1 mg/kg-fish.

CONCLUSIONS

1. The concentrations of mercury in some largemouth bass in Putah Creek are at levels of health concern for fetuses and nursing children whose mothers eat these fish.

2. The concentrations of lead and other metals in crayfish in Putah Creek are *not* at levels of health concern for people who eat these fish.

3. The 101 bluegill, 4 carp, 1 channel catfish, and 1 black bullhead fish that we caught did not contain toxic metals at levels of public health concern.

4. None of the radiological analyses of any of the fish indicate that radionuclides in the fish pose a public health hazard.

5. None of the analyses indicate that metals or radionuclides in water pose a public health hazard.

6. None of the analyses indicate that metals or radionuclides in sediment pose a public health hazard.

RECOMMENDATIONS

Women of child bearing age, especially those who are pregnant or are nursing, should refrain from eating largemouth bass from Putah Creek.

FOLLOW-UP PUBLIC HEALTH ACTIONS

1. ATSDR representatives will meet with local health officials to develop and implement a plan for providing information about the fish survey to people who eat fish from Putah Creek. This information will include a brochure that outlines the results of the fish survey, provides suggestions to reduce exposure to mercury, and provides names of agency representatives who can answer questions about the study.

2. ATSDR will work with representatives from the local health departments to distribute information to local health care providers who provide care to pregnant or lactating women who may consume fish from Putah Creek. This information will include a summary of the fish survey and health implications of mercury exposure, and will be targeted to the interests of health care providers.

DISCUSSION

Although we were able to catch a substantial number of bluegill and we had enough fish of each species to adequately complete our laboratory analyses, we had important gaps in some fish species and fish sizes that limit what we can state about the hazards from eating these fish. The low numbers of channel catfish, carp, and black bullhead we collected mean that we have less certainty that the concentrations of metals and radionuclides we measured are typical of the concentrations we would find throughout these species in Putah Creek. In addition, the numbers of fish of different species that we caught may not be representative of what local fishers typically catch and eat. For example, we collected only one channel catfish. However, catfish are a species sought by fishers, and people who fish from Putah Creek likely catch and eat more of these fish than our data suggest.

Largemouth bass:

Mercury was detected in all the largemouth bass that we caught. The large-sized largemouth bass have more mercury and higher concentrations of mercury in them than the small-sized largemouth bass; thus, the largemouth bass are bioaccumulating mercury. As a first approximation, mercury concentration increases in largemouth bass by one unit (1 mg/kg-fish) for every two kilogram increase in body mass of the fish. See Figure 1. We have also plotted milligrams of mercury vs. fish mass for largemouth bass in Figure 2 to show how mercury content increases with (largemouth bass) fish size.

There is no indication that the location where we caught largemouth bass had any significant bearing on the accumulation of mercury. When we take into consideration the size of the fish, mercury accumulation in largemouth bass was consistent at all locations where we caught those fish. However, we only caught large-sized largemouth bass at locations 1 and 2, and no largemouth bass at location 4. We would have liked to have caught fish from each size range at each location to better determine whether location had any affect on mercury accumulation. We suspect, however, that these data gaps are not important because the fish do not stay at one location and mercury concentrations in sediment were similar at all locations (0.7

± 0.4 mg mercury per kilogram sediment dry weight). Therefore, until more or better data become available, we expect that other largemouth bass caught in this area of Putah Creek will contain mercury at concentrations similar to those we found in this survey.

ATSDR has proposed a minimum risk level (MRL) for chronic oral exposure to methylmercury of 0.0005 milligrams of methylmercury per kilogram body weight per day (0.0005 mg/kg/day) [3]. An MRL is an estimate of the daily human exposure to a hazardous substance that is likely to be without an appreciable risk of adverse noncancerous health effects over a specified duration of exposure. ATSDR derived this proposed MRL primarily from a study designed to test the hypothesis that prenatal exposure to low concentrations of methylmercury through maternal ingestion of fish is related to child development outcomes [4]. The child development outcome that was noted in the study that apparently arose from the lowest exposure levels of mercury that were above the proposed MRL is decreased physical activity in male infants.

We have assumed that all the mercury in the fish we caught in Putah Creek is methylmercury. We considered, as we did in our previous health consultation, an average consumption rate of 54 grams of fish per day [5]. This amount (54 grams = 1.9 ounces) is an average daily rate derived from an equivalent of approximately two meals of fish per week (e.g., 1.9 ounces/day x 7 days = 13.3 ounces per week). For a 60 kilogram adult female eating 54 grams of fish per day, the proposed MRL equates to approximately 0.56 mg/kg-fish, or 0.56 ppm in fish. We used 0.56 mg/kg-fish as our screening value for mercury in fish. Mercury concentrations in the two largest largemouth bass exceeded this value.

The concentrations of mercury we observed in the two largest largemouth bass could have an effect on the development of the fetus or the nursing child whose mother eats these fish more than once a week. We acknowledge that a typical fish meal from Putah Creek will likely contain fish other than largemouth bass, and mercury levels in the majority of the largemouth bass caught in this survey are below the ATSDR proposed MRL. However, Putah Creek may also contain larger largemouth bass than the ones we caught, and we expect larger largemouth bass will have higher levels of mercury than those we measured[1]. Therefore, we recommend that pregnant and nursing women avoid eating largemouth bass from Putah Creek because of the possibility they will eat larger fish than those we caught, as well as the uncertainties in the consumption rates of women eating fish from Putah Creek.

Crayfish:

Crayfish contained the highest levels of lead we measured in this fish survey. Lead was detected in all the crayfish samples.

---

[1] The state record for the largest largemouth bass caught in the State of California, i.e., 21.75 lbs., is more than five times larger than the largest one we caught, though we don't know whether Putah Creek could support larger fish than those we caught [6].

Lead is a toxic metal that affects virtually every system in the body. It is particularly toxic to developing fetuses and young children. Developmental neurobehavior effects have been observed in humans following prenatal exposure to low levels of lead [7]. In 1991, the Centers for Disease Control (CDC) recommended a threshold for intervention of 10 micrograms of lead per deciliter of blood (10 μg/dL) in children [8]. We evaluated lead in fish by considering whether the concentrations of lead in the crayfish could lead to blood lead levels of 10 μg/dL.

We used a consumption rate of 54 grams of crayfish per day and a diet slope factor of 0.034 μg/dL per μg of lead ingested per day to calculate the blood lead level of a pregnant woman eating crayfish at the highest concentration of lead in crayfish that we measured [5, 9].

We considered that people may eat more crayfish (total mass) per meal than they eat of finfish, but they eat fewer meals of crayfish per month (on average) than meals of finfish. There are few fish consumption surveys available that estimate shellfish consumption separate from total fish consumption. It appears that the consumption of shellfish among fishers and their families may be half, or less, than that of finfish [10]. For our calculations, and to be conservative, we used the same consumption rate (54 grams per day) as we used for finfish.

Our calculations indicate the blood lead level of a woman eating crayfish with the maximum levels of lead we measured would be approximately 2 μg/dL. Inhalation of dust and consumption of other food and beverages will contribute an additional 0.5 μg lead per dL blood [7]. The combined blood lead concentration (2.5 μg/dL) from crayfish and other environmental sources is well below the threshold for intervention (10 μg/dL) for blood lead levels in children. Therefore, the lead levels in the fish we collected from Putah Creek are not a public health hazard to fetuses or infants whose mothers eat those fish.

OTHER RESULTS AND ISSUES

In addition to the fish, EPA staff collected water and sediment samples at the five fishing locations along Putah Creek. None of the concentrations of metals or radionuclides detected in water or sediment samples were at levels of health concern. The only radionuclides detected in these samples that are not naturally occurring are cesium-134, cesium-137, and iodine-131. Iodine-131 was detected in water and the cesium isotopes were detected in sediment. Neither iodine nor cesium were detected in fish[2]. The concentrations of metals and radionuclides in sediment were similar at all five locations. We are providing those data at the end of this report along with the fish data.

---

[2] Based on our results in the first fish survey, our highest analytical priority for these fish samples was mercury and lead concentrations. Therefore, NAREL analyzed the metals first to insure compliance with sample holding times specified by the analytical methodologies for mercury and lead. Because we did not expect to find short-lived radionuclides in the fish, gamma spectrometry was not performed early enough to have been able to detect iodine-131 in the fish.

This health consultation does not address whether some fish in Putah Creek may be safe to eat. We did not collect a sufficient quantity of some fish species (e.g., black bullhead, channel catfish) to know whether the contaminant levels we measured in these fish are representative of the concentrations in their respective populations in Putah Creek. In addition, we have only incomplete data describing concentrations of toxic organic substances, such as pesticides, in the fish in Putah Creek. (The NAREL laboratories did not analyze any of the fish collected in this survey for toxic organic substances.) None of the information we do have— except mercury in largemouth bass as described in this report— indicates the fish in Putah Creek pose a health hazard to people who eat them. However, the data we have do not fully address whether toxic organic substances are at levels of health concern in the fish.

We have found, after two surveys, that it is not a simple matter to collect sufficient numbers of fish of different species to perform all the laboratory analyses we need to reach conclusions and make public health recommendations. This suggests that we may not be able to catch enough fish to answer all the questions about the safety of the fish as a food source that we would like to have answered. An alternate approach, such as conducting a more thorough survey of creek sediment, or surveying an indicator species, such as freshwater clams (*Corbicula fluminea*) may provide more useful information. ATSDR is currently evaluating the information that is available. We welcome any comments and suggestions and will evaluate these fully before recommending further investigations of Putah Creek.

Figure 1.

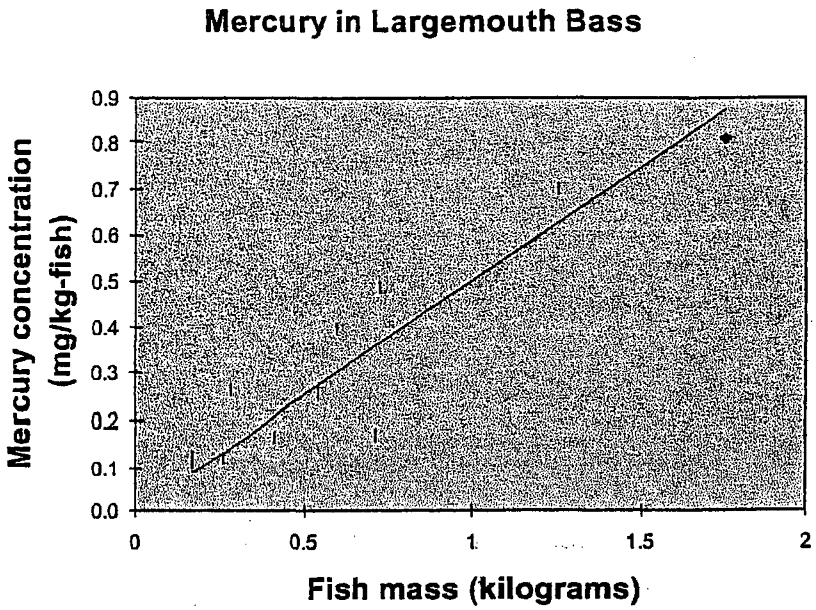
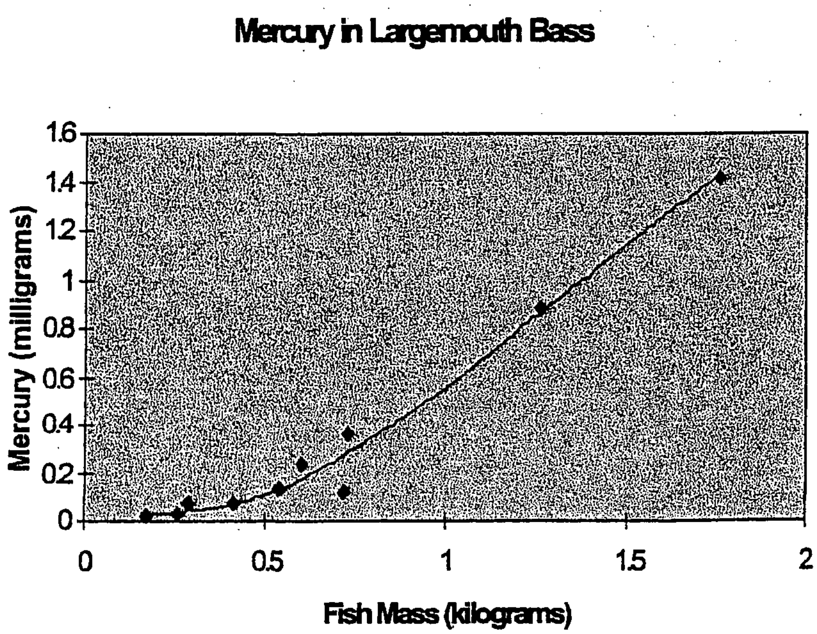


Figure 2.



PREPARERS OF REPORT

William H. Taylor, PhD, DABT
Health Assessor
Federal Facilities Assessment Branch
ATSDR

REVIEWERS OF REPORT

Burt J. Cooper
Chief, Energy Section
Federal Facilities Assessment Branch
Division of Health Assessment and Consultation
ATSDR

ACKNOWLEDGMENTS

ATSDR acknowledges and thanks Thomas Payne and Associates, Inc., California Department of Health Services-Environmental Health Investigations Branch, EPA Region IX, and EPA NAREL for assistance with this project.

The preparer of this report also acknowledges and thanks the following ATSDR staff who provided their assistance and expertise: Henry Abadin, M.S.P.H.; Richard Canady, PhD; Gwendolyn Eng; Richard (Mike) Fay, PhD; Beverly Harris; Theresa NeSmith; John Risher, PhD; Allan Susten, PhD.

RESOURCES

For further information, or to request copies of our documents, including Toxicological Profiles and Case Studies in Environmental Medicine, contact ATSDR on our toll-free number: 1-800-447-1544, or visit our Internet Home Page at http://atsdr1.atsdr.cdc.gov:8080/.

REFERENCES

7. Agency for Toxic Substances and Disease Registry. Site Summary, Laboratory for Energy-Related Health Research. December 1995.

8. Agency for Toxic Substances and Disease Registry. Health Consultation, Fish Sampling in Putah Creek, 1996. April 4, 1997.

9. Agency for Toxic Substances and Disease Registry. Toxicological Profile for Mercury (Update), Draft for Public Comment, August 1997.

10. Davidson PW, Myers GJ, Cox C, et al. Longitudinal neurodevelopmental study of Seychellois children following in utero exposure to methylmercury from maternal fish ingestion: outcomes at 19 and 29 months. Neurotoxicol 16(4):677-688, 1995.

11. United States Environmental Protection Agency. Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Supplement Guidance, Standard Default Exposure Factors (Interim Final). Washington, DC: USEPA, OERR, TIB. OSWER Directive 9285.6-03. 1991.

12. California Resources Agency, Department of Fish and Game, Inland Fisheries Division, California Inland Water Angling Records, http://www.dfg.ca.gov/ifd/fishrec.html, (revised December 13, 1996).

13. Agency for Toxic Substances and Disease Registry. Toxicological profile for lead. Draft for Public Comment (Update) August 1997.

14. Centers for Disease Control. Preventing lead poisoning in young children. 1991.

15. Sherlock JC, Smart G, Forbes GI, Assessment of lead intakes and dose-response for a population in Ayr exposed to a plumbosolvent water supply. Human Toxicol 1:115-122, 1982.

16. California Environmental Protection Agency, Office of Environmental Health Hazard Assessment, Pesticide and Environmental Toxicology Section. Chemicals in fish, report no. 1, consumption of fish and shellfish in California and the United States. Final draft report, July 1997.

Putah Crk, Upper & Lower-UTX

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL VALLEY REGION

Cache Creek and Putah Creek Watersheds Toxicity Monitoring Results: 1998-1999 Final Report

November 2000

REPORT PREPARED BY:

KAREN LARSEN
MICHELLE MCGRAW
Environmental Specialist
Sacramento River Watershed Unit

Valerie Connor
Senior Environmental Specialist
Sacramento River Watershed Unit

Linda Deanovic
Tom Kimball
Dr. David E. Hinton
University of California, Davis

PROJECT FACT SHEET

The Yolo County Department of Environmental Health, in partnership with the University of California, Davis and the Regional Water Quality Control Board, conducted chemical and aquatic toxicity monitoring in the Cache and Putah Creek watersheds between November 1998 and November 1999. The project, funded with a 205(j) grant, was designed to characterize aquatic life toxicity over a complete hydrologic cycle employing the US EPA three species toxicity tests. The three species employed in the tests are *Selenastrum capricornutum* (green algae), a primary producer, *Ceriodaphnia dubia* (crustacean), a primary consumer, and *Pimephales promelas* (minnow), a secondary consumer. To assess aquatic life toxicity, the US EPA three species toxicity tests ask the question, "Can the organism live, grow, and reproduce in the water sample?" More specifically, this project was designed to answer the question "Are contaminants present at concentrations that affect the organisms' ability to live, grow, and reproduce in the water sample?" The scope of the project did not address human health, bioaccumulation, or mercury impacts. A technical advisory committee (TAC) appointed by the Yolo County Board of Supervisors and chaired by Regional Board staff provided technical assistance on the project.

Six sites in each watershed were sampled monthly for twelve months. In the Putah Creek watershed, sites were selected to bracket the UC Davis wastewater treatment plant and the Laboratory for Energy-related Health Research (LEHR; a superfund site). One site upstream and one downstream of Lake Berryessa was sampled, however, the emphasis was on the impacts from UC Davis. Minor incidents of toxicity were detected, however, these tended to be watershed-wide events not related to the wastewater treatment plant discharge suggesting that the UC Davis wastewater treatment plant does not contribute to toxicity in Putah Creek. Sampling of runoff from the LEHR facility did not occur when runoff was expected. The TAC determined that this study was inconclusive regarding impacts from the LEHR site and further investigation, including episodic sampling during runoff events, is necessary.

In addition, invertebrate and algae impairment was observed in samples collected from Putah Creek upstream of Lake Berryessa. These observations warrant further investigation at this site. Currently, investigation of the algae impairment is ongoing through funding from CALFED.

In the Cache Creek watershed, site selection attempted to comprehensively cover the entire watershed because half of the creek is considered water quality limited due to unknown toxicity as required by the Clean Water Act Section 303(d). Significant fish and invertebrate toxicity was detected in samples collected from Cache Creek at the Rumsey Bridge. However, in general, few toxic events were detected throughout the Cache Creek watershed.

Willow Slough was sampled to complement studies being conducted by the Yolo County Resources Conservation District. Notable invertebrate and algal impairment was observed in samples collected from Willow Slough warranting further investigation into causes and sources.

Based on the results of this one-year study, aquatic toxicity may not be a contributor to the decline of native aquatic species in Cache Creek and Putah Creek, but the isolated instances of toxicity that have been observed should be investigated to determine the ecological significance.

TECHNICAL SUMMARY

Characteristics of the Study Area

The study area for this project is made up of two watersheds: Cache Creek and Putah Creek. Cache Creek originates at Clear Lake, flows through the Capay Valley and Woodland in the Central Valley eventually discharging into the Yolo Bypass. During low flow periods Cache Creek is not contiguous. It dries in the summer between the Capay Bridge and Yolo and begins flowing again (with groundwater recharge and agricultural discharge) below Highway 505. The Cache Creek basin drains 1,150 square miles on the eastern slope of the northern part of the Coast Range. Beneficial uses of Cache Creek include municipal and domestic water supply, irrigation, stock watering, recreation, warm water fish habitat and wildlife habitat (CVRWQCB, 1998). Land use within the watershed include municipalities, agriculture, grazing, and mercury and gravel mining. Impacts resulting from these uses have not been completely characterized, however, some preliminary studies conducted by the Regional Board and UC Davis have demonstrated toxicity to the bioassay species, *Ceriodaphnia dubia,* in several samples collected from Cache Creek (unreported data). The cause of the toxicity was not identified. As a result, Cache Creek appeared on the 1998 Clean Water Act Section 303(d) list of impaired water bodies for "unknown toxicity".

Putah Creek originates at Cobb Mountain 60 miles northwest of Davis in the Central Valley, flows easterly through Lake Berryessa and Monticello Dam ultimately discharging into the Yolo Bypass. During low flow Putah Creek is not contiguous with the Bypass instead flow becomes subsurface. Beneficial uses of Putah Creek include municipal, domestic and agriculture supply, recreation and fish and wildlife habitat. Land use along Putah Creek includes agriculture and municipalities. In addition, under permit from the Regional Water Quality Control Board, the University of California, Davis discharges wastewater from the UCD wastewater treatment plant, two fish research facilities, and the USDA Aquatic Weed Control Laboratory.

In addition to Cache and Putah Creek, Willow Slough was sampled at the request of the Yolo County Resources Conservation District to assess the effects of agriculture runoff on the surface water. Willow Slough drains the area just south of Cache Creek east of the Capay Dam and drains into the Yolo Bypass.

Study Objectives

The specific objectives of this study are outlined below:

- To characterize aquatic life toxicity in the Putah Creek and Cache Creek watersheds over a complete hydrologic cycle. Characterization includes monitoring of water column toxicity and, when toxicity is detected, analysis of chemical constituents.
- To use these water quality assessments to develop Implementation Plans to achieve water quality objectives where they currently are exceeded.
- To foster comprehensive watershed management that focuses on ecosystem protection, ongoing local stewardship, and participation of multiple interests.

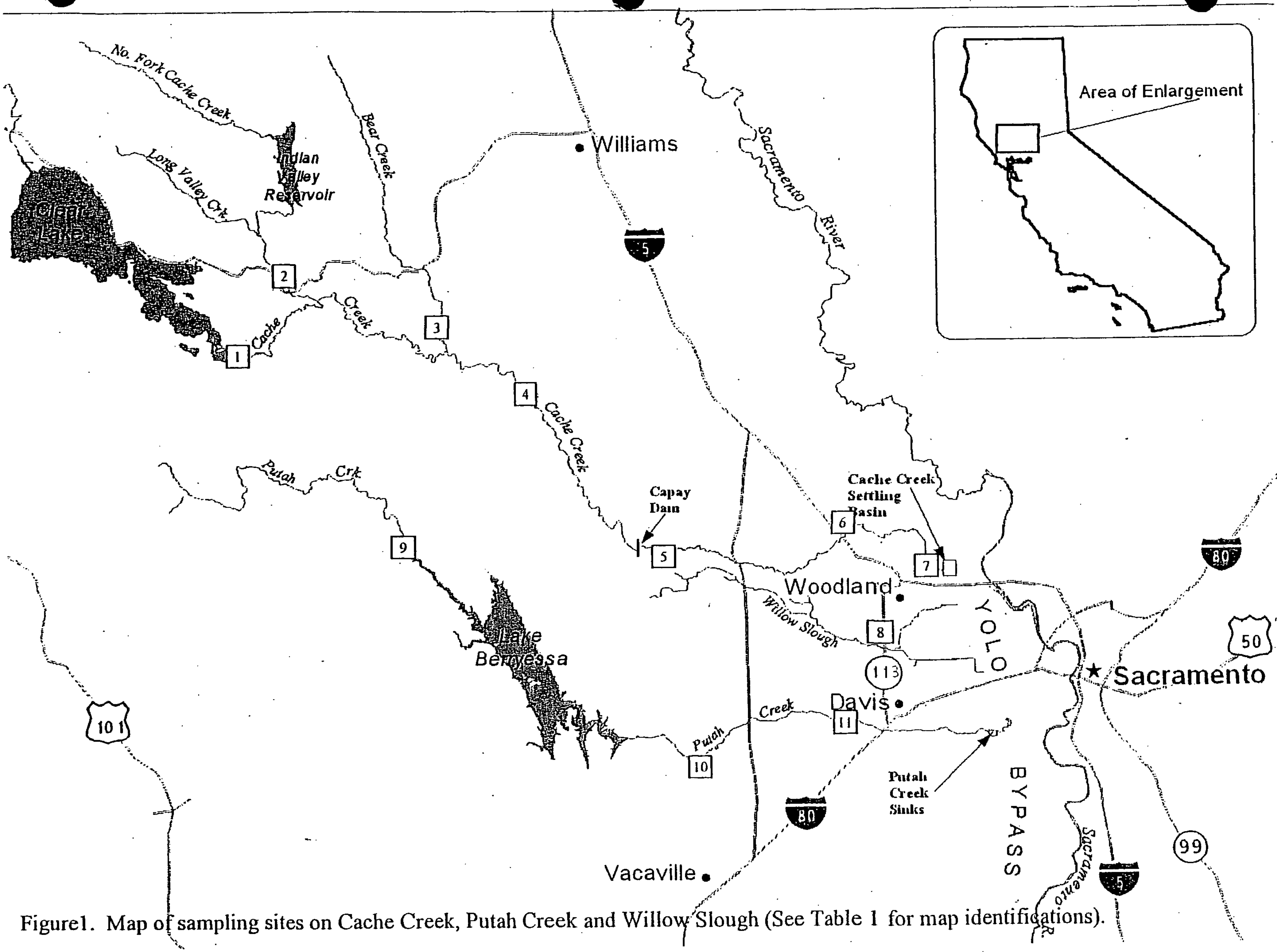


Figure1. Map of sampling sites on Cache Creek, Putah Creek and Willow Slough (See Table 1 for map identifications).

Table 1. Description of sampling sites monitored during the Cache and Putah Creek Watersheds Project toxicity monitoring survey.

Map ID[1]	Site Location	Rationale for Selection[2]				
		1	2	3	4	5
1	Cache Creek downstream of Clear Lake	X		X	X	
2	North Fork Cache Creek at Hwy. 20	X	X	X	X	X
3	Bear Creek upstream of the confluence with Cache Creek	X	X	X	X	X
4	Cache Creek at Rumsey Bridge	X		X		
5	Cache Creek at Capay	X		X		
6	Cache Creek at Yolo	X	X	X		
7	Cache Creek upstream of the Yolo bypass	X	X	X	X	X
8	Willow Slough at Hwy. 113	X	X	X		X
9	Putah Creek upstream of Lake Berryessa	X		X		X
10	Putah Creek downstream of Lake Solano	X	X	X		
11	Putah Creek upstream of UC Davis	X	X	X		X
12	Putah Creek at I-80 (sampled only during wet weather)	X	X	X		X
13	Putah Creek upstream of the UCD Wastewater Treatment Plant		X	X		X
14	Putah Creek downstream of the UCD Wastewater Treatment Plant	X	X	X	X	X

1. Numbers refer to the site locations on the maps of the study areas (Figures 1 and 2).
2. Numbers refer to the following site and sampling time criteria:

2. The site was a representative type of drainage (i.e., agricultural, urban, mining, etc.)
3. The site was a critical or sensitive habitat area (i.e., spawning and nursery area for anadromous fishes).
4. The site had existing indications of water quality degradation (i.e., previous toxicity or water quality objective exceedances).
5. The site afforded opportunities to collaborate with other monitoring programs.

Table 6. Summary of *Ceriodaphnia* toxicity testing mortality endpoint from November 1998 to October 1999.

Site	Toxicity testing endpoint[1]: % Mortality											
Sample Date:	11/2-3/98	12/1,7/98	1/11/99	2/8-9/99	3/9,23/99	4/5-6/99	5/10-11/99	6/7-8/99	7/12-13/99	8/9-10/99	9/13-14/99	10/4-5/99
Laboratory Control	0[P]	0[P]/0[P]	0[P]	0[P]	10[P]/0[P]	0[P]	0[P]	0[P]	5[P]	5[P]	5[P]	0[P]
Cache Creek d/s Clear Lake	0	0[a]	10	0	0[a]	10	0	0	0	0	0	30
North Fork Cache Creek at Hwy 20	0	0[a]	0	0	0[a]	0	0	0	0	0	0	20
Bear Creek u/s Cache Creek Confluence	0	0[a]	0	0	0[a]	0	0	0	0	0	0	0
Cache Creek at Rumsey Bridge	0	0[a]	0	0	0[a]	0	0	0	40	10	0	10
Cache Creek at Capay	0	0[a]	0	0	0[a]	10	10	0	0	0	0	20
Cache Creek at Yolo	0	0[a]	0	0	0[a]	0	0	0	0	0	0	20
Cache Creek u/s Yolo Bypass	0	0[a]	0	0	0[a]	0	0	0	0	0	0	0
Willow Slough at Hwy 113	0	0[a]	0	0	0[a]	80	0	0	0	0	0	40
Putah Creek u/s Lake Berryessa	10	0[b]	0	0	0[b]	0	0	0	0	0	0	20
Putah Creek d/s Lake Solano	0	0[b]	10	0	0[b]	0	0	0	0	0	0	0
Putah Creek u/s UCD	0	0[b]	0	0	0[b]	0	0	0	10	10	0	0
Putah Creek u/s UCD WWTP	0	0[b]	0	0	0[b]	0	0	0	0	0	10	0
Putah Creek d/s UCD WWTP	0	0[b]	0	20	0[b]	0	0	0	10	0	10	10
Putah Creek u/s of Yolo Bypass at Mace Blvd.	0	0[b]	0	0	0[b]	0	0	0	0	0	0	0

P. The laboratory control met all EPA criteria for test acceptability.
1. Highlighted cells indicate a significant increase in mortality compared to the laboratory control. The mortality endpoint was analyzed with Fisher's Exact Test.
2. In December 1998 and March 1999, the Cache and Putah Creek watersheds were sampled on separate dates and set up as separate tests. Endpoints designated with an "a" were compared to the first laboratory control listed while those designated with a "b" were compared to the second laboratory control listed.
d/s = downstream
u/s = upstream
* Due to significant mortality observed in these samples, reproduction was not calculated.

Table 7. Summary of *Ceriodaphnia* toxicity testing reproduction endpoint from November 1998 to October 1999.

Site	Toxicity testing endpoint[1]: Reproduction (average neonates/adult)											
Sample Date:	11/2-3/98	12/1,7/98	1/11/99	2/8-9/99	3/9,23/99	4/5-6/99	5/10-11/99	6/7-8/99	7/12-13/99	8/9-10/99	9/13-14/99	10/4-5/99
Laboratory Control	27.2^{P}	$23.7^{P}/21.8^{P}$	23.2^{P}	20.5^{P}	$20.7^{P}/21.5^{P}$	23.7^{P}	19.1^{P}	18.5^{P}	23.6^{P}	20.5^{P}	24.3^{P}	25.3^{P}
Cache Creek d/s Clear Lake	28.9	30.7^{a}	29.4	28.4	24.5^{a}	24.6	25.2	25.8	25.1	30.4	19.7	11.3
North Fork Cache Creek at Hwy 20	26.3	24.8^{a}	23.1	7.5	21.1^{a}	25.1	18.1	21.2	19.2	12.1	17.2	15.4
Bear Creek u/s Cache Creek Confluence	23.0	21.6^{a}	24.0	17.9	24.9^{a}	22.5	23.5	24.0	17.8	7.8	16.7	1.9
Cache Creek at Rumsey Bridge	27.0	15.2^{a}	27.4	8.7	24.3^{a}	24.7	24.9	27.1	*	20.4	20.0	15.0
Cache Creek at Capay	27.2	14.4^{a}	23.5	6.3	24.6^{a}	26.0	25.3	25.9	24.3	27.1	24.4	11.5
Cache Creek at Yolo	24.1	14.8^{a}	24.2	1.9	21.0^{a}	22.8	21.7	26.1	22.6	28.8	33.0	11.7
Cache Creek u/s Yolo Bypass	29.0	19.0^{a}	20.4	6.6	22.7^{a}	25.1	20.7	26.8	27.2	33.6	24.6	19.5
Willow Slough at Hwy 113	22.8	22.9^{a}	21.1	4.8	26.4^{a}	*	20.9	20.5	28.7	28.8	23.9	*
Putah Creek u/s Lake Berryessa	23.4	25.0^{b}	19.8	18.7	24.6^{b}	18.8	22.3	22.1	24.1	10.6	9.7	5.6
Putah Creek d/s Lake Solano	28.0	26.1^{b}	25.3	12.8	23.4^{b}	23.7	25.8	21.4	22.7	15.8	25.8	18.5
Putah Creek u/s UCD	28.4	24.9^{b}	26.7	5.0	23.8^{b}	25.5	22.3	22.5	16.3	23.4	20.5	10.7
Putah Creek u/s UCD WWTP	25.6	23.6^{b}	23.5	3.6	19.4^{b}	26.3	23.8	25.1	20.9	16.9	22.1	20.2
Putah Creek d/s UCD WWTP	26.9	24.1^{b}	23.1	5.6	24.9^{b}	27.3	25.3	21.0	23.3	26.1	22.9	14.8
Putah Creek u/s of Yolo Bypass at Mace Blvd.	26.9	20.1^{b}	24.5	8.2	24.5^{b}	25.1	20.4	25.9	27.3	30.2	24.4	21.1

P. The laboratory control met all EPA criteria for test acceptability.
1. Highlighted cells indicate a significant decrease in reproduction compared to the laboratory control. The reproduction endpoint was analyzed with Dunnett's Test ($p<0.05$).
2. In December 1998 and March 1999, the Cache and Putah Creek watersheds were sampled on separate dates and set up as separate tests. Endpoints designated with an "a" were compared to the first laboratory control listed while those designated with a "b" were compared to the second laboratory control listed.
d/s = downstream
u/s = upstream
* Due to significant mortality observed in these samples, reproduction was not calculated.

Table 8. Summary of frequency of toxicity to *Ceriodaphnia* in samples collected from the Cache and Putah Creek watersheds from November 1998 to October 1999.

Site	No. of Samples Tested	No. of Samples Exhibiting Toxicity			Frequency of Toxicity
		Acute Mortality	Chronic Mortality	Reproductive Impairment	
Cache Creek d/s Clear Lake	12	0	0	1	8
North Fork Cache Creek at HWY 20	12	0	0	2	17
Bear Creek u/s Cache Creek Confluence	12	0	0	1	8
Cache Creek at Rumsey Bridge	12	0	1	3	33
Cache Creek at Capay	12	0	0	3	25
Cache Creek at Yolo	12	0	0	3	25
Cache Creek u/s Yolo Bypass	12	0	0	2	17
Willow Slough at HWY 113	12	0	2	2	33
Putah Creek u/s Lake Berryessa	12	0	0	4	33
Putah Creek d/s Lake Solano	12	0	0	1	8
Putah Creek u/s UCD	12	0	0	2	17
Putah Creek u/s UCD WWTP	12	0	0	1	8
Putah Creek d/s UCD WWTP	12	0	0	2	17
Putah Creek u/s of Yolo Bypass at Mace Blvd.	12	0	0	1	8

1. Frequency of toxicity represents the total number of times any type of toxicity occurred divided by the total number of times the site was sampled. When significant mortality was detected, reproduction was not calculated so when chronic mortality was observed, reproductive impairment was not considered.

d/s = downstream

u/s = upstream

Table 9. Summary of *Pimephales* toxicity testing mortality endpoint from November 1998 to July 1999.

Site	Toxicity testing endpoint[1]: % Mortality											
Sample Date:	11/2-3/98	12/1,7/98	1/11/99	2/8-9/99	3/9,23/99	4/5-6/99	5/10-11/99	6/7-8/99	7/12-13/99	8/9-10/99	9/13-14/99	10/4-5/99
Laboratory Control	0[P]	0[P]/2.5[P]	5[P]	0[P]	0[P]/2.5[P]	0[P]	3.8[P]	1.25[P]	2.5[P]	3.8[P]	0[P]	1.3[P]
Cache Creek d/s Clear Lake	0.0	40[a]	7.5	17.5	0[a]	20.0	13.8	5.0	0.0	12.5	5.0	10.0
North Fork Cache Creek at Hwy 20	5.0	30[a]	0.0	22.5	12.5[a]	2.5	10.0	2.5	10.0	25.8	10.0	2.5
Bear Creek u/s Cache Creek Confluence	2.5	22.5[a]	2.5	7.5	0[a]	5.0	5.0	2.5	5.0	5.0	2.5	7.5
Cache Creek at Rumsey Bridge	32.5	42.5[a]	2.5	5.0	17.5[a]	10.0	15.0	2.5	10.0	27.5	22.5	20.3
Cache Creek at Capay	5.0	7.5[a]	10.0	2.5	0[a]	2.5	5.0	7.5	5.0	5.0	12.5	15.0
Cache Creek at Yolo	0.0	17.5[a]	5.0	22.7	12.5[a]	0.0	10.0	0.0	0.0	17.5	2.5	5.0
Cache Creek u/s Yolo Bypass	0.0	15[a]	0.0	15.0	0[a]	0.0	2.5	0.0	7.5	10.0	5.0	0.0
Willow Slough at Hwy 113	2.5	10[a]	7.5	10.0	0[a]	0.0	7.5	5.0	0.0	7.5	2.5	2.5
Putah Creek u/s Lake Berryessa	0.0	5.0[b]	0.0	7.5	2.5[b]	0.0	7.5	7.5	0.0	2.5	0.0	2.5
Putah Creek d/s Lake Solano	2.5	2.5[b]	7.5	12.5	5.0[b]	0.0	20.0	5.0	15.0	17.5	10.0	10.0
Putah Creek u/s UCD	5.0	2.5[b]	2.5	15.0	20.0[b]	0.0	2.5	5.0	5.0	10.0	0.0	0.0
Putah Creek u/s UCD WWTP	0.0	10[b]	2.5	23.3	10.0[b]	25.0	5.0	2.5	2.5	7.5	10.0	7.5
Putah Creek d/s UCD WWTP	0.0	2.5[b]	5.0	10.0	5.0[b]	5.0	5.0	2.5	2.5	5.0	5.0	2.5
Putah Creek u/s of Yolo Bypass at Mace Blvd.	0.0	5.0[b]	5.0	10.0	27.5[b]	2.5	10.0	5.0	0.0	7.5	5.0	32.5

P. The laboratory control met all EPA criteria for test acceptability.
1. Highlighted cells indicate a significant increase in mortality compared to the laboratory control. The mortality endpoint was analyzed with Dunnett's test.
2. In December 1998 and March 1999, the Cache and Putah Creek watersheds were sampled on separate days and set up as two separate tests. Endpoints designated with an "a" were compared to the first laboratory control listed and endpoints designated with a "b" were compared to the second laboratory control listed.
d/s = downstream
u/s = upstream

Table 10. Summary of *Pimephales* toxicity testing growth endpoint from November 1998 to October 1999.

Site	Toxicity testing endpoint[1]: Growth (mg/surviving fish)											
Sample Date:	11/2-3/98	12/1,7/98	1/11/99	2/8-9/99	3/9,23/99	4/5-6/99	5/10-11/99	6/7-8/99	7/12-13/99	8/9-10/99	9/13-14/99	10/4-5/99
Laboratory Control	0.564[P]	0.410[P]/0.446[P]	0.515[P]	0.413[P]	0.423[P]/0.396[P]	0.340[P]	0.250[P]	0.313[P]	0.349[P]	0.311[P]	0.357[P]	0.380[P]
Cache Creek d/s Clear Lake	0.590	0.549[a]	0.452	0.444	0.423[a]	0.348	0.146	0.306	0.344	0.385	0.335	0.382
North Fork Cache Creek at Hwy 20	0.611	0.531[a]	0.482	0.505	0.461[a]	0.344	0.327	0.330	0.377	0.408	0.366	0.347
Bear Creek u/s Cache Creek Confluence	0.601	0.474[a]	0.556	0.500	0.454[a]	0.343	0.262	0.324	0.339	0.418	0.388	0.422
Cache Creek at Rumsey Bridge	0.752	0.482[a]	0.490	0.470	0.468[a]	0.349	0.266	0.323	0.342	0.455	0.359	0.421
Cache Creek at Capay	0.579	0.437[a]	0.523	0.457	0.413[a]	0.307	0.244	0.293	0.359	0.363	0.326	0.385
Cache Creek at Yolo	0.602	0.481[a]	0.498	0.473	0.456[a]	0.355	0.243	0.352	0.323	0.352	0.317	0.378
Cache Creek u/s Yolo Bypass	0.643	0.469[a]	0.403	0.499	0.424[a]	0.339	0.244	0.305	0.373	0.402	0.357	0.355
Willow Slough at Hwy 113	0.580	0.504[a]	0.532	0.470	0.460[a]	0.360	0.267	0.303	0.338	0.333	0.351	0.399
Putah Creek u/s Lake Berryessa	0.534	0.461[b]	0.428	0.458	0.379[b]	0.333	0.246	0.293	0.344	0.346	0.370	0.337
Putah Creek d/s Lake Solano	0.554	0.336[b]	0.475	0.456	0.426[b]	0.320	0.255	0.295	0.389	0.314	0.344	0.371
Putah Creek u/s UCD	0.585	0.588[b]	0.457	0.480	0.450[b]	0.304	0.229	0.288	0.378	0.389	0.310	0.377
Putah Creek u/s UCD WWTP	0.584	0.356[b]	0.437	0.467	0.404[b]	0.309	0.245	0.312	0.348	0.330	0.364	0.375
Putah Creek d/s UCD WWTP	0.581	0.403[b]	0.477	0.418	0.433[b]	0.342	0.234	0.342	0.336	0.368	0.327	0.334
Putah Creek u/s of Yolo Bypass at Mace Blvd.	0.596	0.308[b]	0.496	0.472	0.424[b]	0.312	0.274	0.306	0.292	0.340	0.322	0.388

P. The laboratory control met all EPA criteria for test acceptability.

1. Highlighted cells indicate a significant decrease in growth compared to the laboratory control. The growth endpoint was analyzed with Dunnett's test.

2. In December 1998 and March 1999, the Cache and Putah Creek watersheds were sampled on separate days and set up as two separate tests. Endpoints designated with an "a" were compared to the first laboratory control listed and endpoints designated with a "b" were compared to the second laboratory control listed.

d/s = downstream

u/s = upstream

Table 11. Summary of frequency of toxicity to *Pimephales* in samples collected from the Cache and Putah Creek watersheds from November 1998 to October 1999.

Site	No. of Samples Tested	No. of Samples Exhibiting Toxicity			Frequency of Toxicity
		Acute Mortality	Chronic Mortality	Growth Impairment	
Cache Creek d/s Clear Lake	12	0	1	1	17
North Fork Cache Creek at HWY 20	12	0	3	0	25
Bear Creek u/s Cache Creek Confluence	12	0	1	0	8
Cache Creek at Rumsey Bridge	12	0	5	0	42
Cache Creek at Capay	12	0	0	0	0
Cache Creek at Yolo	12	0	0	0	0
Cache Creek u/s Yolo Bypass	12	0	0	0	0
Willow Slough at HWY 113	12	0	0	0	0
Putah Creek u/s Lake Berryessa	12	0	0	0	0
Putah Creek d/s Lake Solano	12	0	0	0	0
Putah Creek u/s UCD	12	0	0	0	0
Putah Creek u/s UCD WWTP	12	0	0	0	0
Putah Creek d/s UCD WWTP	12	0	0	0	0
Putah Creek u/s of Yolo Bypass at Mace Blvd.	12	0	1	0	8

1. Frequency of toxicity represents the total number of times any type of toxicity occurred divided by the total number of times the site was sampled. Chronic mortality and growth inhibition never occurred in the same sample at the same time.

d/s = downstream
u/s = upstream

Table 12. Summary of *Selenastrum* toxicity testing endpoints from November 1998 to October 1999.

Site / Sample Date:	Toxicity testing endpoint[1]: Number of Cells (x 10^4)										
	11/2-3/98	12/1,7/98	1/11/99	2/8-9/99	3/9,23/99	4/5-6/99	5/10-11/99	6/7-8/99	7/12-13/99	8/9-10/99	9/13-14/99	10/4-5/99
Laboratory Control	131.7[P]	243.7[P]/206.4[P]	204.7[P]	207.6[P]	237.3[P]/223.5[P]	89.5[P]	122.5[NP]	74.7[P]	60.3[P]	48.3[NP]	189.9[P]	230.3[NP]
Cache Creek d/s Clear Lake	236.4	308.6[a]	262.5	279.7	298.7[a]	274.6	210.6	188.0	159.6	156.0	225.4	223.1
North Fork Cache Creek at HWY 20	264.1	289.6[a]	294.6	243.9	295.3[a]	303.5	243.4	209.9	207.8	158.5	240.7	413.3
Bear Creek u/s Cache Creek Confluence	184.9	319.3[a]	236.2	269.1	306.5[a]	222.6	228.3	232.6	122.1	161.0	180.2	221.6
Cache Creek at Rumsey Bridge	283.1	316.0[a]	316.3	261.2	354.7[a]	280.2	243.1	113.5	159.3	213.2	220.5	219.6
Cache Creek at Capay	300.5	340.4[a]	272.9	256.9	305.3[a]	291.9	248.5	178.3	140.8	213.1	220.2	272.3
Cache Creek at Yolo	246.3	328.2[a]	222.2	307.7	288.4[a]	255.4	193.8	204.9	164.8	179.3	276.6	356.5
Cache Creek u/s Yolo Bypass	134.1	247.0[a]	175.4	275.2	208.1[a]	248.2	235.9	174.0	47.2	48.7	173.1	299.6
Willow Slough at HWY 113	241.7	219.8[a]	143.6	11.4	161.3[a]	155.8	182.7	248.4	206.2	139.9	207.8	238.3
Putah Creek u/s Lake Berryessa	262.3	239.0[b]	282.9	234.4	185.0[b]	277.5	223.8	236.6	30.9	100.3	259.6	344.4
Putah Creek d/s Lake Solano	280.1	295.1[b]	282.1	319.5	193.0[b]	248.5	230.3	270.2	221.2	216.6	223.8	272.4
Putah Creek u/s UCD	268.7	314.9[b]	321.9	231.7	231.5[b]	279.2	248.6	287.9	90.3	182.0	276.1	247.8
Putah Creek u/s UCD WWTP	279.9	293.5[b]	299.6	198.3	209.0[b]	277.0	261.0	249.3	243.1	224.3	259.5	339.4
Putah Creek d/s UCD WWTP	310.1	312.2[b]	266.3	213.9	197.0[b]	191.7	276.4	274.1	198.9	191.9	276.5	240.7
Putah Creek u/s of Yolo Bypass at Mace Blvd.	276.0	330.9[b]	310.4	183.9	232.1[b]	275.1	265.6	252.5	250.1	221.3	261.2	317.0

P. The laboratory control met all EPA criteria for test acceptability.

NP. The laboratory control did not meet all EPA criteria for test acceptability. The coefficient of variation was higher than 20%.

1. Highlighted cells indicate a significant decrease in number of cells compared to the laboratory control. The cell number endpoint was analyzed using Dunnett's Test ($p<0.05$).

2. In December 1998 and March 1999, the Cache and Putah Creek watersheds were sampled on separate days and set up as two separate tests. Endpoints designated with an "a" were compared to the first laboratory control listed and endpoints designated with a "b" were compared to the second laboratory control listed.

d/s = downstream

u/s = upstream

Table 13. Summary of frequency of toxicity to *Selenastrum* in samples collected from the Cache and Putah Creek watersheds from November 1998 to October 1999.

Site	No. of Samples Tested	No. of Samples Exhibiting Algal Growth Impairment	Frequency of Toxicity (%)
Cache Creek d/s Clear Lake	9	0	0
North Fork Cache Creek at HWY 20	9	0	0
Bear Creek u/s Cache Creek Confluence	9	0	0
Cache Creek at Rumsey Bridge	9	0	0
Cache Creek at Capay	9	0	0
Cache Creek at Yolo	9	0	0
Cache Creek u/s Yolo Bypass	9	0	0
Willow Slough at HWY 113	9	2	22
Putah Creek u/s Lake Berryessa	9	1	11
Putah Creek d/s Lake Solano	9	0	0
Putah Creek u/s UCD	9	0	0
Putah Creek u/s UCD WWTP	9	0	0
Putah Creek d/s UCD WWTP	9	0	0
Putah Creek u/s of Yolo Bypass at Mace Blvd.	9	0	0

1. Frequency of toxicity represents the total number of times any type of toxicity occurred divided by the total number of times the site was sampled. Tests that did not pass the EPA criteria for test acceptability were not included in the calculation of the frequency of toxicity.

d/s = downstream
u/s = upstream

SJR - Hg

B.1.43 Lower San Joaquin River, Mercury

Summary of Proposed Action

The California Regional Water Quality Control Board, Central Valley Region, (Regional Board) recommends the addition of the lower San Joaquin River to California's Clean Water Act Section 303(d) list due to impairment by mercury. Information available to the Regional Board on mercury levels in fish tissue samples indicates that water quality objectives are not being attained in the lower San Joaquin River. The description for the basis for this determination is given below.

Table B-1. 303(d) Listing/TMDL Information

Waterbody Name	Lower San Joaquin River	**Pollutants/Stressors**	Mercury
Hydrologic Unit	544.00	**Sources**	Resource extraction (abandoned mines)
Total Waterbody Size	330 miles	**TMDL Priority**	
Size Affected	60 miles	**TMDL Start Date (Mo/Yr)**	
Extent of Impairment	From the confluence with Bear Creek to Vernalis	**TMDL End Date (Mo/Yr)**	
Upstream Extent Latitude	37° 16' 44"	**Upstream Extent Longitude**	120° 49' 39"
Downstream Extent Latitude	37° 40' 32.6"	**Downstream Extent Longitude**	121° 15' 54"

Watershed Characteristics

The San Joaquin River flows for approximately 330 miles from the headwaters to the Delta boundary near Vernalis in central California. The hydrology in the lower San Joaquin River is highly managed, with numerous tributary impoundments and extensive diversion of river flows. The lower San Joaquin River is intermittently dry between Gravelly Ford and the Bear Creek confluence, except when Friant Dam releases water for flood control.

Water Quality Objectives Not Attained

The narrative objective for toxicity is not being attained for mercury in the lower San Joaquin River. The narrative toxicity objective in the Basin Plan states, in part, "All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life." The narrative toxicity objective further states that "The Regional Water Board will also consider ... numerical criteria and guidelines for toxic substances developed by the State Water Board, the California Office of Environmental Health Hazard Assessment, the California Department of Health Services, the U.S. Food and Drug Administration, the National Academy of Sciences, the U.S. Environmental Protection Agency, and other appropriate organizations to evaluate compliance with this objective" (CRWQCB-CVR, 1998; http://www.swrcb.ca.gov/~rwqcb5/bsnplnab.pdf).

Numeric criteria for mercury in fish tissue have been developed for both human health and wildlife protection. The U.S. Environmental Protection Agency (USEPA) recently established a human health protection criterion of 0.3 milligrams per kilogram (mg/kg; equivalent to parts per million, [ppm]) methylmercury in the edible portions of fish (USEPA, 2001b). This criterion is used to determine attainment of the narrative toxicity objective.

Evidence of Impairment

The Toxic Substances Monitoring Program (TSMP) and San Francisco Estuary Institute (SFEI) collected numerous trophic level 3 and 4 fish samples from the San Joaquin River between 1979 and 1999 (SWRCB, 1995; Davis and May, 2000). Trophic level 3 fish (e.g., carp and green sunfish) feed on zooplankton, phytoplankton, and benthic invertebrates. Trophic level 4 fish (e.g., channel catfish and largemouth bass) consume trophic level 3 fish as part of their diet. Methylmercury and total mercury bioaccumulates in aquatic organisms and tends to increase with increasing trophic levels (USEPA, 1997a). The trophic level 4 fish had an average mercury concentration of 0.45 ppm, which exceeds the USEPA criterion of 0.3 ppm. Table B-2 summarizes the available mercury concentration data for trophic level 4 fish.

Table B-2. Summary of Mercury Concentration Data for Lower San Joaquin River Fish

Sampling Location	Fish Species	Mean Mercury Concentration (ppm)	# of Fish Sampled
Landers Ave / RT 165	Channel Catfish	0.51	3
	Largemouth Bass	0.68	22
	Sacramento Pike Minnow	0.10	24
	Striped Bass	0.49	1
	White Catfish	0.42	22
Between Crow's Landing and Las Palmas roads	Largemouth Bass	0.66	25
	Striped Bass	0.46	1
	White Catfish	0.45	20
Near Vernalis	Channel Catfish	0.32	64
	Largemouth Bass	0.65	27
	Striped Bass	0.73	7
	White Catfish	0.42	48
Summary	Trophic Level 4 Fish	0.45	264

Extent of Impairment
Evidence suggests the lower San Joaquin River is impaired by mercury from the confluence with Bear Creek to Vernalis. Bear Creek was chosen as the upstream extent because it is both a major source of water to the San Joaquin River and is located just upstream of the Landers Avenue/Route 165 sampling site sampled by the SFEI study (Davis and May, 2000).

Potential Sources
The principal sources of mercury to aquatic ecosystems in northern California are historic mercury and gold mining sites (CRWQCB-SFB *et al*, 1995).

B.1.49 Lower Stanislaus River, Mercury

Summary of Proposed Action

The California Regional Water Quality Control Board, Central Valley Region (Regional Board) recommends the addition of the lower Stanislaus River to California's Clean Water Act Section 303(d) list due to impairment by mercury. Information available to the Regional Board on mercury levels in fish tissue samples indicates that water quality objectives are not being attained in the lower Stanislaus River. The description for the basis for this determination is given below.

Table B-1. 303(d) Listing/TMDL Information

Waterbody Name	Lower Stanislaus River	**Pollutants/Stressors**	Mercury
Hydrologic Unit	535.30	**Sources**	Resource extraction (abandoned mines)
Total Waterbody Size	58 miles	**TMDL Priority**	
Size Affected	58 miles	**TMDL Start Date (Mo/Yr)**	
Extent of Impairment	Entire Lower Stanislaus River	**TMDL End Date (Mo/Yr)**	
Upstream Extent Latitude	37° 52' 25"	**Upstream Extent Longitude**	120° 36' 17"
Downstream Extent Latitude	37° 39' 53"	**Downstream Extent Longitude**	121° 14' 28"

Watershed Characteristics

The lower Stanislaus River flows 58 miles from the Goodwin Diversion Dam through the towns of Oakdale, Riverbank and Ripon to its confluence with the San Joaquin River. The upstream segment forms the Calaveras-Tuolumne County line, the middle segment flows through Stanislaus County, and the downstream segment forms the Stanislaus-San Joaquin County line. The Goodwin Diversion Dam serves as an after bay for hydropower and spillway releases from Tulloch Dam, which is immediately upstream. The Tulloch Dam serves as an after bay for hydropower releases from the upstream New Melones Dam. The New Melones Dam regulates the flows of the Stanislaus River. Neither the Tulloch nor Goodwin reservoirs have flood control space; large releases are passed through both reservoirs. The Oakdale and South San Joaquin Irrigation Districts operate Goodwin Diversion Dam and Tulloch Reservoir; the U.S. Bureau of Reclamation operates the New Melones Dam (USBR, 2001).

Water Quality Objectives Not Attained

The narrative objective for toxicity is not being attained for mercury in the lower Stanislaus River. The narrative toxicity objective in the Basin Plan states, in part, "All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life." The narrative toxicity objective further states that "The Regional Water Board will also consider ... numerical criteria and guidelines for toxic substances developed by the State Water Board, the California Office of Environmental Health Hazard Assessment, the California Department of Health Services, the U.S. Food and Drug Administration, the National Academy of Sciences, the U.S. Environmental Protection Agency, and other appropriate organizations to evaluate compliance with this objective (CRWQCB-CVR, 1998; http://www.swrcb.ca.gov/~rwqcb5/bsnplnab.pdf)."

Numeric criteria for mercury in fish tissue have been developed for both human health and wildlife protection. The U.S. Environmental Protection Agency (USEPA) recently established a human health protection criterion of 0.3 milligrams per kilogram (mg/kg; equivalent to parts per million [ppm]) methylmercury in the edible portions of fish (USEPA, 2001b). This criterion is used to determine attainment with of the narrative toxicity objective.

Evidence of Impairment

The Toxic Substances Monitoring Program (TSMP) and San Francisco Estuary Institute (SFEI) collected composite samples of trophic level 3 and 4 fish from the Stanislaus River between 1978 and 1998

(SWRCB, 1995; Davis and May, 2000). Trophic level 3 fish feed on zooplankton, phytoplankton, and benthic invertebrates. Trophic level 4 fish consume trophic level 3 fish as part of their diet. Methylmercury and total mercury bioaccumulate in aquatic organisms and tend to increase with increasing trophic levels (USEPA, 1997b). The TSMP and SFEI sampled 45 trophic level 4 fish (largemouth bass, channel catfish, and white catfish). These trophic level 4 fish had an average mercury concentration of 0.53 ppm, which exceeds the USEPA criterion of 0.3 ppm.

Extent of Impairment

The lower Stanislaus River flows 58 miles from Goodwin Diversion Dam to its confluence with the San Joaquin River. Data are available only for the downstream segment of the river. However, the entire 58-mile reach is probably impaired because there is no substantial input downstream of Goodwin Dam.

Potential Sources

The principal source of mercury to Stanislaus River is historic gold mining sites in the upper portion of the watershed (OMR, 2000).

■ Interagency Ecological Program for the San Francisco Estuary ■

IEP NEWSLETTER

VOLUME 13, NUMBER 4, FALL 2000

CONTENTS

■

OF INTEREST TO MANAGERS

Chuck Armor, DFG
carmor@delta.dfg.ca.gov

- **Mitten Crabs.** p 4. May and Brown describe Chinese mitten crab distribution in the San Joaquin River drainage and found no crabs at any of the sites sampled. This suggests there are fewer mitten crabs in the San Joaquin drainage this year than in past years, and associated problems with large mitten crab numbers at the CVP and SWP facilities may be less this year.

- **Striped Bass and Delta Smelt Fish Abundance Indices.** p 8–10. Gartz reports on the status of various fish species of special interest, which is a mixture of good and bad news. The striped bass 38-mm index was set at 5.5, twice the 1999 index of 2.2, and the highest index since 1996. The townet survey index for delta smelt decreased from 11.9 in 1999 to 8.0 in 2000. Catch indices for longfin smelt and starry flounder are both significantly lower this year than in previous years.

- **Sherman Island Agricultural Diversion Evaluation.** p 11. Nobriga and Matica observed a large increase in the fish diverted by an unscreened diversion during the incoming tide at night. This suggests management of diversion periods may be an effective tool to reduce fish entrainment into Delta agricultural diversions. Additional work is planned when delta smelt and young salmon are present next year.

- **Fish Diet Analysis from Suisun Marsh Points to Implications for the San Francisco Estuary.** p 21–27. Feyrer and Matern compare the diets of five important species of fish and found in Suisun Marsh between 1987 and 1999 found a significant change in their diets, mostly due to the large decrease of the mysid shrimp, *Neomysis mercedis* in the Suisun Marsh. Potential implications of this change are discussed.

- **Pesticides in Delta Smelt Habitat.** p 27–33. In 1999 numerous pesticides were detected in areas inhabited by larval and small juvenile delta smelt. Moon and others compare 1998 and 1999 pesticide data from the Delta to demonstrate that the mixture, concentrations, and distributions of pesticides found in delta smelt habitat is strongly influenced by a number of factors, including river discharge and CVP and SWP diversions.

Potential Mercury Problems with Delta Restoration Sites. p 34–44. Slotton and others report spatial differences in Delta mercury levels are most closely related to proximity to upstream sources, such as the Yolo Bypass and Cosumnes River, as well as residual sediments from California's Gold Rush era. Areas with organic-rich vegetated wetland tracts had a higher potential to convert mercury into a form accumulated by the biota; however, this did not necessarily result in higher accumulation in organisms tested. This information along with other findings will be critical to the selection and restoration of sites within the Delta. One additional finding was the identification of an area of high mercury bioaccumulation between the confluence of the Sacramento and San Joaquin rivers and Carquinez Strait.

- **Effects of *Potamocorbula* on the Estuarine Food Web.** p 45–54. Since the decline in zooplankton abundance and the concurrent rise in the exotic clam *Potamocorbula* was detected in the estuary in 1986, the nature of the interactions between the exotic clam and the zooplankton community has been poorly understood. Kimmerer and Peñalva discusses the results of a number of laboratory and field experiments that provide some insight to the direct and indirect effects of *Potamocorbula* on the zooplankton community.

- **Mortality Rates of Largemouth Bass.** p 54–60. Largemouth bass mortality rates have traditionally been calculated using tag return data. Schaffter presents tag return data from 1980–1984 and compares natural and angler mortality rates in the Delta to other waters in the State. Delta largemouth bass mortality rates were lower than those estimated for several major reservoirs in the State. Although his analysis was complicated by a shift in the Delta largemouth bass recreational fishery to a "catch and release" fishery, such a shift gives insights into Delta recreation priorities.

Delta Wetlands Restoration and the Mercury Question: Year 2 Findings of the CALFED UC Davis Delta Mercury Study

Darell G. Slotton[1], Thomas H. Suchanek[2], and Shaun M. Ayers[1]
[1]Dept. of Environmental Science and Policy
[2]Dept. of Wildlife, Fish and Conservation Biology
University of California, Davis
dgslotton@ucdavis.edu

Abstract

Field and laboratory measures were developed for the determination of relative sediment mercury methylation potential and biotic mercury accumulation in the Sacramento-San Joaquin Delta. Mercury bioaccumulation was investigated at over 60 varied sites. Methylation potential experiments found flooded wetland sediments to exhibit between 200% and 3,000% greater potential to convert inorganic mercury to methyl mercury than sediments of adjacent channels and flats. However, biological findings to date suggest wetlands restoration projects may result in localized mercury bioaccumulation at levels similar to, but not necessarily greater than, general levels within their surrounding Delta region. Delta regions with elevated biotic mercury concentrations included areas fed by inflows from the Cosumnes River, Yolo Bypass and, to a lesser extent, Sacramento River. The Central and South Delta were markedly lower, despite high signals in some southern tributaries and the presence of numerous flooded tracts in the Central Delta. One of the most important new findings was the identification of an extensive additional zone of elevated mercury bioaccumulation in the West Delta between the Sacramento-San Joaquin confluence and Carquinez Strait. Possible mechanisms are discussed.

Background

Mercury contamination is one of the primary water quality issues in the San Francisco Bay-Delta watershed. This is the result, in large part, of the Gold Rush era legacy of extensive mercury use in Sierra Nevada gold mining, as well as the now abandoned mercury mines in the California coast ranges that supplied this mercury. It is clear that both regions remain major sources of ongoing mercury contamination, both locally and downstream (Slotton and others 1995, 1997, 1998, 1999; Suchanek and others 1997; Foe and Croyle 1998; Domagalski 1998; Roth and others 2000). The relative effect of that mercury loading is dependent on how much is converted to methyl mercury, the form which bioconcentrates through food webs and can lead to neurological damage in top consumers. International mercury research during the past decade has found that wetland habitats can be sites of significantly elevated mercury methylation (Rudd 1995). This is not surprising, as methyl mercury production is known to be stimulated by sulfate-reducing and other bacteria, which typically occupy the zone just below the oxic-anoxic interface in aquatic systems. Organic-rich and potentially sulfate-rich wetlands can provide optimal habitat for these microbes.

Our UC Davis study is investigating mercury methylation and bioaccumulation patterns throughout the Sacramento-San Joaquin Delta system. This research focuses on habitat-specific and site-specific measures of these phenomena. Thus, while mercury concentrations in edible fish species is perhaps the primary ultimate concern, our project targets more sedentary and short-lived lower trophic level biota, as well as surficial sediment chemistry, as localized indicators of relative mercury exposure. A primary goal is to provide management recommendations that address the mercury question with regard to wetland restoration projects. In the first year of this ongoing research, initial results suggested flooded Delta tracts—in a variety of configurations—may not, in fact, lead to locally elevated levels of mercury bioaccumulation (Suchanek and others 1999). Instead, first year results indicated that spatial differences in Delta mercury bioaccumulation may be linked most closely to proximity to upstream sources such as the Yolo Bypass and the Cosumnes River. Within Delta subregions, preliminary results suggested biotic mercury might be quite uniform, irrespective of habitat.

In the second year of the project, reported here, we used surficial sediments and carefully chosen bioindicator organisms to comprehensively sample the entire Delta, with comparable protocols and collections at over 60 sampling sites. We also conducted laboratory experiments to investigate the mercury methylating potential of sediments from key locations and micro-habitats. The results of this ongoing work provide a new picture of mercury dynamics in the Delta.

Methods

Sampling sites were chosen to be representative of important Delta subregions and habitat types, with a particular focus on flooded tracts across a range of ages. Sampling was conducted throughout the fall of 1999. Fish were collected with a variety of seines. Crayfish were collected with baited traps. Clams were generally taken by hand during low tides. Sediment samples were taken from the top centimeter of undisturbed grab samples, primarily collected using an Ekman grab sampler. Biota and sediment samples were placed immediately on ice in the field, within secure clean containers, for transport to the UC Davis laboratories. Fish were cleaned, identified, and sorted within 24 hours of collection, then frozen with water in Ziploc bags to avoid freezer desiccation. Fish were weighed and measured prior to processing. Clams were maintained live in clean water, which was changed twice daily for four days to purge them of all major gut contents and associated sediment, and were then frozen for storage. Crayfish were also stored frozen.

Crayfish tail muscle and clam soft tissues were excised with a clean scalpel prior to analysis. Crayfish digestive tracts were removed. Biota samples were dried at 60 °C, ground, and powdered. Both individual and composite samples were used. Small fish were prepared whole body, as were the clams (minus shells). Crayfish mercury was analyzed in tail muscle. Percentage moisture was determined for all sample types to allow conversion of wet or dry weight analytical results. UC Davis analysis of total mercury used dry biota samples and fresh, wet sediment. Clam composite samples typically used 10 to 25 purged individuals within the optimal size range. Inland silverside composites contained a minimum of six and typically 30 to 40 individuals in the key size range.

Samples were digested in 2:1 sulfuric:nitric acid under pressure (capped vessels) at approximately 90 °C for one hour, and then for two additional hours, uncapped, with the addition of potassium permanganate and potassium persulfate. Mercury was analyzed using a FIMS cold vapor atomic absorption system. Sediment and biota moisture percentage was determined with oven drying and sequential weighings. Sediment loss on ignition was determined with sequential weighings and 475 °C muffle furnace ashing. Laboratory experiments using sediment slurries to estimate maximal potential methyl mercury production rates were conducted with 2:1 mixtures of site water:site sediment (top 1 cm). Mixtures were spiked with mercury chloride to 1.00 $\mu g\ Hg\ g^{-1}$. After placing identical aliquots into multiple incubation chambers and sparging to uniform anoxia with nitrogen, samples were incubated at 22 °C for varying lengths of time. Individual methylation experiments were stopped by freezing at defined endpoints. Methyl mercury concentrations were analyzed by Battelle Marine Science Laboratories in Sequim, Washington.

SECOND YEAR RESULTS

Mercury in Sediment

Surficial sediments (top 1 cm) were collected at most of the fall 1999 biota stations. Dry weight, whole-sediment Delta mercury concentrations all occurred within a range of 0.01 to 0.33 $\mu g\ Hg\ g^{-1}$. Particle size varied dramatically in these samples, from fine clay and silt in depositional areas to coarse sand in some of the more erosional locations. Metals, including mercury, tend to be most concentrated in fine grained particles (Theis and others 1988; Roth and others 2000). Future sampling rounds will normalize to grain size and a variety of other sediment parameters. The whole-sediment mercury values are useful, however, as they represent the environment the organisms are exposed to. Greatest concentrations occurred at North Delta and East Delta inflow regions and in depositional regions where finest particle sizes dominated. This particularly included West Delta sites (0.18 to 0.33 $\mu g\ Hg\ g^{-1}$), with moderate levels interspersed within the Central Delta (0.08 to 0.26 $\mu g\ Hg\ g^{-1}$). South Delta sites were uniformly low in total mercury (0.02 to 0.15 $\mu g\ Hg\ g^{-1}$).

Potential Methyl Mercury Production from Sediments: Experimental Results

Initially, we attempted to quantify methyl mercury efflux from Delta sediments into overlying water. In laboratory core-tube experiments, we found that the changes in aqueous methyl mercury levels were too low for accurate measurement within our project constraints. Subsequently, we chose an alternate technique which provided excellent detection levels and results. Laboratory slurry experiments introduced spike additions of reactive inorganic mercury (mercury chloride) to Delta sediment samples and measured the methyl mercury production that resulted over a 16-day period. These measurements of "methylation potential" determine not what is naturally produced from a given sediment, but that sediment's propensity to methylate inorganic mercury if it is presented in a bioavailable form. Results from the Delta have been enlightening.

Figure 2 represents time series methylation data from a representative experimental set. Following identical spike additions to 1.00 $\mu g\ Hg\ g^{-1}$, sediments from three different representative habitat types at the Cosumnes River all reached a maximum methyl mercury balance within two days. Peak concentrations differed in the three representative sediments, though all rose well above initial levels. Methyl mercury subsequently declined in the coarsest, mid-channel sample after day two. In the most organic-rich sediment, taken from a depositional, well-vegetated, off-channel marsh, methyl mercury persisted at maximal levels for six additional days beyond the initial rise. In the intermediate sediment, taken from a depositional (but not marsh) environment, peak levels persisted for through day four, an intermediate length of time. In all three sediments, following maximal initial methyl mercury concentrations, levels maintained at approximately 50% of peak levels (well above baseline) for at least 8 to 16 days. The experimental declines from peak levels may be indicative of a demethylating phase.

The magnitude of the methyl mercury production peak was lowest in the coarse, mid-channel sediment (90 ng Hg g^{-1}, baseline = 10), intermediate in the off-channel depositional zone sediment (130 ng Hg g^{-1}, baseline = 20), and notably greatest in the lower marsh sediment (390 ng Hg g^{-1}, baseline = 30). Figure 3 displays reduced data from this and other representative Delta marsh habitats and their respective non-marsh controls in units of peak methyl mercury concentrations during identical methylation potential experiments. Sediments from the Cosumnes River, Liberty Island in the North Delta, and Venice Cut Island in the Central Delta all demonstrated dramatically elevated levels of mercury methylation potential in the more organic-rich, heavily vegetated, flooded wetland sediments, relative to adjacent non-marsh controls. In the North Delta, while absolute levels were much lower, the difference in peak methyl mercury response to spike additions of inorganic mercury was 39 ng Hg g^{-1} (marsh) and 2 ng Hg g^{-1} (submerged island flats). Much of the North Delta is characterized by sandy sediments and turbid water that does not readily promote macrophyte development. Cosumnes region concentrations, as noted above, were ten times greater at 399 ng Hg g^{-1} (marsh) and 93 ng g^{-1} (channel). At Venice Cut Island, representative of peat-based Central Delta flooded tracts, the maximum methyl mercury concentration in spiked flooded peat material was an astounding 1,077 ng Hg g^{-1}, with 34 ng Hg g^{-1} in the adjacent control (submerged island flats). In all paired tests, flooded wetland sediments exhibited between 200% and 3,000% greater mercury methylation potential than adjacent channels and flats.

Choosing Appropriate Bioindicator Species

In the first year collections, we found that many locally abundant small fish and macro-invertebrate species had relatively limited ranges throughout the Delta. While these will be useful bioindicators of local food web dynamics, we needed organisms which exhibited strong site fidelity and could be taken from a wide variety of Delta locations and habitats. Our prime candidates were Asiatic clams (*Corbicula fluminea*), signal crayfish (*Pacifasticus leniusculus*), and inland silversides (*Menidia beryllina*). One major focus during the past year was the study of individual variation in mercury levels, within each of the primary sample types, from identical locales. To be most useful in describing potential spatial and inter-habitat variation in Delta mercury bioavailability, low levels of within-site variation were needed in the monitoring organisms. In Figures 4, 5, and 6, typical within-site mercury variability in individuals of each of the three types of biota is displayed in size versus mercury plots.

Crayfish (*Pacifasticus leniusculus*, Figure 4) were found to have unacceptably high levels of within-site variability in tail muscle mercury concentration. This was likely a function of a highly variable, opportunistic diet and the co-occurrence of widely varying age classes. Individual variability was frequently equal to or greater than the spatial and habitat related mercury variability. There was no apparent size range that was free of this high variability. This was unfortunate as, otherwise, crayfish could be ideal candidates as bioindicator species. They accumulate mercury to high concentrations, similar to predatory fish, but maintain highly localized home ranges.

The variability of mercury concentration in Asiatic clams (*Corbicula fluminea*, Figure 5) was very low in the smaller size classes from most locations investigated. Among the fall 1999 samples, whole body mercury concentration in individuals <28 mm (maximum shell diameter) were quite consistent. Above this size at a number of sites tested, individual variability increased significantly. We attributed this to age structure and sexual maturity. Larger fall clams demonstrated a significant variation in body mass, likely a function of reproductive energy needs and spawning. Individuals which metabolized much of their body mass were left with similar mercury body burdens but elevated concentrations. Based on these findings, we chose 15- to 27-mm *Corbicula* as one of our two primary Delta-wide mercury bioindicators.

Inland silversides (*Menidia beryllina*, Figure 6) were found to behave primarily as annuals in the Delta, as is the case in other parts of California. Fall silversides were typically very consistent in same-site, individual, whole body mercury concentration at sizes of about 45 to 75 mm. Above this size, individual mercury concentrations were often significantly more variable. Our interpretation, supported by field observation of Delta silverside life history, is that fall individuals less than about 75 mm are the young of the year. Larger individuals consist primarily of over-wintering fish from the previous year. We chose 45 to 75 mm silversides as our second Delta-wide mercury bioindicator.

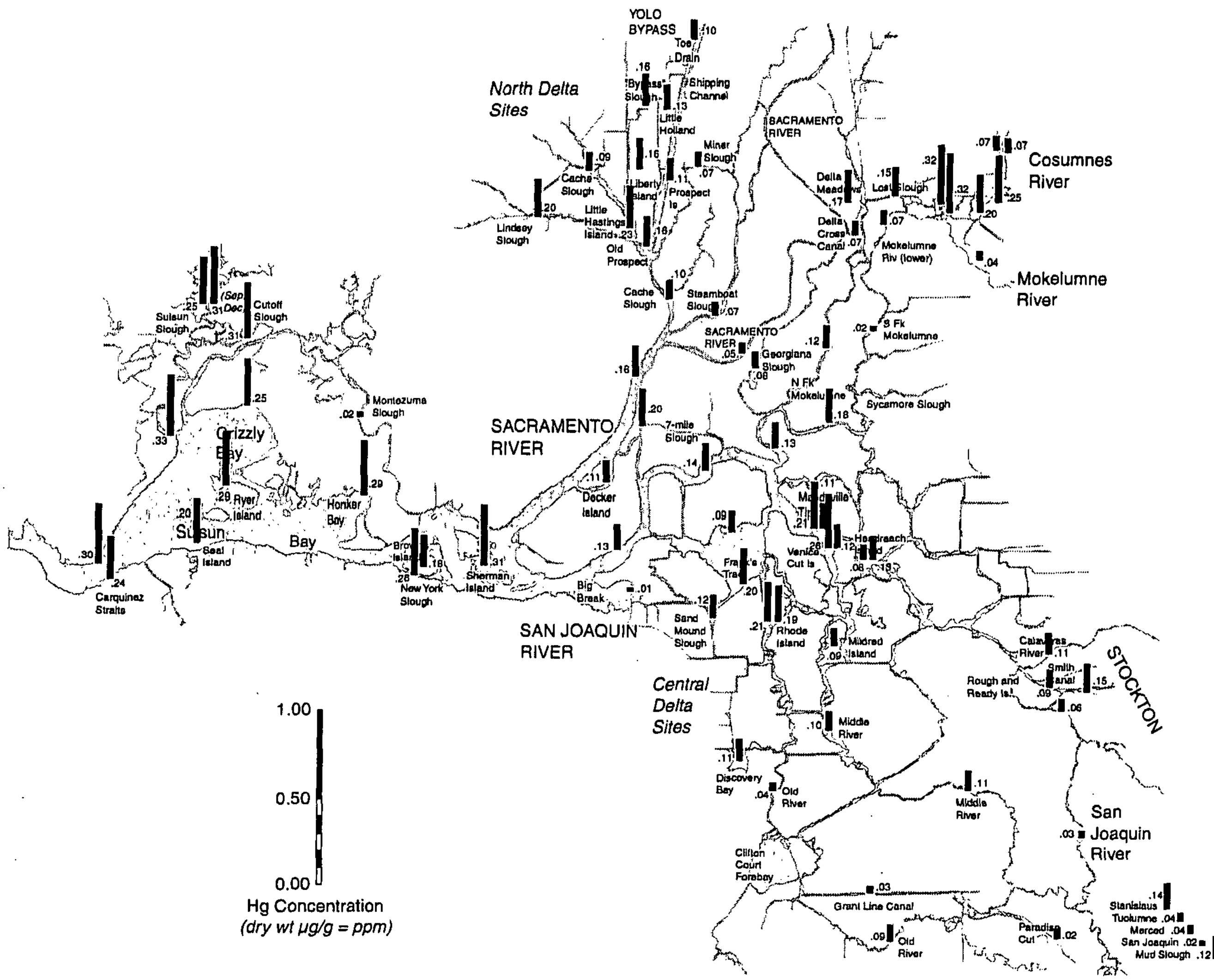


Figure 1 Surficial whole-sediment mercury spatial distribution. Fall 1999 collections; top 1 cm.

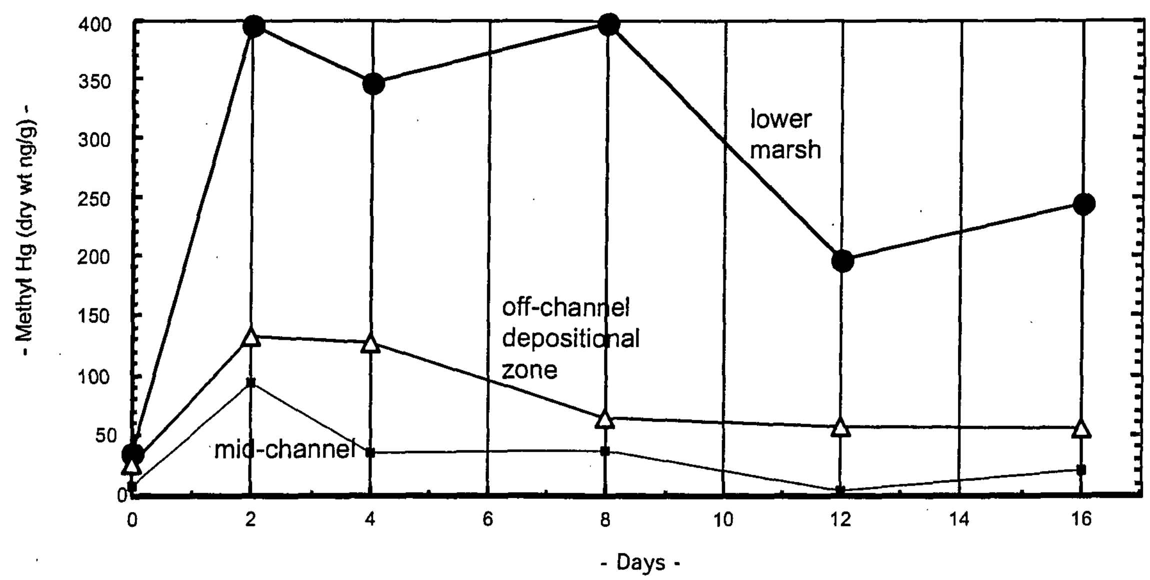


Figure 2 Time course of methyl mercury concentration in spiked laboratory sediment slurry incubations. Cosumnes region sediment slurries; 2:1 mixtures of site water:site sediment; inorganic mercury added to 1.00 µg Hg g^{-1}; anoxic incubations at 22 °C.

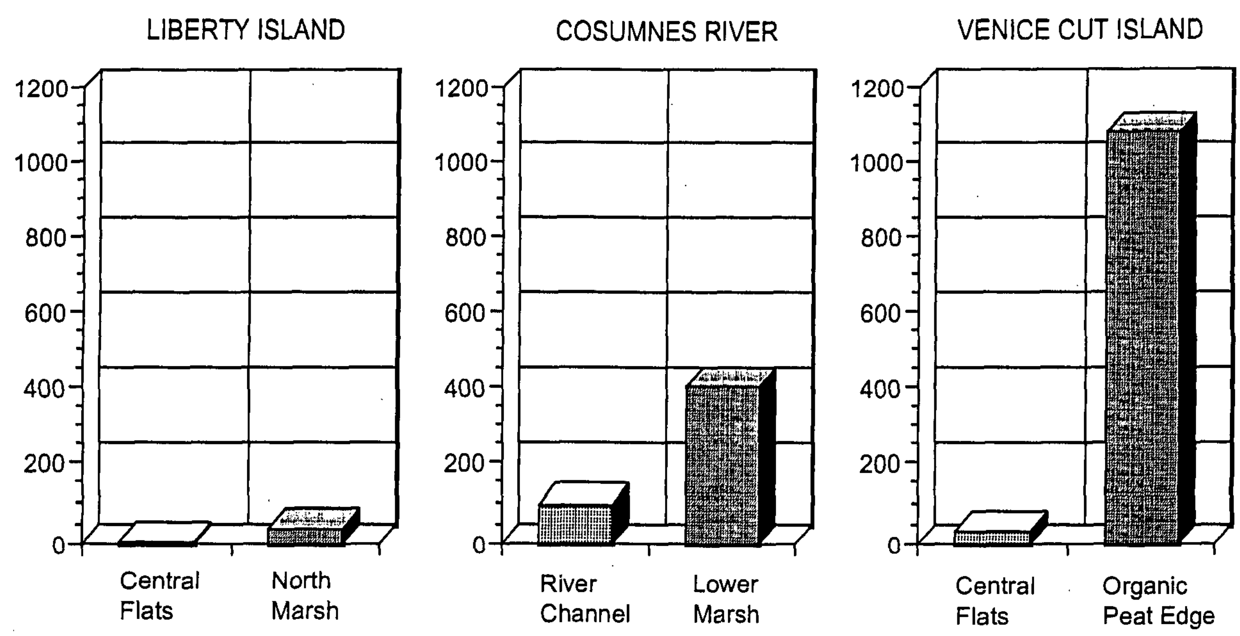


Figure 3 Relative mercury methylation potential of Delta marsh habitats vs. adjacent aquatic habitat. Mean maximum methyl mercury concentrations in inorganic mercury addition experiments to 1.00 µg Hg g^{-1}; methyl mercury concentrations in dry wt ng Hg g^{-1}.

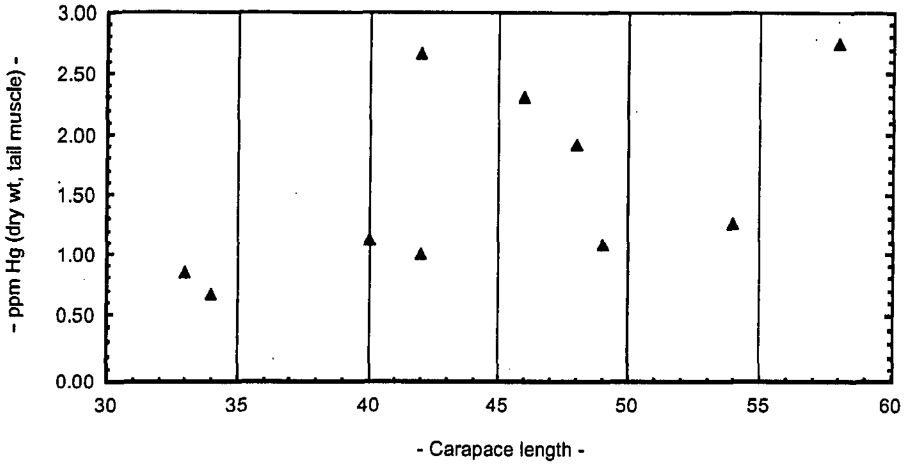


Figure 4 Individual mercury variability in signal crayfish, *Pacifasticus leniusculus*. Sacramento River at Isleton, December 9, 1999; tail muscle with gut removed.

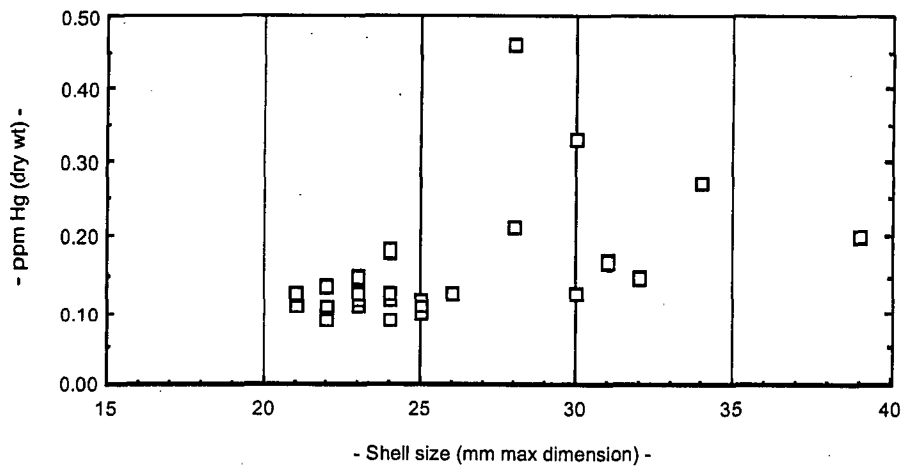


Figure 5 Individual mercury variability in the Asiatic clam, *Corbicula fluminea*. Cosumnes North Slough, October 26, 1999; whole body clams were purged four days before analysis.

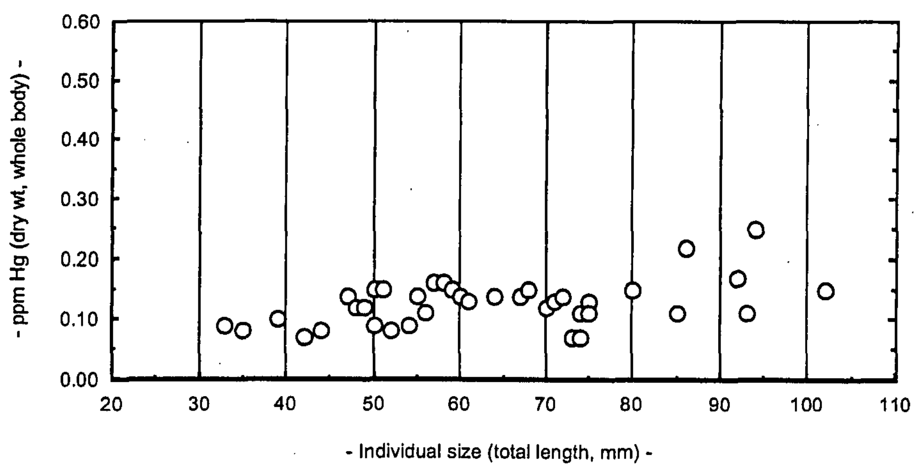


Figure 6 Individual mercury variability in inland silverside *Menidia beryllina*. Mildred Island, November 9, 1999.

Mercury in Clams (*Corbicula fluminea*)

Figure 7 shows mercury concentrations in 15- to 27-mm *Corbicula* from multi-individual, whole body composites taken consistently throughout the Delta. *Corbicula* mercury concentrations were relatively elevated in the Cosumnes and Mokelumne rivers (0.34 to 0.38 μg Hg g^{-1}) and moderately elevated in downstream channels carrying their water (0.18 to 0.26 μg Hg g^{-1}). Sacramento River inflows (0.15 to 0.22 μg Hg g^{-1}) and North Delta sites exposed to Yolo Bypass flows had similar levels (0.14 to 0.29 μg Hg g^{-1}). Clams from the Stanislaus (0.34 μg Hg g^{-1}), Tuolumne (0.20 μg Hg g^{-1}), and Merced (0.17 μg Hg g^{-1}) rivers were also elevated to varying degrees. Clams from the entire South Delta region were consistently low (0.0 to 0.16 μg Hg g^{-1}), except for one outlier from Old River south of Clifton Court Forebay (0.35 μg Hg g^{-1}). The Central Delta region, with its many flooded tracts, demonstrated clam mercury concentrations similar to those in the inflows at sites north of Mildred Island (0.16 to 0.35 μg Hg g^{-1}).

Throughout the Delta, there was no indication of localized increases in mercury concentrations of *Corbicula* as a function of habitat. Flooded wetland tracts consistently exhibited mercury levels that were similar to those from control sites within the same subregion. In paired collections (inside and outside flooded tracts) from Venice Cut and Rhode islands, concentrations were not statistically different.

Notably, the highest overall values in the *Corbicula* mercury data set were recorded at West Delta and Suisun Bay sites between Ryer Island to the west and Big Break, Gallagher Slough, and Sand Mound Slough to the east. Throughout this region, *Corbicula* mercury concentrations were between 0.32 and 1.08 μg Hg g^{-1}. Composites of another bivalve, *Potamocorbula amurensis*, taken at the upstream side of Carquinez Strait, were also relatively high (0.37 to 0.42 μg Hg g^{-1}). Suisun Slough and Grizzly Bay (0.15 to 0.26 μg Hg g^{-1}) did not appear to be the source of elevated West Delta and Suisun Bay mercury bioaccumulation.

Mercury in Inland Silversides (*Menidia beryllina*)

Figure 8 displays inland silverside mercury from 45 to 75 mm, multi-individual, whole body composites taken at 64 sites throughout the Delta. These small, schooling fish accumulate mercury over a larger region than the clams, likely integrating mercury across each flooded tract or slough, thus, being more representative of average mercury conditions at each site. As a result, the silverside data set grades very evenly from site to adjacent site and provides perhaps the best broad spatial measure to date of relative mercury bioavailability to fishes throughout the Delta. Additionally, mercury bioaccumulation in small fishes is dominated by methyl mercury (similar to large fishes), whereas bivalve mercury bioaccumulation may include substantial amounts of inorganic mercury (Brenda Lasorsa, personal communication, see "Notes"). Thus, the silverside data set may be the better indicator of relative methyl mercury exposure. Ongoing work will directly determine the methyl mercury component in our primary indicator organisms.

Mercury concentrations in silversides were consistently elevated in the Cosumnes and Mokelumne rivers (0.30 to 0.55 μg Hg g^{-1}) and the North Delta sites exposed to Yolo Bypass flows (0.18 to 0.46 μg Hg g^{-1}), with highest regional levels closest to the undiluted inflows. Elevated to a lesser extent were the channels carrying Sacramento River water (Sacramento River, Steamboat and Georgiana sloughs, Delta Cross Canal), which had very similar mercury levels in silversides at 0.21 to 0.28 μg Hg g^{-1}. Collections in the target size class were not possible in the Stanislaus, Tuolumne, or Merced rivers, but composites from the San Joaquin River upstream of the Merced (0.79 μg Hg g^{-1}) and from Mud Slough at Kesterson Reserve (0.69 μg Hg g^{-1}) contained the highest mercury levels in silversides of the survey. However, as in the clams, this did not translate into elevated levels downstream in the South Delta. Silversides from the entire south and central portions of the Delta were uniformly low in mercury (0.08 to 019 μg Hg g^{-1}) relative to the inflow values.

As with clams, silversides demonstrated little or no localized elevation in mercury concentrations in relation to flooded wetland habitats. Fish from large, relatively isolated flooded tracts in the North Delta such as Liberty Island (0.29 μg Hg g^{-1}) and Little Holland Tract (0.18 μg Hg g^{-1}) were not elevated over control samples from adjacent and regional channel and slough sites (0.21 to 0.46 μg Hg g^{-1}). The Central Delta, with its prevalence of flooded tracts, also showed no relative increase in silverside mercury concentration in flooded tracts compared to control sites, with all concentrations throughout the region being uniformly low relative to inflow sites and the West Delta. In fact, the Central Delta demonstrated the lowest levels of silverside mercury bioaccumulation in the entire system.

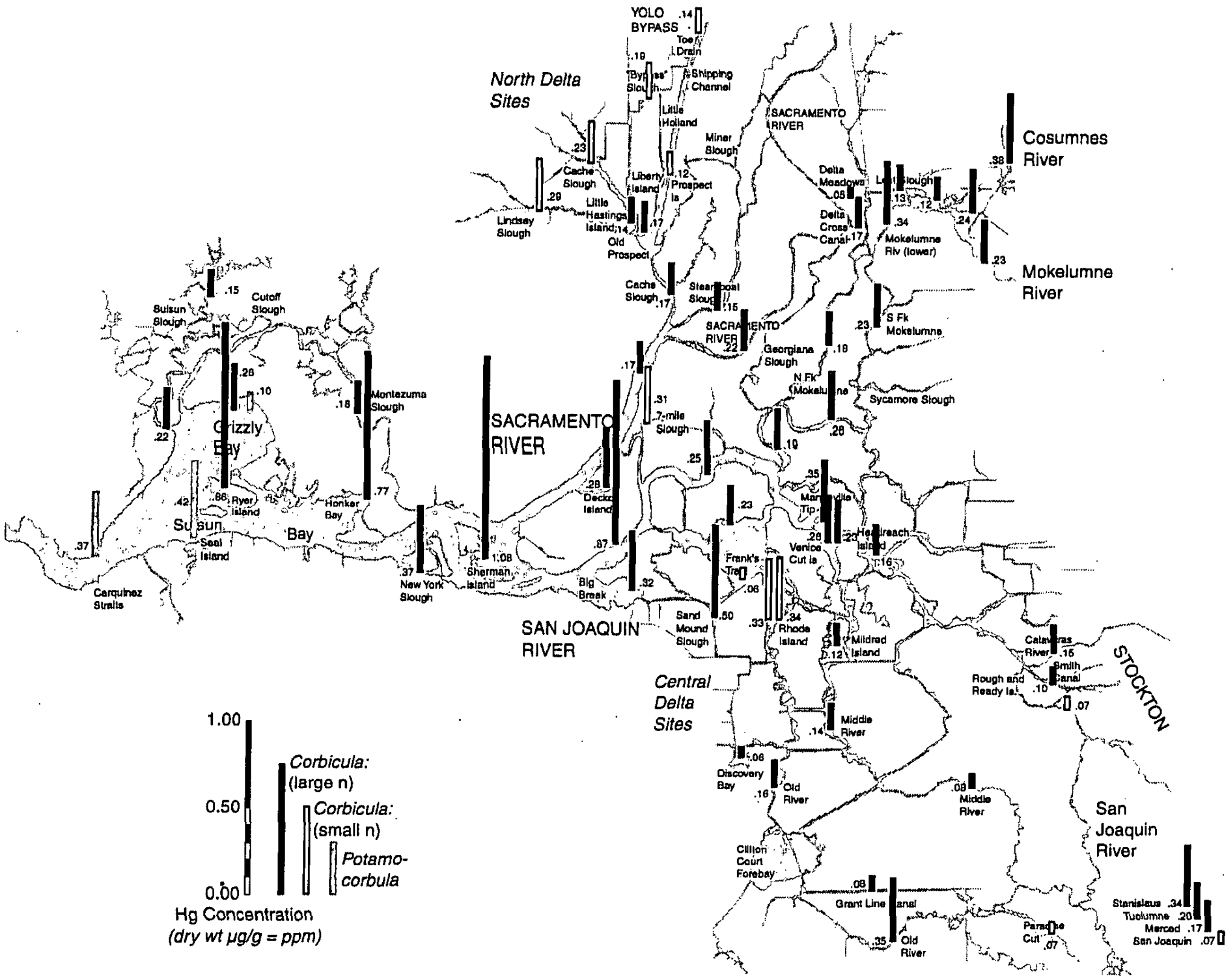


Figure 7 Mercury spatial distribution of the Asiatic clam, *Corbicula fluminea*. Fall 1999 collections; 15 to 27 mm, multi-individual composites; clams purged four days before analysis; "small *n*" ≤ 5.

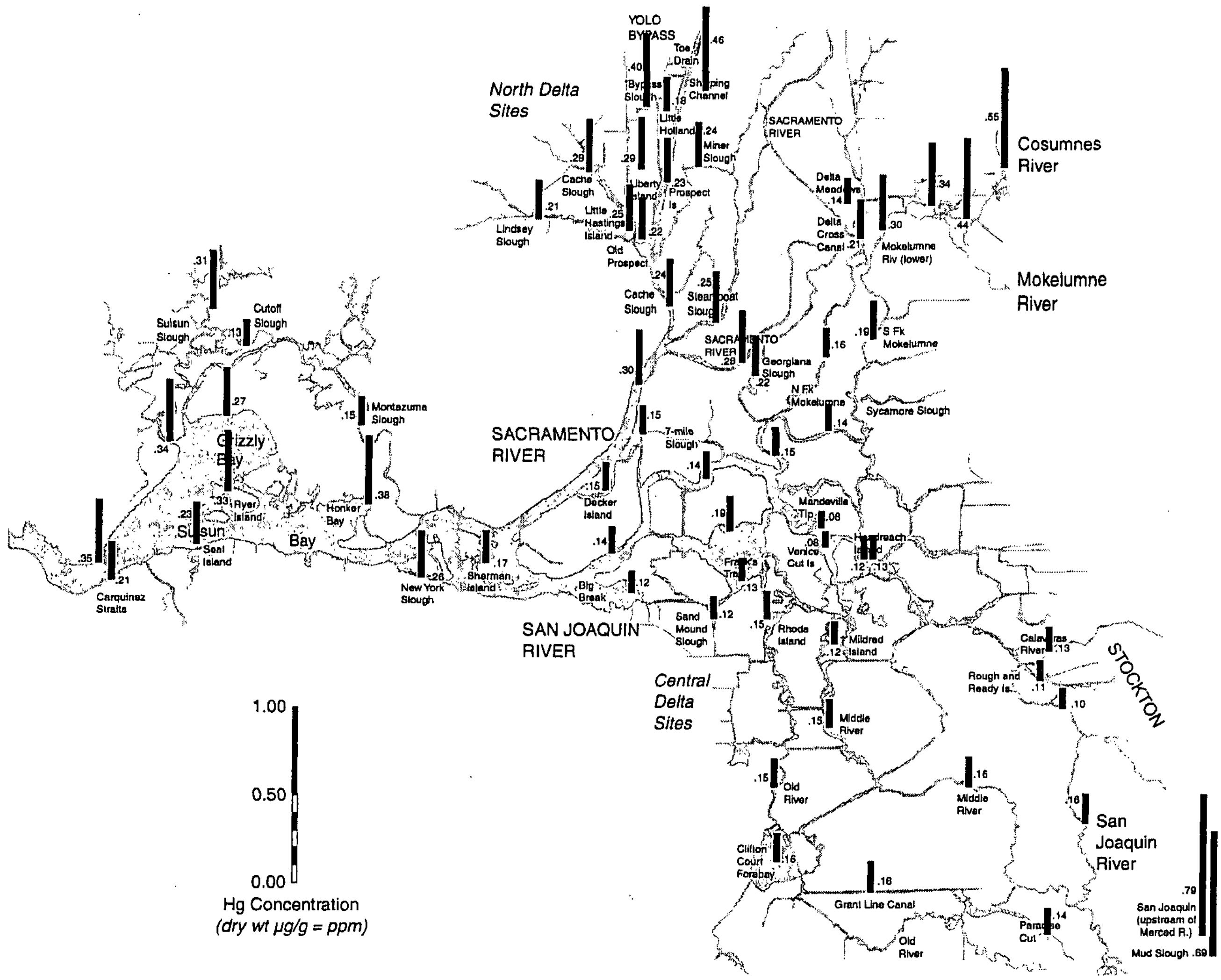


Figure 8 Mercury spatial distribution of inland silverside, *Menidia beryllina*. Fall 1999 collections; 45 to 75 mm, multi-individual composites; $n \geq 6$; whole body dry wt µg Hg g^{-1}.

Inland silversides in the West Delta and Suisun Bay again showed a distinct signal of increased mercury bioaccumulation relative to the Central Delta. While increases were not as apparent as those seen in the clams (Sand Mound Slough, Gallagher Slough, Big Break, Sherman Lake: 0.12 to 0.17 µg Hg g^{-1}), silversides from west of the Sacramento-San Joaquin confluence to the Carquinez Strait exhibited elevated levels similar to those of the northern and eastern inflow regions at 0.21 to 0.38 µg Hg g^{-1}.

Conclusions and Implications for Delta Wetlands Restoration

For problem levels of methyl mercury to accumulate in fish, several factors must interact. There must be a source of inorganic mercury that is bioavailable to mercury methylating bacteria. There must be conditions that promote the methylation of this mercury. And, finally, the methyl mercury that is produced must move efficiently into and up through aquatic food webs. It is clear, from this study and upstream studies preceding it, that the Bay-Delta system contains a significant watershed source of mercury, largely linked to historic mining. Results to date suggest the Cosumnes River, Yolo Bypass, and Sacramento River are primary ongoing sources, with additional elevated inflows in some of the San Joaquin tributaries. This is in addition to the depositional mercury within the system that has presumably accumulated since the Gold Rush period. The methylation experiments indicate that flooded Delta wetland sediments have the strong potential to methylate bioavailable inorganic mercury. Preliminary results suggest methylation potential is proportional to the level of wetland ecological development. The bioindicator data show marked differences in localized mercury bioaccumulation across the Delta, with several regions of elevated mercury uptake that may be of particular concern. However, these elevated mercury bioaccumulation zones do not appear to directly correspond with tract flooding and wetland restoration. Within each Delta region, mercury bioaccumulation was typically similar in marsh, sand and mud flat, and channel and slough habitats. One possibility is that regional mercury bioavailability may be largely a function of methylation in flooded marsh zones, with this methyl mercury being subsequently distributed throughout all adjacent aquatic habitats as a result of vigorous tidal mixing. However, we found the Central Delta, with a preponderance of flooded tracts and a demonstrated high mercury methylating potential, was the lowest fish mercury bioaccumulation region of all, indicating several potentially competing processes may be involved in the dynamics of mercury bioaccumulation associated with flooded tracts.

Consistent with preliminary findings from 1998–1999, the 1999–2000 results reported here suggest relative mercury bioaccumulation may be more closely linked to location within the Delta than habitat type. This may be a function of proximity to inflowing sources, methylation efficiency, methyl mercury bioaccumulation efficiency, or food web complexity. Ongoing research is examining these and other factors. Delta regions with elevated mercury accumulation in localized bioindicators included areas fed by inflows from the Cosumnes River, Yolo Bypass and, to a lesser extent, Sacramento River. The Central and South Delta were markedly lower, despite high signals in some southern tributaries. One of the most important new findings of this year's research was the identification of an extensive additional zone of elevated mercury bioaccumulation in the West Delta between the Sacramento-San Joaquin confluence and Carquinez Strait.

The West Delta region encompasses the estuary entrapment zone, where fresh and salt water meet and inorganic and organic particulates typically accumulate. Several interrelated mechanisms may play a role in the apparent West Delta elevated biotic mercury phenomenon, including (1) the localized accumulation of organic and fine-grained inorganic material, promoting general bacterial activity and increased food web complexity, (2) sulfate increases associated with the transition to salinity, supporting sulfate-reducing bacteria, and (3) chemistry of the neutral form of mercury in this transition zone, which has been hypothesized to be optimal for cross-membrane transport into methylating bacteria (Mark Marvin Di Pasquale and Cynthia Gilmour, personal communications, see "Notes").

The configuration and magnitude of water diversion operations within the Delta can be expected to play an important, ongoing role in the mercury dynamics of the different regions, influencing the location of the entrapment zone, the re-distribution of elevated mercury inflows, and the re-distribution of within-Delta methyl mercury production.

Findings to date suggest organic-rich, vegetated wetland tracts have dramatically greater potential to methylate mercury than adjacent channel or flats habitat. However, this does not appear to result in localized increases in mercury accumulation in organisms. Mercury levels in bioindicator organisms showed regional trends, apparently related to inflow sources and differences in mercury cycling dynamics. Results to date suggest that wetlands restoration projects may result in localized mercury bioaccumulation at levels similar to, but not necessarily greater than, general levels within their surrounding Delta sub-region. Nevertheless, high methylation potential, flooded wetland habitat may be the primary source of methyl mercury production in the overall system: further work is being done to look at the specific contribution of flooded tracts. Careful monitoring will be essential to assess the actual effects of new wetlands restoration projects.

FUTURE WORK

Ongoing UC Davis CALFED research on Delta mercury dynamics includes:

- Determination of the methyl mercury component of total mercury in the bioindicator organisms and the spatial pattern of biotic methyl mercury and methyl:total mercury ratio.
- Investigation of possible seasonal and inter-annual variation in Delta mercury methylation and bioaccumulation at 12 representative index locations (May, August, November).

- Paired flooded tract and adjacent channel or slough sediment sampling at primary existing flooded tracts. Methyl mercury absolute concentration and methyl/total ratio are key variables, with additional comparisons of potentially driving variables including particle size, percentage moisture, percentage organic matter, sulfide, sulfate, pH, and dissolved organic carbon.
- Methylation potential experiments across the salinity gradient, including Franks Tract, Sherman Island, Grizzly Bay, and San Pablo Bay.
- Mercury bioaccumulation in additional species.
- Stable isotope investigations of food web structure.

ACKNOWLEDGEMENTS

The authors gratefully thank past and present members of the UC Davis Delta mercury research team, including Ron Weyand and Anne Liston who carefully prepared and analyzed the bulk of the samples reported here, Chance MacDonald and Professor Douglas Nelson for their work with the sediment slurry experiments, and Brenda Johnson. Additional thanks to numerous agency personnel who provided a variety of help and advice, including Chris Foe, Curtis and Jackie Hagen, Mark Stephenson, and Lenny Grimaldo. Funding for this research is provided by the CALFED Bay-Delta Program under Contract No. 97–C05 to the University of California, Davis.

REFERENCES

Domagalski J. 1998. Occurrence and transport of total mercury and methyl mercury in the Sacramento River Basin, California. J Geochem Exp 64:277–91.

Rudd JWM 1995. Sources of methyl mercury to freshwater ecosystems: a review. Water Air Soil Poll 80:697–713.

Foe C, Croyle W. 1998. Mercury concentrations and loads from the Sacramento River and from Cache Creek to the Sacramento-San Joaquin Delta estuary. Central Valley Regional Water Quality Control Board staff report. 101 p.

Roth DA, Taylor HE, Peart DB, Antweiler RC, Domagalski JL, Dileanis PD, Alpers CN. 2000. Distribution of inorganic mercury in Sacramento River water and suspended colloidal sediment material. Archives of Environmental Contamination and Toxicology. Forthcoming.

Slotton DG, Ayers SM, Reuter JE, Goldman CR. 1995. Gold mining impacts on food chain mercury in northwestern Sierra Nevada streams. Technical Completion Report for the University of California Water Resources Center, Project W–816. 46 p.

Slotton DG, Ayers SM, Reuter JE, Goldman CR. 1997. Cache Creek watershed preliminary mercury assessment, using benthic macro-invertebrates. Final Report for the Central Valley Regional Water Quality Control Board and the National Science Foundation. 36 p.

Slotton DG, Ayers SM, Reuter JE. 1998. Marsh Creek watershed mercury assessment project: third year (1997) baseline data report with 3-yr review of selected data. Report for Contra Costa County. 62 p.

Slotton DG, Ayers SM, Reuter JE, Goldman CR. 1999. Lower Putah Creek 1997–1998 mercury biological distribution study. Report for the Department of Environmental Health and Safety, University of California, Davis. 59 p.

Suchanek TH, Richerson PJ, Mullen LJ, Brister LL, Becker JC, Maxson A, Slotton DG. 1997. The role of the Sulphur Bank Mercury Mine site (and associated hydrogeological processes) in the dynamics of mercury transport and bioaccumulation within the Clear Lake aquatic ecosystem. A report prepared for the USEPA, Region IX Superfund Program. 479 p.

Suchanek TH, Slotton DG, Ayers SM, Johnson B, Nelson DC. 1999. Effects of wetlands restoration on the production of methyl mercury in the San Francisco Bay-Delta system: preliminary results. Interagency Ecological Program for the San Francisco Estuary. IEP Newsletter 12(3):19–24.

Theis TL, Young TC, DePinto JV. 1988. Factors affecting metal partitioning during resuspension of sediments from the Detroit River. J Great Lakes Research 14(2):216–26.

NOTES

Cynthia Gilmour (Academy of Natural Sciences, Estuarine Research Center, St. Leonard, Maryland). Telephone conversation on July 15, 2000.

Brenda Lasorsa (Battelle Marine Sciences Laboratory, Sequim Washington). Telephone conversation on August 14, 2000.

Mark Marvin Di Pasquale (US Geological Survey, Menlo Park). In-person conversation on March 20, 2000.

COUNTY OF GLENN

HEALTH SERVICES AGENCY

Environmental Health
240 N. Villa
Willows, California 95988
530-934-6588 ✱ Fax: 530-934-6463
gchs3@glenncounty.net

MIKE CASSETTA
Director
gchs2@glenncounty.net

Don Holm
ENVIRONMENTAL HEALTH SPECIALIST

November 2, 1999

NEWS RELEASE

Contact: Don Holm, EHS III
Greg Lindholm, EHS II
Doug Danz, EHS II
Glenn County Health Department, 934-6588

Cal EPA's Office of Environmental Health Hazard Assessment recently released the results of a fish study in Black Butte Lake. The study included chemical sampling of 57 fish taken from the lake in November and December of 1997. Analysis of the fish showed that the levels of organic chemicals (including PCBs, dioxin and some pesticides) are not a concern. However, the analysis also showed that fish from Black Butte Lake have somewhat elevated levels of mercury in their flesh. Even low levels of mercury in the diet are a concern because mercury can have an adverse affect on the neurological development of children. Higher levels of mercury are toxic to the nervous system of adults.

Almost all fish whether purchased commercially or caught as sport fish contain mercury. Mercury is a widespread contaminant in California lakes and reservoirs, especially in the coast range where there are naturally high levels of mercury in the rock formations. The average level of mercury encountered in Black Butte lake fish was lower then the federal action level for commercially marketed fish (one part per million), but similar to levels of mercury in sport fish from other Northern California lakes where fish consumption advisories were published by the state. The levels of mercury in Black Butte Lake fish are close to levels found in fish from Clear Lake. The state does not anticipate completing a risk analysis and consumption advisory until next May. Since eating fish from Black Butte Lake could represent a hazard to the public, the Glenn County Health Department has adopted the Clear Lake Consumption Advisory as an interim fish consumption guidance document.

Smith CANAl-OP

B.1.46 Smith Canal, Organophosphorus Pesticides

Summary of Proposed Action

The California Regional Water Quality Control Board-Central Valley Region, Regional Board, recommends the addition of Smith Canal to California's Clean Water Act Section 303(d) list due to impairment by Organophosphorus (OP) pesticides. Information available to the Regional Board on OP pesticide levels in Smith Canal indicates that water quality objectives are not being attained. A description for the basis for this determination is given below.

Table B-1. 303(d) Listing/TMDL Information

Waterbody Name	Smith Canal	**Pollutants/Stressors**	Organophosphorus pesticides
Hydrologic Unit	544.00	**Sources**	Urban runoff
Total Waterbody Size	2 miles	**TMDL Priority**	
Size Affected	2 miles	**TMDL Start Date (Mo/Yr)**	
Extent of Impairment	From Yosemite Lake to the confluence with the San Joaquin River	**TMDL End Date (Mo/Yr)**	
Upstream Extent Latitude	37° 58' 03"	**Upstream Extent Longitude**	121° 18' 24"
Downstream Extent Latitude	37° 57' 25"	**Downstream Extent Longitude**	121° 20' 54"

Watershed Characteristics

The Smith Canal is located within and receives all of its water from the City of Stockton, in San Joaquin County. It flows for approximately 2 miles, from Yosemite Lake, in Yosemite Lake Park, to the San Joaquin River-Stockton Deep Water Ship Canal, just east of Louis Park. Land use around the area is primarily urban.

Water Quality Objectives Not Attained

The narrative objectives for pesticides and toxicity are not being attained for OP pesticides in the Smith Canal. The narrative objective for pesticides states, "No individual pesticide or combination of pesticides shall be present in concentrations that adversely affect beneficial uses." The narrative toxicity objective in the Basin Plan states "All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life." It further states that "The Regional Water Board will also consider ... numerical criteria and guidelines for toxic substances developed by the State Water Board, the California Office of Environmental Health Hazard Assessment, the California Department of Health Services, the U.S. Food and Drug Administration, the National Academy of Sciences, the U.S. Environmental Protection Agency, and other appropriate organizations to evaluate compliance with this objective...As a minimum, compliance with this objective...shall be evaluated with a 96-hour bioassay (CRWQCB-CVR, 1998; http://www.swrcb.ca.gov/~rwqcb5/bsnplnab.pdf)."

The toxicity objective was evaluated for Smith Canal by comparing toxicity test results of ambient water grab samples collected from Smith Canal with laboratory control results. These toxicity test procedures estimate the acute and chronic responses of aquatic test species from three phyla (representing three trophic levels) as an assessment of the toxicity of the ambient water samples. The tests include fathead minnow (a fish, *Pimephales promelas*) larval survival (mortality) and growth tests, zooplankton (a cladoceran, *Ceriodaphnia dubia*) survival and reproduction (offspring counts) tests, and algal (*Selenastrum capricornutum*) growth (chlorophyll a production) tests. The test results produced by the ambient canal water samples were compared to test results of the laboratory control water samples, to identify ambient creek water samples that caused statistically significant test species impairment.

Additionally, the pesticide and toxicity objectives were evaluated for Smith Canal by comparing OP concentrations measured in Smith Canal to chlorpyrifos and diazinon criteria developed by the California Department of Fish and Game to protect freshwater aquatic life (Siepmann and Finlayson, 2000).

Evidence of Impairment

Between 1994 and 1998 toxicity tests, toxicity identification evaluation (TIE) tests, chemical analysis, and the toxic units (TUs) of OP pesticides (the weighted toxicity caused by the OP pesticides) calculated by GF Lee (Lee and Jones-Lee, 2001a and 2001b) were conducted on water samples from Smith Canal. Four of eight ambient water samples collected from Smith Canal showed survival impairments to *Ceriodaphnia*. On all four occasions, the impairments caused complete (100%) mortality within 7 days (Lee and Jones-Lee, 2001a and 2001b). The toxicity events occurred in October, November, and March (Lee and Jones-Lee, 2001a and 2001b). On each occasion, TIEs were conducted, and on three of the occasions water quality tests were conducted and TUs were calculated.

On three of the four dates that TIE tests were conducted, the addition Piperonyl Butoxide (PBO), a substance that inhibits OP pesticides (Larsen *et al*, 2000), completely eliminated the previously observed toxicity. This indicates that OP pesticides caused the toxicity. On two of the three days, water quality was measured. The ambient water sample was analyzed for pesticides and found to contain detectable levels of diazinon, ranging in concentration from 0.129 to 0.166 ug/L. These levels exceed the chronic and acute CDFG levels for diazinon, indicating that the concentrations of diazinon are acutely and chronically toxic to freshwater aquatic life. Toxicity units (TUs) for the additive effects of diazinon and chlorpyrifos were also calculated. The TUs for both days was approximately 0.25 (25%), indicating that diazinon (and chlorpyrifos) could not account for the complete mortality of the samples. Since diazinon could not account for all of the toxicity observed, but the toxicity could be completely eliminated by adding PBO, other OP pesticides, in addition to diazinon and chlorpyrifos, may cause the toxicity in Smith Canal.

On the fourth date, the addition of PBO to the water sample reduced the mortality and caused a delay in the onset of mortality, but did not completely eliminate the mortality. This indicates that OP pesticides played a role in the toxicity. The ambient water sample was analyzed for pesticides and found to contain detectable levels of diazinon (or 0.186 ug/L) and chlorpyrifos (or 0.122 ug/L). These concentrations are above the chronic and acute CDFG criteria. Since the additive concentration of diazinon and chlorpyrifos can cause high levels of mortality and the addition of PBO could reduce the mortality and delay its onset, it is likely that OP pesticides, including diazinon and chlorpyrifos, cause at least some of the toxicity in Smith Canal.

Extent of Impairment

Samples appear to be collected from only one location within Smith Canal. However, because the sole source of the water is the City of Stockton, it is likely that the entire waterbody is impaired.

Potential Sources

Chlorpyrifos is an OP pesticide that has been commonly used by homeowners, pest control operators for structural and garden pest control, and on agriculture, including orchards. Diazinon is one of the most commonly used home and garden pesticides. Because the sole source of the water is from Stockton, it is likely that the source of the OP pesticides is urban run-off from the Stockton area.

Review of the City of Stockton Urban Stormwater Runoff Aquatic Life Toxicity Studies Conducted by the CVRWQCB, DeltaKeeper and the University of California, Davis, Aquatic Toxicology Laboratory between 1994 and 1999

Prepared by

G. Fred Lee, PhD, DEE and Anne Jones-Lee, PhD
G. Fred Lee & Associates
El Macero, CA
Ph: 530-753-9630 - Fx: 530-753-9956 - Em: gfredlee@aol.com

April 2001

R49-C

5 mile – Diaz = Pest
Chlor = Pest
Mosher – Chlor = Pest
Diaz = Pest
Smith – OP = Smith
Walker – Diaz – Smith

Beginning in 1994, the Central Valley Regional Water Quality Control Board (CVRWQCB) under Dr. Val Connor's leadership with support of a US EPA grant and with the assistance of the University of California, Davis, Aquatic Toxicology Laboratory (UCD-ATL), initiated a study of aquatic life toxicity in the City of Stockton's urban stormwater runoff to the city's sloughs. Samples of stormwater runoff were obtained from Mosher Slough, Five Mile Slough, Calaveras River, Walker Slough and the Smith Canal. Smith Canal and Five Mile Slough receive stormwater runoff only from the City of Stockton. Mosher Slough, Calaveras River and Walker Slough also at times receive stormwater runoff from agricultural areas and agricultural return (drain waters) upstream of the City of Stockton. All of these waterbodies are tidal freshwater within the City of Stockton with a one- to three-foot tide. The City of Stockton pumps dry weather flow from the City's storm sewer system and stormwater runoff into these waterbodies.

An extensive set of samples and detailed analyses were conducted in 1994. Additional sampling was done in 1995. Beginning in 1996 through 1999, the DeltaKeeper continued the sample collection and supported the toxicity testing and chemical analysis of the samples. A total of about 160 toxicity tests have been conducted on these samples over this time. Figure 1 shows the location of the sampling stations. In general, the samples of each waterbody were taken at the location where it crosses I-5.

All samples were analyzed for aquatic life toxicity by the University of California, Davis, Aquatic Toxicology Laboratory using the US EPA standard three species toxicity test (Lewis, *et al.*, 1994) with *Ceriodaphnia dubia* (freshwater zooplankton), *Pimephales promelas* (fathead minnow larvae) and *Selenastrum capricornutum* (freshwater alga) as the test organisms. Some of the samples were processed through a toxicity testing dilution series in order to estimate the total amount of toxicity present in the sample. Some of the original and dilutions were treated with piperonyl butoxide (PBO). PBO interacts with organophosphate pesticides such as diazinon and chlorpyrifos to eliminate and/or reduce their toxicity (Bailey, *et al.*, 1996).

Some of the samples were analyzed for the OP pesticides diazinon and chlorpyrifos using the enzyme linked immuno sorbent assay (ELISA) procedure. Details of the sampling and analytical procedures are provided by the UCD-ATL QAPP.

Figure 1

While not involved in the original studies, the authors, Drs. G. Fred Lee and Anne Jones-Lee, were asked to assist the DeltaKeeper in developing a report summarizing the data obtained in these studies. In addition to the CVRWQCB/DeltaKeeper/UCD ATL data, the City of Stockton holds an NPDES stormwater permit that requires monitoring of stormwater runoff. Stormwater monitoring data was available for 1997–1998 (Stockton 1998, San Joaquin County 1997). Additional aquatic life toxicity and/or OP pesticide data has been collected by Stockton that is not available. Summaries of that data indicate that the results are similar to the 1997-1998 data. This report presents an overview assessment of the information available from the 1994-1999 City of Stockton urban stormwater runoff aquatic life toxicity studies. Some of the data used in this report have previously been reported on by Connor (1994, 1995) and Fong, *et al.* (2000).

REGULATORY REQUIREMENTS

In accord with the US EPA Clean Water Act requirements, the CVRWQCB has adopted a Basin Plan objective of no toxicity in ambient waters. The CVRWQCB (1998) states,

> *"Toxicity*
> *All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life. This objective applies regardless of whether the toxicity is caused by a single substance or the interactive effect of multiple substances. Compliance with this objective will be determined by analyses of indicator organisms, species diversity, population density, growth anomalies, and biotoxicity tests of appropriate duration or other methods as specified by the Regional Water Board. The Regional Water Board will also consider all material and relevant information submitted by the discharger and other interested parties and numerical criteria and guidelines for toxic substances developed by the State Water Board, the California Office of Environmental Health Hazard Assessment, the California Department of Health Services, the U.S. Food and Drug Administration, the National Academy of Sciences, the U.S. Environmental Protection Agency, and other appropriate organizations to evaluate compliance with this objective. The survival of aquatic life in surface waters subjected to a waste discharge or other controllable water quality factors shall not be less than that for the same water body in areas unaffected by the waste discharge, or, when necessary, for other control water that is consistent with the requirements for "experimental water" as described in Standard Methods for the Examination of Water and Wastewater, latest edition. As a minimum, compliance with this objective as stated in the previous sentence shall be evaluated with a 96-hour bioassay. In addition, effluent limits based upon acute biotoxicity tests of effluents will be prescribed where appropriate; additional numerical receiving water quality objectives for specific toxicants will be established as sufficient data become available; and source control of toxic substances will be encouraged."*

The toxicity reported herein is a violation of the CVRWQCB Basin Plan objective for protection of aquatic life from aquatic life toxicity. This toxicity has caused Five Mile Slough and Mosher Slough to be listed on the Clean Water Act 303(d) list of "impaired" waterbodies. This listing requires that a total maximum daily load (TMDL) be established to control the constituents responsible for the toxicity.

Water Quality Criteria/Standards as TMDL Goals. The current US EPA approach for establishing TMDL goals is to control the constituent that causes the 303(d) listing of the waterbody as being an "impaired" waterbody. Typically, the 303(d) listing arises out of an exceedance of a worst-case-based water quality standard. While the US EPA (1987) published a water quality criterion for chlorpyrifos, the Agency did not require that this criterion be adopted by the states as a standard since chlorpyrifos is not considered a "toxic" pollutant.

The US EPA has not developed a water quality criterion for diazinon. An Agency contractor has developed a proposed acute criterion; however, there are problems in developing the chronic criterion. The California Department of Fish and Game, however, using US EPA criteria development approaches, has developed recommended water quality criteria for diazinon and chlorpyrifos. Siepmann and Findlayson (2000) have recently completed an updated evaluation of the recommended water quality criteria for diazinon and chlorpyrifos. They recommend a freshwater diazinon acute criterion (CMC) of 80 ng/L and a chronic criterion (CCC) of 50 ng/L. No saltwater criteria were recommended for diazinon. They recommend a freshwater chlorpyrifos CMC of 20 ng/L and a CCC of 14 ng/L. The corresponding recommended chlorpyrifos saltwater CMC was 20 ng/L and CCC was 9 ng/L. They also indicate that the diazinon and chlorpyrifos toxicities are additive.

Implementation of these criteria as worst case water quality standards which are not to be exceeded by any amount more than once in three years would likely mean that neither diazinon nor chlorpyrifos could be used on residential properties where there is any possibility of runoff from the property that has either of these OP pesticides in the runoff waters.

Strauss (2000) has indicated that the Fish and Game criteria would be acceptable TMDL goals to the US EPA Region IX.

SUMMARY OF RESULTS

A summary of the data obtained in these studies is presented in Tables 1-8. The original data tables with some minor modifications from that developed by the UCD-ATL are included in the Appendix to this report. Also included in the Appendix is a brief discussion of the data pertinent to a particular sampling event.

The rainfall data reported in Table 9 was collected from the City of Stockton Metro as retrieved from www.ncdc.noaa.gov/onlineprod/gsod/temp/gsod_28393.txt. At times, precipitation can be highly localized, where the amount of precipitation collected at a particular gage may not be representative of the amount of precipitation that occurred at other locations within the City of Stockton. The rainfall record of data for Stockton indicates that there was no recording of rainfall data during weekends.

Tables 1-8 provide information on the toxicity test results and chemical analyses obtained in these studies for each of the dates for which samples were collected. The *Ceriodaphnia* data set "% Sample" column indicates whether there was any dilution of the sample or any additions such as PBO or EDTA. The "Toxic Response" column provides the percent kill information on the day indicated in parentheses. The "Comments" column provides a brief summary of the most outstanding feature of that particular data set. The "Diazinon" and "Chlorpyrifos" concentrations are based on the ELISA testing where the < value was the indicated detection limit of the test. The "Calculated TUa" column represents a value obtained by dividing the concentration of diazinon or chlorpyrifos by the LC_{50} value and summing the two quotients. For diazinon a *Ceriodaphnia* LC_{50} value of 450 ng/L was used. For chlorpyrifos, the LC_{50} value that was used was 80 ng/L.

For the fathead minnow larvae tests, the "% Mortality" is provided with a comment as to whether it was statistically significant. The *Selenastrum* tests were summarized in terms of whether there was a toxic response based on a decrease in the number of *Selenastrum* cells in the test samples compared to the control. The "Comment" section indicates whether the algae in the test samples grew to a greater degree than the reference, indicating a "stimulation" of growth by nutrients in the samples.

CONCLUSIONS

The overall conclusions from the City of Stockton urban stormwater runoff aquatic life toxicity studies of Mosher Slough, Five Mile Slough, Calaveras River, Walker Slough, and Smith Canal (waterbodies) are presented below.

- Stormwater runoff to the investigated waterbodies causes the waterbody to be toxic to *Ceriodaphnia*.
- Typically, one to two acute toxic units (TUa) were present in the waterbodies during a stormwater runoff event.
- The concentrations of diazinon and chlorpyrifos found in Stockton slough and other waterbodies investigated in this study following stormwater runoff events frequently exceeded the California Department of Fish and Game recommended criteria for these pesticides. This exceedance would cause these waterbodies to be in violation of a TMDL goal for the control of aquatic life toxicity caused by these pesticides that was numerically equal to the California Department of Fish and Game criterion.
- Samples taken the day after a stormwater runoff event were nontoxic and had low levels of OP pesticides.
- Stormwater runoff to these waterbodies did not cause toxicity to fathead minnow larvae or the alga *Selenastrum*. Typically, samples of the waterbodies during stormwater runoff stimulated the growth of the test alga.
- Based on toxicity investigation evaluations (TIEs), PBO and ELISA testing, diazinon is the chemical primarily responsible for the observed toxicity. Some samples had sufficient chlorpyrifos concentrations to contribute to the toxicity found.
- Based on limited TIE studies utilizing EDTA to complex the heavy metals, heavy metals do not appear to be a contributor to the aquatic life toxicity found.
- Samples of precipitation taken in Stockton in 1996 showed concentrations of diazinon and chlorpyrifos well below toxic levels for *Ceriodaphnia*.
- There is some indication of possible pyrethroid pesticide toxicity as indicated by PBO enhanced toxicity.
- Urban stormwater runoff monitoring conducted by the City of Stockton during 1995-1998 shows *Ceriodaphnia* toxicity
- Studies conducted by the DeltaKeeper and UCD-ATL during the fall and winter of 1998-1999 of the various Stockton Sloughs and rivers show that stormwater runoff was toxic to *Ceriodaphnia* due to OP pesticides.
- The Stockton stormwater runoff associated toxicity to zooplankton may be having an adverse impact on the dissolved oxygen concentrations in the Stockton sloughs, as well as in the San Joaquin River Deep Water Ship Channel, as a result of killing zooplankton in the sloughs, Ship Channel and San Joaquin River that normally graze phytoplankton. The lack of grazing due to toxicity to zooplankton could be responsible for phytoplankton blooms that lead to DO depletion in the sloughs and Deep Water Ship Channel below water quality objectives.
- The aquatic life toxicity found in City of Stockton stormwater runoff is similar to what has been found in urban stormwater runoff in the San Francisco Bay region, Sacramento area, Orange County, Los Angeles and San Diego (Lee and Taylor 1999, 2001).
- There is need for the CVRWQCB to consider adding the other Stockton sloughs and waterbodies investigated in this study to the 303(d) list of impaired waterbodies because of the aquatic life toxicity found.

RECOMMENDATIONS FOR FUTURE WORK

Presented below are recommendations for future studies and programs that need to be evaluated and, if appropriate, implemented.

- There is need to evaluate the contribution of agricultural stormwater runoff to the aquatic life toxicity present in the City of Stockton waterbodies that receive agricultural runoff/drainage from upstream sources.

- There is need to evaluate the potential for enhanced toxicity due to OP pesticides associated with low dissolved oxygen concentrations in the waterbodies and downstream.
- There is need to understand the dry weather flow toxicity to young fathead minnows (not larvae) that the DeltaKeeper is finding in caged fathead minnows placed in the waterbodies near City of Stockton stormwater sewer discharges.
- There is need to evaluate the water quality/ecological significance of periodic toxic pulses associated with stormwater runoff events within the City of Stockton on the sloughs' aquatic resources and the nearby Delta aquatic resources. The slough backwater areas could be important nursery grounds for Delta fish that are being adversely impacted by current OP pesticide-caused aquatic life toxicity.
- There is need to determine whether the toxicity of fall stormwater runoff events kills zooplankton in the San Joaquin River and/or Deep Water Ship Channel and thereby enables a greater algal bloom to occur than would occur if the zooplankton were able to graze the phytoplankton. If the zooplankton populations are depressed following a fall precipitation runoff event, then there is need to see if a phytoplankton bloom occurs which causes a greater DO depletion in the Deep Water Ship Channel than normally occurs during the fall.
- During the fall and winter of 1999, US EPA announced agreements which effectively phase out the use of the OP pesticides diazinon and chlorpyrifos in residential areas during 2001 for chlorpyrifos and by 2005 for diazinon. This situation means that the aquatic life toxicity due to the use of these pesticides in residential areas within Stockton will be significantly decreased, and possibly eliminated, within a few years. Since some uses of these pesticides will still be allowed, such as on golf courses and in agricultural pest control, it will be important to continue to monitor diazinon, chlorpyrifos and aquatic life toxicity in stormwater runoff within the City of Stockton and upstream of the City's sources that receive agricultural stormwater runoff and irrigation tailwater.
- Since the phase-out of residential use of diazinon and chlorpyrifos will result in the use of other pesticides that have the potential to be present in stormwater runoff, it will be important to determine what pesticides are being used on residential properties, the amounts used, how and where they are being applied and the concentrations present in stormwater runoff. Also, the aquatic life toxicity of stormwater runoff to Stockton sloughs should be monitored on a regular basis, using the US EPA standard three species tests to evaluate how the toxicity of the runoff changes as diazinon and chlorpyrifos are phased out of urban residential use and new pesticides are used in their place. It is possible that this substitution of pesticides could cause significantly greater adverse impacts to the aquatic life-related beneficial uses of Stockton sloughs and the nearby associated Delta waters than were caused by the OP pesticides diazinon and chlorpyrifos.
- There is need to evaluate the possible control of OP pesticide-and other/substitute pesticide-caused aquatic life toxicity in Stockton stormwater runoff. Consideration should be given to public education as a means of controlling both residential and agriculturally-derived pesticide-caused aquatic life toxicity.
- There is need to understand how the use of pesticides in residential areas for termite and ant control and lawn and garden pest control leads to stormwater runoff that is toxic to *Ceriodaphnia*.
- There is need to evaluate the effectiveness of education programs in reducing the amounts of pesticides and aquatic life toxicity in City of Stockton waterbodies. Also, consideration should be given to assessing the improvements in the aquatic life-related beneficial uses that could result from controlling the use of pesticides within the City of Stockton that causes aquatic life toxicity in the City's waterbodies and nearshore regions of the Delta.

ACKNOWLEDGMENTS

Dr. Val Connor of the Central Valley Regional Water Quality Control Board planned many of these studies. Her assistance in obtaining these data and in this project is appreciated. The assistance of Bryan Stafford and Karen Larsen of the CVRWQCB staff is appreciated.

All samples except those collected by the Stockton Stormwater monitoring program were processed by the University of California, Davis, Aquatic Toxicology Laboratory. The assistance of Linda Deanovic, Stephanie Fong and Karen Larsen of the UCD ATL is greatly appreciated. The DeltaKeeper (Bill Jennings) and its staff were responsible for sample collection during 1996–1999. The assistance of Bill Jennings in providing information for the development of this report is appreciated.

REFERENCES

Bailey, H.C., DiGiorgio, C., and Kroll, K., "Development of Procedures for Identifying Pesticide Toxicity in Ambient Waters: Carbofuran, Diazinon, Chlorpyrifos," Environmental Toxicology andChemistry, 15:(6) 837-845 (1996).

Connor, V., "Toxicity and Diazinon Levels Associated with Urban Storm Runoff," Memorandum to Jerry Bruns, Chief, Standards, Policies & Special Studies, California Regional Water Quality Control Board, Central Valley Region, Sacramento, CA, February 15 (1994).

Connor, V., "Status of Urban Storm Runoff Projects," Memorandum to Jerry Bruns, Chief, Standards, Policies & Special Studies, California Regional Water Quality Control Board, Central Valley Region, Sacramento, CA, January 30 (1995).

CVRWQCB, "The Water Quality Control Plan (Basin Plan) for the California Regional Water Quality Control Board Central Valley Region," Fourth Edition – 1998, California Regional Water Quality Control Board, Central Valley Region, Sacramento, CA, September (1998).

Fong, S., Reyes, E., Larsen, K., Louie, S., and Deanovic, L., "Sacrament-San Joaquin Delta Toxicity Test Monitoring Report: 1998-99, The Final Report for DeltaKeeper," Aquatic Toxicology Laboratory, University of California, Davis, Davis, CA. (2000).

Lee, G. F., Taylor, S., and Palmer, F., "Results of Aquatic Toxicity Testing Conducted During 1999-2000 in the Upper Newport Bay Watersheds," submitted to State Water Resources Control Board, Santa Ana Regional Water Quality Control Board and Orange County Public Facilities and Resources Department to meet the requirements of the US EPA 319(h) Project, G. Fred Lee & Associates, El Macero, CA and RBF Consulting, Irvine, CA, January (2001).

Lewis, P.A., Klemm, D.J., Lazorchak, J.M., Norberg-King, T., Peltier, W.H., and Heber, M.A., "Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms," Environmental Monitoring Systems Laboratory, Cincinnati, Ohio, Environmental Research Laboratory, Duluth, Minnesota, Region 4, Environmental Services Division, Athens, Georgia, Office of Water, Washington, D.C., Environmental Monitoring Systems Laboratory, Cincinnati, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio (1994).

San Joaquin County, "1996-1997 Fiscal Year Annual Report for the San Joaquin County National Pollutant Discharge Elimination System, Permit No. CA0083470," September (1997).

Siepmann, S. and Findlayson, B., "Water Quality Criteria for Diazinon and Chorpyrifos," California Department of Fish and Game, Administrative Report 00-3, Rancho Cordova, CA (2000).

Stockton, "City of Stockton 1997-98 Storm Water Monitoring Program," Prepared by Kinnetic Laboratories, Inc. for the City of Stockton, Stockton, CA, August (1998).

Strauss, A., "Comments on the Use of Probabilistic Ecological Risk Assessment to Establish Organophosphate Pesticide Aquatic Life Toxicity TMDL Goal," Letter to G. Carlton, Executive Officer, Central Valley Regional Water Quality Control Board, Sacramento, CA, from US EPA Region IX, San Francisco, CA, April (2000).

US EPA, "Water Quality Criterion for Chlorpyrifos," in Quality Criteria for Water 1986, EPA 440/5086-001, US Environmental Protection Agency, Office of Water Regulations and Standards, Washington, D.C. (1987).

Table 1. Summary of Aquatic Toxicity Test Data
Mosher Slough, Stockton, CA (1994-1999)

Ceriodaphnia

Date	% Sample	Toxicity Response %kill in (days)	Comments	Diazinon (ng/L)	Chlor-pyrifos (ng/L)	Calculated TUa
2/6/94	100	100 (1)		900	--	2
2/6/94	100	100 (1)		--	--	
2/6/94	100+200µg/L PBO	20 (2)	PBO reduced toxicity	--	--	
2/7/94	100	100 (1)		630	--	1.2
2/7/94	100	100 (1)		--	--	
2/7/94	100+200µg/L PBO	0 (7)	PBO reduced toxicity	--	--	
10/5/94	100	100 (2)		459	<80	1
10/5/94	100	100 (3)		--	--	
10/5/94	100	50 (2)		--	--	1 to 2
10/5/94	50	0 (4)		--	--	
10/5/94	100+200µg/L PBO	10 (4)	PBO reduced toxicity	--	--	
11/6/94	100	100 (2)		--	--	
11/6/94	100	100 (3)		499	<80	1
11/6/94	100+200µg/L PBO	0 (4)	PBO reduced toxicity	--	--	
5/3/95	100	100 (2)	At Don Ave.	417	120	2
5/3/95	100+200µg/L PBO	0 (4)	PBO reduced toxicity	--	--	
10/29/96	100	100 (7)	No information on kill rate	486	103	2
10/29/96	100+200µg/L PBO	100 (7)		--	--	
10/29/96	100	100 (1)	(H36)	--	--	
10/29/96	50	80 (4)		--	--	
10/29/96	50+100µg/L PBO	0 (4)	PBO reduced toxicity	--	--	
10/29/96	50+200µg/L PBO	13 (4)	PBO activated toxicity	--	--	
10/29/96	25	0 (4)		--	--	2 to 4
10/29/96	25+100µg/L PBO	0 (4)		--	--	
10/29/96	25+200µg/L PBO	77 (3)	PBO activated toxicity	--	--	
10/29/96	12.5	7 (4)		--	--	
10/29/96	100+15mg/L EDTA	93 (4)	Not metal toxicity	--	--	
10/29/96	100+30mg/L EDTA	100 (1)		--	--	
11/16/96*	100		At Kelley Drive	640 830	80 120	2 2.5
11/16/96*	100		At Thornton Road	760	70	2
11/10/97*			At Thornton Road	1,500	100	3
11/10/97*	100	6.0 TUa	At Kelley Drive	2,300	150	6

(continues)

Table 1. Summary of Aquatic Toxicity Test Data
Mosher Slough, Stockton, CA (1994-1999) (continued)

Date	% Sample	Toxicity Response %kill in (days)	Comments	Diazinon (ng/L)	Chlor-pyrifos (ng/L)	Calculated TUa
11/10/97*	100+125µg/L PBO	1.6 TUa	At Thornton Road PBO reduced toxicity	--	--	
11/13/97	100	100 (3)		461	59	2
11/13/97	100+ 100 µg/L PBO	90 (3)		--	--	
1/14/98*			at Kelley Drive	830	<500	--
1/14/98*			at Thornton Road	360J	<500	--
2/19/98*			at Kelley Drive	430J	<500	--
2/19/98*			at Thornton Road	320J	<500	--
9/9/98	100	0 (7)		--	--	
10/24/98	100	100 (3)	At Mariner	310	--	
10/24/98	100+ 100 µg/L PBO	20 (7)		--	--	
12/7/98	100	60 (7)		--	--	
12/7/98	100	90 (7)		--	--	
12/7/98	100+ 100 µg/L PBO	0 (7)	PBO reduced toxicity	--	--	
1/20/99	100	100 (1)		--	--	
1/20/99	100+100 µg/L PBO	100 (6)	PBO slowed kill rate	--	--	
1/20/99	100	100 (1)	At I-5	1,200	50	3
1/20/99	100	100 (1)	At Don Ave	--	--	
2/8/99	100	100 (1)	At I-5	820	40	
2/8/99	100+ 100 µg/L PBO	0 (4)	At I-5	--	--	
2/8/99	50	100 (2)	At I-5	--	--	
2/8/99	25	0 (4)	At I-5	--	--	
2/8/99	25+ 100 µg/L PBO	0 (4)	At I-5	--	--	
2/8/99	12.5	0 (4)	At I-5	--	--	
2/8/99	100	100 (1)	At Don Ave	860	30	
2/8/99	100+ 100 µg/L PBO	5 (3)	At Don Ave; PBO reduced toxicity	--	--	
2/8/99	50	100 (1)		--	--	
2/8/99	25	0 (4)		--	--	
2/8/99	25+ 100 µg/L PBO	0 (4)		--	--	
9/22/99	100	100 (3)				
9/22/99	100+100 µg/L PBO	20	PBO reduced toxicity			

* – City of Stockton data
J – Estimated < detection limit
-- – Not measured

(table continues)

Table 1. Summary of Aquatic Toxicity Test Data
Mosher Slough, Stockton, CA (1994-1999) (continued)

Fathead Minnow Larvae

Date	% Mortality	Comment
10/5/96	0	
10/29/96	5	Not statistically significant
11/13/97	22	Not statistically significant
9/9/98	0	
10/24/98	2.5	Not statistically significant
12/7/98	0	
2/8/99	5	at I-5; Not statistically significant
2/8/99	10	at Don Ave; Not statistically significant

Selenastrum capricornutum

Date	Toxic Response	Comment
10/5/94	No	Stimulation
11/6/94	No	
10/29/96	No	Stimulation
11/13/97	No	
9/9/98	No	Stimulation
10/24/98	No	Stimulation
12/7/98	No	
1/20/99	No	
2/8/99	Yes	At I-5
2/8/99	Yes	At Don Ave

Table 2. Summary of Aquatic Toxicity Test Data
Five Mile Slough, Stockton, CA (1994-1998)

Ceriodaphnia

Date	% Sample	Toxicity Response %kill in (days)	Comments	Diazinon (ng/L)	Chlor-pyrifos (ng/L)	Calculated TUa
2/6/94	100	100 (2)		1,000	--	2
2/6/94	100	100 (1)		--	--	
2/6/94	100+200µg/L PBO	80 (4)	PBO reduced toxicity	--	--	
2/7/94	100	100 (1)		>1,000	--	> 2
2/7/94	100	100 (1)		1,200	--	2.5
2/7/94	100+200µg/L PBO	20 (4)	PBO reduced toxicity	--	--	
10/5/94	100	100 (2)		278	<80	0.5
10/5/94	100	100 (3)		--	--	
10/5/94	50	0 (4)	Between 1 and 2 TUa	--	--	
10/5/94	100+200µg/L PBO	60 (7)	PBO reduced toxicity	--	--	
11/6/94	100	0 (4)		80	<80	1
10/29/96	100	100 (7)	No information on rate of kill	304	84	1.5
10/29/96	100+100µg/L PBO	0 (7)	PBO reduced toxicity	--	--	
11/13/97	100	100 (5)		359	52	2
11/13/97	100+100µg/L PBO	0 (7)	PBO reduced toxicity	--	--	
10/24/98	100	0 (7)		--	--	
10/24/98	100+100µg/L PBO	10 (7)		--	--	
9/22/99	100	100 (7)				
9/22/99	100+100µg/L PBO	0				

-- – Not measured

Fathead Minnow Larvae

Date	% Mortality	Comment
10/5/94	7	Not statistically significant
10/29/96	42	Not statistically significant
11/13/97	75	Statistically significant
10/24/98	0	

Selenastrum capricornutum

Date	Toxic Response	Comment
10/5/94	No	Stimulation
11/6/94	No	
10/29/96	No	Stimulation
11/13/97	No	Stimulation
10/24/98	No	Stimulation

Table 3. Summary of Aquatic Toxicity Test Data
Calaveras River, Stockton, CA (1994-1998)

Ceriodaphnia

Date	% Sample	Toxicity Response %kill in (days)	Comments	Diazinon (ng/L)	Chlor-pyrifos (ng/L)	Calculated TUa
2/6/94	100	100 (2)		380	--	0.8
2/6/94	100	100 (2)		--	--	
2/6/94	100+200µg/L PBO	0 (7)	PBO reduced toxicity	--	--	
2/7/94	100	100 (2)		450	--	1
2/7/94	100	100 (2)		--	--	
2/7/94	100+200µg/L PBO	0 (7)	PBO reduced toxicity	--	--	
10/5/94	100	100 (4)		299	<80	0.5
10/5/94	100	100 (4)		--	--	
10/5/94	100+100µg/L PBO	5 (6)	PBO reduced toxicity	--	--	
11/6/94	100	0 (4)		199	88	1.5
10/29/96	100	0 (7)	TUa could not be calculated	36	<50	
10/29/96	100+100µg/L PBO	0 (7)			--	
11/16/96*			At Sutter Street	640	<50	
11/16/96*			At West Lane	170	<50	
1/22/97*			At Sutter Street	130	70	
1/22/97*			At West Lane	210 200	100 90	
11/10/97*			At Sutter Street	480	<50	
11/10/97*	100	<1.0TUa	At West Lane	380	<50	
11/10/97*	100+125µg/L PBO		At West Lane	--	--	
1/14/98*			At Sutter Street	320J	<500	
1/14/98*			At West Lane	310J	<500	
2/19/98*			At Sutter Street	<500	<500	
2/19/98*			At West Lane	<500	<500	
10/24/98	100	10 (7)	At Pershing	--	--	
10/24/98	100+100µg/L PBO	0 (7)		--	--	

* - City of Stockton data
J – Estimated < detection limit
-- – Not measured

(continues)

4 & 6 toxic-

Table 3. Summary of Aquatic Toxicity Test Data
Calaveras River, Stockton, CA (1994-1998) (continued)

Fathead Minnow Larvae

Date	% Mortality	Comment
10/5/94	0	
10/29/96	2	Not statistically significant
10/24/98	2	Not statistically significant

Selenastrum capricornutum

Date	Toxic Response	Comment
10/5/94	No	
11/6/94	No	Stimulation
10/29/96	No	Stimulation
10/24/98	No	Stimulation

Table 4. Summary of Aquatic Toxicity Test Data
Walker Slough, Stockton, CA (1994-1998)

Ceriodaphnia

Date	% Sample	Toxicity Response %kill in (days)	Comments	Diazinon (ng/L)	Chlor-Pyrifos (ng/L)	Calculated TUa
10/5/94	100	100 (7)	No information on rate of kill	273	<80	0.5
11/6/94	100	0 (4)	TUa could not be calculated	<30	<80	
12/11/95	100	100 (2)	White light	--	--	
12/11/95	100	100 (2)	UV light	--	--	
12/11/95	80	100 (3)		--	--	
12/11/95	60	100 (4)		--	--	
12/11/95	40	64 (7)		--	--	
12/11/95	20	0 (7)		--	--	4 to 5
10/29/96	100	0 (7)		96	65	1
10/29/96	100+100µg/L PBO	0 (7)		--	--	
11/16/96*			At Western Pacific Industrial Park	470	<50	
1/22/97*			At Western Pacific Industrial Park	150	90	
11/10/97*	100	<1.0 TUa	At Western Pacific Industrial Park	<50	<50	
11/10/97*	100+125µg/L PBO	<1.0 TUa	At Western Pacific Industrial Park	--	--	
1/4/98*			At Western Pacific Industrial Park	<320J	<500	
2/19/98*			At Western Pacific Industrial Park	<500	<500	
9/9/98	100	0 (7)			--	
10/24/98	100	100 (2)		170	--	
10/24/98	100+100µg/L PBO	0 (7)		--	--	
12/7/98	100	0 (7)		--	--	

* – City of Stockton data
J – Estimated < detection limit
-- – Not measured

(continues)

3 of 7
toxic

Table 4. Summary of Aquatic Toxicity Test Data
Walker Slough, Stockton, CA (1994-1998) (continued)

Fathead Minnow Larvae

Date	% Mortality	Comment
10/5/94	0	Impaired growth
10/29/96	0	
9/9/98	5	Not statistically significant
10/24/98	10	Not statistically significant
12/7/98	0	

Selenastrum capricornutum

Date	Toxic Response	Comment
10/5/94	No	
11/6/94	No	Stimulation
10/29/96	No	Stimulation
9/9/98	No	Stimulation
10/24/98	No	Stimulation
12/7/98	No	
12/7/98	Yes	
12/7/98	No	
12/14/98	No	

Table 5. Summary of Aquatic Toxicity Test Data
Smith Canal, Stockton, CA (1994-1998)

Ceriodaphnia

Date	% Sample	Toxicity Response %kill in (days)	Comments	Diazinon (ng/L)	Chlor-Pyrifos (ng/L)	Calculated TUa
11/6/94	100	100 (7)	No information on rate of kill	186	122	1.5
11/8/96	100	0 (7)	TUa could not be calculated	<30	<80	
11/6/94	100	100 (6)		--	--	
11/6/94	100+100µg/L PBO	87 (7)	PBO caused delayed mortality	--	--	
11/9/94	100	100 (7)		166	<80	0.25
11/9/94	100	??		--	--	
11/9/94	100+200µg/L PBO	0 (7)		--	--	
11/25/94	100	20 (7)		106	<80	0.25
12/4/94	100	0 (7)	TUa could not be calculated	<30	<80	
3/11/95	100	100 (7)		--	--	
3/11/95	100+200µg/L PBO	20 (3)	PBO reduced toxicity	--	--	
10/29/96	100	100 (7)		129	<30	0.25
10/29/96	100+100µg/L PBO	0 (7)	PBO reduced toxicity	--	--	
10/24/98	100	0 (7)-?	At Pershing	--	--	
10/24/98	100+100µg/L PBO	0 (7)		--	--	

-- Not measured

Fathead Minnow Larvae

Date	% Mortality	Comment
11/6/94	7	Not statically significant
1/25/94	7	Not statically significant
12/4/94	0	
10/29/96	2	Not statistically significant
10/24/98	0	

Selenastrum capricornutum

Date	Toxic Response	Comment
11/6/94	No	
11/8/94	No	Stimulation
11/19/94	No	Stimulation
11/25/94	No	Stimulation
12/4/94	No	Stimulation
10/24/98	No	Stimulation

6 of 8

Table 6 Summary of Aquatic Toxicity Test Data
Mormon Slough, Stockton, CA (1994)

Ceriodaphnia

Date	% Sample	Toxicity Response %kill in (days)	Comments	Diazinon (ng/L)	Chlor-pyrifos (ng/L)	Calculated TUa
2/6/94	100	100 (6)		320	--	0.8
2/6/94	100	100 (7)		--	--	
2/6/94	100+200µg/L PBO	0 (7)	PBO reduced toxicity	--	--	
2/7/94	100	100 (1)		900	--	2
2/7/94	100	100 (1)		--	--	
2/7/94	100+200µg/L PBO	100 (2)	PBO reduced toxicity	--	--	

-- – Not measured

Table 7. Summary of Aquatic Toxicity Test Data
Lake McLeod, Stockton, CA (1994)

Ceriodaphnia

Date	% Sample	Toxicity Response %kill in (days)	Comments	Diazinon (ng/L)	Chlor-pyrifos (ng/L)	Calculated TUa
2/6/94	100	100 (6)		200	--	< 0.5
2/6/94	100	100 (6)		--	--	
2/6/94	100+200µg/L PBO	0 (7)	PBO reduced toxicity	--	--	
2/7/94	100	100 (2)		500	--	1
2/7/94	100	100 (2)		--	--	
2/7/94	100+200µg/L PBO	0 (7)	PBO reduced toxicity	--	--	

-- – Not measured

Table 8. Summary of Aquatic Toxicity Test Data
Turning Basin, Stockton, CA (1994)

Ceriodaphnia

Date	% Sample	Toxicity Response %kill in (days)	Comments	Diazinon (ng/L)	Chlor-pyrifos (ng/L)	Calculated TUa
2/6/94	100	0 (7)		190	--	< 0.5
2/6/94	100	0 (7)		--	--	
2/6/94	100+200µg/L PBO	0 (7)		--	--	
2/7/94	100	100 (1)		600	--	1
2/7/94	100	100 (1)		--	--	
2/7/94	100+200µg/L PBO	0 (7)	PBO reduced toxicity	--	--	

-- – Not measured

Table 9
City of Stockton Precipitation Data for Sampling Events

Date	Precipitation
2/7/94	0.08
10/5/94	0.42
10/6/94	0.00
11/8/94	0.00
11/9/94	0.00
11/25/94	0.33
3/2/95	0.08
4/27/95	0.04
4/28/95	0.00
4/29/95	0.00
5/1/95	0.33
5/3/95	0.00
12/11/95	0.00
10/29/96	1.28
11/16/96	0.60
11/17/96	1.06
11/18/96	0.71
1/22/97	0.28
11/10/97	0.20
11/13/97	0.12
1/4/98	0.24
1/14/98	0.04
2/19/98	0.08
9/9/98	0.00
10/24/98	0.67
12/7/98	0.00
12/12/98	0.00
1/19/99	0.56
1/20/99	0.00
2/8/99	0.16
3/8/99	0.20
6/7/99	0.00
6/16/99	0.00
8/18/99	0.00
9/22/99	0.24

Source: Stockton Metro precipitation gage, as reported at www.ncdc.noaa.gov/onlineprod/gsod/temp/gsod_28393.txt

Appendix
Background Data for City of Stockton Slough Aquatic Toxicity Testing

Beginning in February 1994, the Central Valley Regional Water Quality Control Board (CVRWQCB), under the leadership of Dr. Val Connor, initiated studies on the aquatic life toxicity of Stockton urban stormwater runoff. Samples were taken of various Stockton sloughs, typically during runoff events. These samples were transported to the University of California, Davis, Aquatic Toxicology Laboratory, where toxicity testing was conducted using the test organisms *Ceriodaphnia dubia, Pimephales promelas* (fathead minnow larvae) and *Selenastrum capricornutum*. The CVRWQCB collected stormwater runoff during 1995. Beginning in 1996 the DeltaKeeper collected stormwater runoff samples through 1999. The results of the toxicity tests are presented in this Appendix. A brief summary of the key features of each of the toxicity test results is presented below. A list of acronyms and abbreviations used in the tables is presented at the end of this Appendix.

February 1994

On February 7, 1994, 0.08 inch of precipitation was recorded in Stockton. Table 94-1 presents the results of the toxicity testing and chemical analyses that were conducted on the Stockton area stormwater runoff samples collected on February 6 and 7, 1994. Seven-day toxicity tests were conducted on these samples, where 100 µg/L PBO were added to one of the tests and no PBO was added to the other. The Mosher Slough samples collected on February 6 and 7, 1994, contained 900 and 630 ng/L diazinon, respectively. As expected, these samples killed 100 percent of the *Ceriodaphnia* organisms within one day. The addition of 100 µg/L PBO eliminated the toxicity over the 7-day period for the February 7 sample, and reduced it to only 20 percent kill on the February 6 sample.

The Five Mile Slough samples collected on February 6 and 7 had 1,000 ng/L diazinon on February 6, and greater than 1,000 ng/L on February 7. Both samples were highly toxic to *Ceriodaphnia*, with 100 percent kill in 2 days on the February 6 sample and 100 percent kill in 1 day on the February 7 sample. The addition of 100 µg/L PBO reduced the rate of kill, so that 100 percent kill was not achieved until 5 days for both the February 6 and 7 samples.

The samples collected of the Calaveras River on February 6 and 7 had 380 ng/L diazinon on February 6 and 450 ng/L diazinon on February 7. Both samples killed all *Ceriodaphnia* in the test system within 2 days. The addition of 100 µg/L PBO eliminated the toxicity from the February 7 sample and reduced the toxicity to 20 percent kill on the February 6 sample.

The Mormon Slough sample collected on February 6 had 320 ng/L diazinon. This sample did not show 100 percent kill until the seventh day of testing. The February 7 sample from Mormon Slough had 900 ng/L diazinon, and, as expected, there was 100 percent kill of *Ceriodaphnia* within 1 day.

The Lake McLeod sample, located in downtown Stockton, had 200 ng/L diazinon, which killed 100 percent of the *Ceriodaphnia* in 6 days. The February 7 sample had 500 ng/L diazinon and killed all *Ceriodaphnia* within 2 days.

The Port of Stockton Turning Basin sample collected February 6 had 190 ng/L diazinon, and this sample was nontoxic to *Ceriodaphnia* over the 7-day test period. On February 7, the Turning Basin sample was found to contain 600 ng/L diazinon, and killed 100 percent of the *Ceriodaphnia* within 1 day. The addition of 100 µg/L PBO essentially eliminated this toxicity, where on days 4 through 7 there was only 20 percent kill of *Ceriodaphnia* in the test system.

The results of the February 6-7 sampling show that high concentrations of diazinon were present in stormwater runoff in City of Stockton sloughs and associated waters, including the Calaveras River. The diazinon concentrations found produced the toxicity expected, with rapid kill of *Ceriodaphnia* within 1 to 2 days when the concentrations were greater than about 450 ng/L (i.e., the LC_{50} value for diazinon's toxicity to *Ceriodaphnia*). The addition of 100 μg/L of PBO to the samples showed that, in general, the toxicity to *Ceriodaphnia* was essentially eliminated. It is of interest to find that the February 6-7, 1994, samples had among the highest concentrations of diazinon found in the 5-year study reported herein.

Table 94-1
Stockton Stormwater Runoff Toxicity to *Ceriodaphnia*
Collected on February 6 and 7, 1994

			Percent Organism Mortality Days of Incubation							
Treatment/ Location/Date	**PBO add**	**Diazinon ng/L**	**1**	**2** % kill	pH	**3**	**4**	**5**	**6**	**7**
SSEPAMH			0	0		0	0	0	15	15
	+PBO		0	0		0	0	0	0	0
Dilute EI			0	0		0	0	0	0	0
	+PBO		0	0		0	0	0	0	0
Mosher Slough	2/6	900	100							
2/6	+PBO		0	20		20	20	80	80	80
Mosher Slough	2/7	630	100		7.8					
2/7	+PBO		0	0		0	0	0	0	0
5-Mile Slough	2/6	1000	80	100						
2/6	+PBO		0	0		20	20	100		
5-Mile Slough	2/7	>1000	100		7.9					
2/7	+PBO		0	0		0	80	100		
Calaveras River	2/6	380	0	100						
2/6	+PBO		0	0		20	20	20	20	20
Calaveras River	2/7	450	0	100	8.3					
2/7	+PBO		0	0		0	0	0	0	0
Mormon Slough	2/6	320	0	0		15	15	20	95	100
2/6	+PBO		0	0		0	0	0	0	0
Mormon Slough	2/7	900	100		8.3					
2/7	+PBO		60	100						
Lake McLeod	2/6	200	0	0		0	0	0	100	
2/6	+PBO		0	0		0	0	0	0	0
Lake McLeod	2/7	500	0	100	8.4					
2/7	+PBO		0	0		0	0	0	0	0
Turning Basin	2/6	190	0	0		0	0	0	0	0
2/6	+PBO		0	0		0	0	0	0	0
Turning Basin	2/7	600	100	0	8.4					
2/7	+PBO		0	0		0	20	20	20	20

PBO added at 100 μg/L

October 1994

On October 5, 1994, 0.42 inch of precipitation was recorded in Stockton. There was no precipitation recorded in Stockton on October 6, 1994. Samples of Five-Mile Slough, Calaveras River, Mosher Slough and Walker Slough were collected on October 5 and 6, 1994. Table 94-2 presents the results of an 8-day toxicity test using *Ceriodaphnia* as the test organism. The results of these tests show that both Five-Mile Slough and Mosher Slough samples killed all *Ceriodaphnia* in two days, while the Calaveras River sample killed all *Ceriodaphnia* in the test system in four days, and Walker Slough, in seven days.

Table 94-2
Stockton Urban Run-off 10/5/94 and 10/6/94
8-day *Ceriodaphnia* Test[1,2]

Set up on 10/6/94

Treatment	Reproduction[3] (neonates/adult)		Mortality (%)	Final pH @ 24 hrs
	mean	standard error		
Dilute EI	38.6P	1.5	0.0P	8.5
SSEPAMH	28.7	2.5	0.0	8.4
Five Mile Slough	0.0	0.0	100 (2)	7.7
Calaveras River	1.2	0.6	100 (4)	7.9
Mosher Slough	0.0	0.0	100 (2)	7.9
Walker Slough	14.9	1.5	100 (7)	8.3

P. The dilute EI control met all US EPA criteria for test acceptability. 100% of the daphnids had a third brood.
1. Ten replicates with 15 ml of sample and one *Ceriodaphnia* each.
2. Standard US EPA feeding procedures were used during this test.
3. Highlighted areas indicate a significant reduction in reproduction or increase in mortality relative to the dilute EI control water. The reproductive endpoint was analyzed using Dunnett's Test ($p<0.05$) and the mortality endpoint was analyzed using Fisher's Exact Test.
(#) Number in parenthesis denotes days to 100% mortality

Table 94-3 presents the results of a 4-day *Ceriodaphnia* dilution series for the Five-Mile Slough and Mosher Slough waters obtained on October 5, 1994. The Five-Mile Slough and Mosher Slough undiluted samples showed 40 to 50 percent kill within two days and 100 percent kill within three days. No toxicity, however, was observed on the 50 percent sample, 25 percent sample or 12.5 percent sample. These results indicate that there was between 1 to 2 TUa of acute *Ceriodaphnia* toxicity in the Five-Mile Slough and Mosher Slough samples obtained on October 5, 1994.

Table 94-3
Five Mile Slough and Mosher Slough 10/5/94
4-day *Ceriodaphnia* Dilution Series[1,2]

Set up on 10/17/94

Treatment (%Sample Water)	% Mortality for each day of the test[3]				Final pH @ 48hrs
	1	2	3	4	
Dilute EI				0P	8.4
Five Mile Slough (12.5%)				0	8.3
Five Mile Slough (25%)				0	8.2
Five Mile Slough (50%)				0	8.1
Five Mile Slough (100%)		40	100	100	8.0
Mosher Slough (12.5%)				0	8.3
Mosher Slough (25%)				0	8.2
Mosher Slough (50%)				0	8.1
Mosher Slough (100%)		50	100	100	8.1

P. The dilute EI control met all US EPA criteria for test acceptability.
1. Two replicates with 18 ml of sample and five *Ceriodaphnia* each.
2. Daphnids were fed the standard US EPA amount of food for only four hours a day.
3. Highlighted cells indicate areas of significant interest. No statistical analyses were done.

Table 94-4 presents the data of a 7-day *Ceriodaphnia* Phase I TIE testing, in which Five-Mile Slough and the Calaveras River samples were subjected to various modified testing procedures. One of these involved the addition of 200 µg/L of piperonyl butoxide (PBO). Table 94-4 shows that the addition of the PBO to the Five-Mile Slough unfiltered sample decreased the toxicity over seven days from 100 percent kill without PBO to 65 percent with PBO. The filtered Five-Mile Slough sample with 200 µg/L PBO also showed a reduced toxicity – in this case, of about 74 percent over seven days. These results are indicative of OP pesticides being potentially responsible for at least part of this toxicity. The filtered Calaveras River samples with 200 µg/L PBO added showed a significant reduction in toxicity compared to the samples without PBO. There was a small difference – probably not statistically significant – depending on whether or not the sample was filtered. Mosher Slough samples also showed a significant decrease in toxicity in the presence of 200 µg/L PBO.

Table 94-4
Stockton Urban Run-off 10/5/94 and 10/6/94
7-day *Ceriodaphnia* Phase I TIE[1,2]

Set up on 10/9/94

Treatment	% Mortality for each day of the test[3]							Conclusions	Final pH @ 48 hrs
	1	2	3	4	5	6	7		
Dilute EI unfiltered				5	5.3	5.5	5.5	Control met US EPA criteria for test acceptability.	8.6
Dilute EI filtered							0	No artifactual toxicity in control blanks.	-
Dilute EI unfiltered + 200 µg/L PBO				5	5	10	10		8.5
Dilute EI filtered + 200 µg/L PBO			5	5	10	10	15		8.6
Five Mile Slough unfiltered	20	100	100	100	100	100	100	Toxicity detected.	8.2
Five Mile Slough filtered		100	100	100	100	100	100		8.1
Five Mile Slough unfiltered + 200 µg/LPBO		5	10	20	50	50	65	The delay in mortality suggests that an OP pesticide may be responsible, in part, for toxicity. However, high mortality suggests a second toxicant may also exist.	7.9
Five Mile filtered + 200 µg/L PBO		5	5	15.8	42.1	73.7	73.7		8.0
Calaveras River unfiltered		5	95	100	100	100	100	Toxicity detected.	8.4
Calaveras River filtered			100	100	100	100	100		8.3
Calaveras River unfiltered + 200 µg/L PBO						5	15	Decrease in mortality relative to ambient water suggests that an OP pesticide is responsible for the toxicity.	8.2
Calaveras River filtered + 200 µg/L PBO			5	5	5	5	5		8.2
Mosher Slough unfiltered	5	100	100	100	100	100	100	Toxicity detected.	8.3
Mosher Slough filtered		100	100	100	100	100	100		8.4
Mosher Slough unfiltered + 200 µg/L PBO			5	10	10	10	10	Decrease in mortality relative to ambient water suggests that an OP pesticide is responsible for the toxicity.	8.2
Mosher Slough filtered + 200 µg/L PBO							0		8.2

1. Three replicates with 18 ml of sample and five *Ceriodaphnia* each.
2. Daphnids were fed the standard US EPA amount of food for only four hours a day.
3. Highlighted cells indicate areas of significant interest. No statistical analyses were done.

The Five-Mile Slough sample taken on October 5, 1994, was subjected to a 6-day *Ceriodaphnia* Phase II TIE, in which the sample was passed through a C8 column, and the toxicity of the eluate was determined. The results of this testing are shown in Table 94-5. The fractions obtained from various methanol (MeOH) eluates of the column show that the toxicity was eluded in certain fractions from 70 to 80 percent. This experiment shows that the toxicant elutes in fractions 70, 75, and 80% (percent methanol by volume). This suggests possible diazinon and/or chlorpyrifos as the toxicant(s). Diazinon elutes in fractions 70, 75, and 80% and chlorpyrifos elutes in fractions 75, 80, and 85%.

Table 94-5
Five Mile Slough 10/5/94
6-day *Ceriodaphnia* Phase II TIE[1,2]

Set up on 11/2/94

Treatment[4]	% Mortality for each day of the test[3]							Conclusions	Final pH @ 48 hrs
	1	2	3	4	5	6	7		
Dilute EI							0	Control met US EPA criteria for test acceptability.	7.5
Dilute EI + 1% MeOH							0	No artifactual toxicity in control blanks.	8.0
Dilute EI C8 Blank for 5-Mile Slough Column 1[4]							0		7.8
Dilute EI C8 Blank for 5-Mile Slough Column 2[4]							0		8.0
Dilute EI + 5-Mile 50% Fraction @ 4.67x							0	Toxicant(s) absent in this fraction.	8.0
Dilute EI + 5-Mile 70% Fraction @ 4.67x							40	Toxicant(s) present in these fractions.	8.1
Dilute EI + 5-Mile 75% Fraction @ 4.67x				30	100	100	100		8.1
Dilute EI + 5-Mile 80% Fraction @ 4.67x		20	60	60	90	100	100		8.1
Dilute EI + 5-Mile 85% Fraction @ 4.67x							0	Toxicant(s) absent in these fractions.	8.2
Dilute EI + 5-Mile 90% Fraction @ 4.67x					10	10	10		8.2
Dilute EI + 5-Mile 95% Fraction @ 4.67x							0		8.2
Dilute EI + 5-Mile 100% Fraction @ 4.67x							0		8.2

1. Two replicates with 18 ml of sample and five *Ceriodaphnia* each.
2. Daphnids were fed the standard US EPA amount of food for only four hours a day.
3. Highlighted cells indicate areas of significant interest. No statistical analyses were done.
4. 600 ml and 800 ml of sample water were run through C8 SPE columns at a rate of 10 ml/min on 10/28/94 and 10/29/94, respectively. The two columns were extracted in series using 3.0 ml of MeOH to produce each fraction 467-times as concentrated as the ambient water.

Similar tests were conducted with Walker Slough samples. These data are presented in Table 94-6. This experiment implicates diazinon and chlorpyrifos as possible causes of toxicity (see explanation of Table 94-8 for fractions that diazinon and chlorpyrifos elute in). The Five Mile Slough part of the experiment was to determine if the column becomes overloaded with toxicant, becoming unable to capture any more after a certain amount of sample has been extracted. This experiment showed that at least for this Five-Mile Slough sample, the column did not become overloaded, as the latest extracted portion was still nontoxic.

Table 94-6

Five Mile Slough and Walker Slough 10/5/94 7-day *Ceriodaphnia* Phase II TIE[1,2]

Set up on 10/23/94

Treatment	No.[4]	% Mortality for each day of the test							Conclusions	Final pH @ 48 hrs
		1	2	3	4	5	6	7		
Dilute EI	4							0	Control met US EPA criteria for test acceptability.	8.1
Dilute EI + 1% MeOH	4					0+			No artifactual toxicity in control blanks.	8.1
Dilute EI C8 Blank for 5-Mile Slough	4							0		8.1
Dilute EI C8 Blank for Walker Slough	4							0		8.1
5-Mile Slough settled	4	5	65	100	100	100	100	100	Toxicity detected.	7.9
1st 530 ml 5-Mile Slough PCCA[5]	4							0	Significant decrease in mortality relative to ambient water suggests that an organic is responsible for toxicity.	7.8
2nd 530 ml 5-Mile Slough PCCA	4						5	10		7.7
3rd 530 ml 5-Mile Slough PCAA	4							0		7.7
Walker Slough unfiltered	4			5	40	85	100	100	Toxicity detected.	7.0
Walker Slough filtered	4				5	20	95	95	Delay in mortality relative to unfiltered sample suggests that a toxicant may be sediment-bound.	7.4
Walker Slough filtered + 200µg/L PBO	4							0	Significant decrease in mortality relative to ambient water suggests that an OP is responsible for toxicity.	7.5
Walker Slough PCCA	4							0	Significant decrease in mortality relative to ambient water suggests that an organic is responsible for toxicity.	8.1
Dilute EI + Walker 50% fraction @5x	2					0+			Toxicant(s) absent in these fractions.	7.6
~~Dilute EI + Walker~~ 70% fraction @5x	~~2~~					~~0+~~				~~7.7~~
Dilute EI + Walker 75% fraction @5x	2		40	100	100	100+			Toxicant(s) present in these fractions. Accelerated mortality in the 75% fraction is consistent with diazinon toxicity.	7.8
Dilute EI + Walker 80% fraction @5x	2		10	30	50	100+				7.9
Dilute EI + Walker 85% fraction @5x	2		10	10	20	50+				7.9
Dilute EI + Walker 90% fraction @5x	1	20	40	40	40	60+				8.0
Dilute EI + Walker 95% fraction @5x	2					0+			Toxicant(s) absent in these fractions.	8.0

Dilute EI + Walker 100% fraction @ 5x	2				20	20+				8.1

1. Each replicate had 18 ml of sample and five *Ceriodaphnia* each. Daphnids were fed the standard US EPA amt of food for only four hrs a d
2. Highlighted cells indicate areas of significant interest. No statistical analyses were done.
3. 1800 ml of sample water were run through a C8 SPE column at a rate of 10 ml/min. The column was extracted using 3.0 ml MeOH to produce each fraction 600 times more concentrated than the ambient water.
4. Number of replicates per given treatment.
5. PCCA - Sample water Post C8 SPE Column Application

\+ These treatments were taken down at 5 days.

Calaveras River samples tested through Phase II TIEs are shown in Table 94-7. Again, similar results to the other Phase II TIEs were found. This experiment implicates diazinon as the primary toxicant in both the Calaveras and Mosher Slough samples (see above for fractions in which diazinon elutes); however, a significant amount of "bleeding" to other fractions occurred as evidenced by the mortality observed in several fractions besides those that diazinon elutes in. Diazinon may be the primary toxicant; however, this experiment does not rule out other possible toxicants.

Table 94-7
Calaveras River and Mosher Slough 10/5/94
4-day *Ceriodaphnia* Phase II TIE[1,2]

Set up on 10/18/94

Treatment	% Mortality for each day of the test[3]				Conclusions	Final pH@ 48hrs
	1	2	3	4		
Dilute EI				0	Control met US EPA criteria for test acceptability.	8.2
Dilute EI + 1% MeOH			10	10	No artifactual toxicity in control blank.	8.3
Dilute EI + Calaveras 50% fraction @ 5x				0	Toxicant(s) absent in this fraction.	8.1
Dilute EI + Calaveras 70% fraction @ 5x			50	50	Toxicant(s) present in these fractions. Accelerated mortality in the 75% fraction is consistent with diazinon toxicity	8.3
Dilute EI + Calaveras 75% fraction @ 5x	90	100	100	100		8.4
Dilute EI + Calaveras 80% fraction @ 5x		80	100	100		8.3
Dilute EI + Calaveras 85% fraction @ 5x			30	50		8.4
Dilute EI + Calaveras 90% fraction @ 5x				0	Toxicant(s) absent in these fractions.	8.4
Dilute EI + Calaveras 95% fraction @ 5x			10	10		8.4
Dilute EI + Calaveras 100% fraction @5x		20	30	40	Toxicant(s) absent in this fraction.	8.4
Dilute EI + Mosher 50% fraction @ 5x				0	Toxicant(s) absent in this fraction.	8.2
Dilute EI + Mosher 70% fraction @ 5x		80	100	100	Toxicant(s) present in these fractions. Accelerated mortality in the 75% fraction is consistent with diazinon toxicity	8.3
Dilute EI + Mosher 75% fraction @ 5x	100	100	100	100		-
Dilute EI + Mosher 80% fraction @ 5x	10	100	100	100		8.4
Dilute EI + Mosher 85% fraction @ 5x				0	Toxicant(s) absent in these fractions.	8.3
Dilute EI + Mosher 90% fraction @ 5x				0		8.4

Dilute EI + Mosher 95% fraction @ 5x			20	40	Toxicant(s) absent in this fraction.	8.4
Dilute EI + Mosher 100% fraction @ 5x		10	20	30	Toxicant(s) absent in this fraction.	8.4

1. Two replicates with 18 ml of sample and five *Ceriodaphnia* each.
2. Daphnids were fed the standard US EPA amount of food for only four hours a day.
3. Highlighted cells indicate areas of significant interest. No statistical analyses were done.
4. 1800 ml of sample water were run through a C8 SPE column at a rate of 10 ml/min. The column was extracted using 3.0 ml of MeOH to produce each fraction 600 times more concentrated than the ambient water.

\- Dash indicates not measured.

Table 94-8 presents the Calaveras River and Mosher Slough test results for a Phase II TIE using *Ceriodaphnia*, in which various percent fractions were examined with and without PBO. It was found that the PBO did alter the toxicity pattern. This experiment is consistent with the previous one in that it shows evidence of a toxicant present other than an OP pesticide (diazinon).

Table 94-8

Calaveras River and Mosher Slough 10/5/94, 4-day *Ceriodaphnia* Phase II TIE[1,2]

Set up on 10/26/94

Treatment[4,5]	No.[6]	% Mortality for each day of the test[3]				Conclusions	Chlor-pyrifos (ng/L)	Diazinon (ng/L)	Final pH @ 48hrs
		1	2	3	4				
Dilute EI	4				5	Control met US EPA criteria for test acceptability.			8.0
Dilute EI + 1% MeOH	4				0	No artifactual toxicity in control blanks.			8.1
Dilute EI + 1% MeOH + 200µg/L PBO	4			5	5				8.1
Dilute EI + Calaveras 70% fraction @ 5x *	2		40	100	100	Toxicant(s) present in these fractions.	ND	241	8.0
Dilute EI + Calaveras 75% fraction @ 5x *	2		100	100	100		ND	391	8.1
Dilute EI + Calaveras 75% fraction @ 5x + 200µg/L PBO	2			20	100	The delay in mortality suggests an OP pesticide may, in part, be responsible for the toxicity. High mortality suggests a second toxicant may exist.			8.1
Dilute EI + Calaveras 80% fraction @ 5x *	2		30	70	100	Toxicant(s) present in this fraction.	ND	191	8.1
Dilute EI + Calaveras 80% fraction @ 5x + 200µg/L PBO	2			50	90	The delay in mortality suggests an OP pesticide may, in part, be responsible for the toxicity. High mortality suggests a second toxicant may exist.			8.1
Dilute EI + Calaveras 85% fraction @ 5x *	2		10	10	40	Toxicant(s) present in these fractions.	ND	ND	8.1
Dilute EI + Mosher 70% fraction @ 5x *	2		100	100	100			295	8.2
Dilute EI + Mosher 70% fraction @ 5x + 200µg/L PBO	2				0	Significant decrease in mortality suggests that an OP pesticide is responsible for toxicity.			8.0
Dilute EI + Mosher 75% fraction @ 5x *	2	100	100	100	100	Toxicant(s) present in this fraction.		538	8.3+
Dilute EI + Mosher 75% fraction @ 5x + 200µg/L PBO	2		100	100	100	The delay in mortality suggests an OP pesticide may, in part, be responsible for toxicity. High mortality suggests a second toxicant may exist.			8.0
Dilute EI + Mosher 80% fraction @ 5x *	2		60	100	100	Toxicant(s) present in this fraction.		317	8.1

Dilute EI + Mosher 80% fraction @ 5x + 200µg/L PBO	2			10	60	The delay in mortality suggests an OP pesticide may, in part, be responsible for the toxicity. High mortality suggests a second toxicant may exist.			8.1

Each replicate contained 18 ml of sample and five *Ceriodaphnia* each.
2. Daphnids were fed the standard US EPA amount of food for only four hours a day.
3. Highlighted cells indicate areas of significant interest. No statistical analyses were done.
4. 1800 ml of sample water were run through a C8 SPE column at a rate of 10 ml/min. The column was extracted using 3 ml of MeOH to produce each fraction 600 times more concentrated than the ambient water.
5. All treatments were renewed only up to 48 hours due to shortage in eluates. The test was then allowed to continue to 96 hours without any water renewal.
6. Number of replicates per given treatment.
\+ Final pH measured at 24 hours.
ND Not detected. Detection limits for ELISA kits were 80 ng/L for chlorpyrifos and 40 ng/L for diazinon.

Table 94-9 shows that the stormwater runoff collected in the various sloughs and the river were not acutely toxic to fathead minnow larvae; however, the sample of Walker Slough water did show a statistically significant reduced rate of growth. The other samples obtained on October 5 did not exhibit any statistically significant inhibition of fathead minnow larval growth during the test period.

Table 94-10 presents the toxicity testing that was done with *Selenastrum*. None of the slough or river samples tested were toxic to *Selenastrum*.

Table 94-9
Stockton Urban Run-off 10/5/94 and 10/6/94
***Pimephales* Test[1,2]**

Set up on 10/5/94

Treatment	Growth (mg)[3]		Mortality (%)		Final pH @ 24 hrs
	mean	standard error	mean	standard error	
Dilute EI	0.43[P]	0.01	0.0[P]	0.00	8.1
Dilute EI aerated[4]	0.46	0.01	3.3	3.33	8.0
SSEPAMH	0.47	0.02	0.0	0.00	8.0
5-Mile Slough aerated[4]	0.38	0.01	6.7	6.67	7.5
Calaveras River	0.39	0.03	0.0	0.00	7.8
Mosher Slough	0.44	0.03	0.0	0.00	7.6
Walker Slough	0.36	0.00	0.0	0.00	7.9

P. The dilute EI control met US EPA criteria for test acceptability.
1. Three replicate beakers with 250 ml of sample and 10 minnows in each replicate.
2. Minnows were fed three times daily.
3. Highlighted areas indicate a significant increase in mortality or decrease in growth when compared to the dilute EI control. The growth and mortality endpoints were analyzed with Dunnett's Test ($p<0.05$).
4. 5-Mile Slough exhibited a notable DO sag within half an hour after normal aeration. This treatment and a control were aerated throughout the test to prevent toxicity to the fish resulting from low DO.

Table 94-10
Stockton Urban Run-off 10/5/94 and 10/6/94
96-hour *Selenastrum* Test[1]

Set up on 10/6/94

Treatment	Cell Count (x 10^4) (2)		% CV	Final pH @ 96 hrs
	mean	standard error		
Glass Distilled	40[NP]	9.6	47.4	8.4
Dilute EI	79	14.1	35.9	8.6

SSEPAMH	87	4.9	11.3	8.2
5-mile Slough	104	22.1	42.5	8.2
Calaveras River	25	1.2	9.9	9.0
Mosher Slough	86	2.4	5.6	8.2
Walker Slough	26	0.4	3.2	9.5

NP. The glass distilled control did not meet all US EPA criteria for test acceptability. The coefficient of variation (CV) was 47.5% in this treatment.
1. Four replicate flasks with 100 ml of sample in each flask.
2. Highlighted areas show a significant reduction in growth compared to the glass distilled control. Cell counts were analyzed using Dunnett's Test ($p<0.05$).

Table 94-11 represents a modification of the standard *Selenastrum* testing, in which the Calaveras River and Walker Slough waters were passed through a C8 column. It is of interest to find that the waters passed through the column inhibited *Selenastrum* growth. A similar result was obtained with the Calaveras River sample, which had passed through a post-C8 SPE (PCCA) column.

Table 94-12 presents the results of the chemical characterization of the samples that were tested. The data show that the Five-Mile Slough, Calaveras River and Walker Slough samples contained from about 273 to 300 ng/L diazinon, while Mosher Slough had about 460 ng/L diazinon. The chlorpyrifos concentrations in these samples were below the detection limit of 80 ng/L. Using an LC_{50} for *Ceriodaphnia* of 450 ng/L over a 4-day period, it is concluded that an appreciable part of the toxicity found in the October 5 sample could have been due to diazinon, although part of this toxicity may have been due to other constituents that were not measured in the chemical analyses.

Table 94-11
Calaveras River and Walker Slough 10/5/94
96-hour *Selenastrum* Test[1]

Set up on 10/13/94

Treatment[3]	Cell Count (x 10^4) (2)		Conclusions	Final pH @ 96 hrs
	mean	standard error		
Glass Distilled	45[P]	1	Control met US EPA criteria for test acceptability.	9.0
Dilute EI	122	5		8.3
Calaveras River C8 Blank	15	2	Inhibition in growth relative to dilute EI suggests that application to C8 columns may be causing toxicity.	8.7
Walker Slough C8 Blank	20	3		8.4
Calaveras River	250	10	Sample lost toxicity due to storage time.	9.1
Calaveras River PCCA[4]	315	13	Slight improvement in growth relative to the ambient water may suggest that some toxicity was due to an organic.	9.2
Walker Slough	377	10	Sample lost toxicity due to storage time.	9.6
Walker Slough PCCA	371	6	No artifactual toxicity resulting from manipulation	9.7

P. The glass distilled control met all US EPA criteria for test acceptability. The coefficient of variation was 5.2% in this treatment.
1. Four replicate flasks with 100 ml of sample in each flask.
2. Highlighted cells indicate areas of significant interest. Cell counts were analyzed using Dunnett's Test ($p<0.05$).
3. 1200 ml of each water was run through a C8 SPE column at a rate of 10.2 ml/min.
4. PCCA - Sample water Post C8 SPE Column Application.

Table 94-12

Chemical Characteristics in Runoff and Test Set-Ups
Stockton Urban Run-off Sites 10/5/94 and 10/6/94

Set up on 10/5/94 and 10/6/94

Treatment	pH	DO (mg/L)	EC (µmhos/cm)	Total Hardness (mg/L as $CaCO_3$)	Calcium Hardness (mg/L as $CaCO_3$)	Alkalinity (mg/L as $CaCO_3$)	NH_3 ($mgNH_3/L$)	Chlor-pyrifos (ng/L)	Diazinon (ng/L)
Glass Distilled	-	-	0	2	0	2	0	-	-
Dilute EI	8.2	8.3	215	96	32	102	-	-	-
Dilute EI aerated	-	-	-	-	-	-	-	-	-
SSEPAMH	8.2	8.3	240	78	44	76	-	-	-
5-mile Slough	7.4	7.0	185	80	40.8	30	1.2	ND	278
Calaveras River	8.0	7.5	260	80	50.8	71	0	ND	299
Mosher Slough	8.0	8.0	185	68	43.2	63	0.5	ND	459
Walker Slough	8.2	8.4	220	78	45.2	73	0	ND	273

ND – Not Detected. Detection limits for ELISA kits are 30 ng/L for diazinon and 80 ng/L for chlorpyrifos.

November 6 and 8, 1994 Samples

On November 6, 1994, and again on November 8, 1994, samples were taken of several of the Stockton sloughs during a stormwater runoff event. No record of precipitation was available for November 6. The rain gage showed 0.15 inch of precipitation on November 7 and no precipitation on November 8. Table 94-13 presents the results for the Smith Canal sample taken on November 6, which showed 100 percent toxicity over a seven-day period. The Smith Canal sample taken on November 8 showed no toxicity over this period.

A 4-day *Ceriodaphnia* test of the November 6 sample was conducted, which showed (Table 94-14) that there was no toxicity.

Table 94-13
Smith Canal 11/6/94 and 11/8/94
7-day *Ceriodaphnia* Test[1,2]

Set up on 11/9/94

Treatment	Reproduction[3] (neonates/adult) mean	standard error	Mortality (%)	Conclusions	Final pH @ 24 hrs
Dilute EI	19.8	1.4	0	Control met all US EPA criteria for test acceptability.	8.4
SSEPAMH	7.1	1.3	10	Toxicity detected in laboratory water.	8.6
Smith Canal 11/6	0	0	100	Toxicity detected.	8.0
Smith Canal 11/8	40.5	1.5	0	Sample non-toxic.	8.2

1. Ten replicates with 15 ml of sample and one *Ceriodaphnia* each.
2. Standard US EPA feeding procedures were used during this test.
3. Highlighted areas indicate a significant reduction in reproduction or increase in mortality relative to the Dilute EI control water. The reproductive endpoint was analyzed using Dunnett's Test ($p<0.05$) and the mortality endpoint was analyzed using Fisher's Exact Test.

Table 94-14
Stockton Urban Run-off 11/6/94

4-Day *Ceriodaphnia* Test[1,2]

Set up on 11/9/94

Treatment[4,5]	% Mortality for each day of the test[3]				Conclusions	Final pH @ 48hrs
	1	2	3	4		
Dilute El				0	Control met US EPA criteria for test acceptability.	8.18
Mosher Slough	0	100	100	100	Toxicity detected.	8.02
5-Mile Slough				0	No toxicity detected.	8.00
Calaveras River				0		8.22
Walker Slough				0		8.39

P. The Dilute EI control met all US EPA criteria for test acceptability.
1. Each replicate contained 18 mls of sample and five Ceriodaphnia each.
2. Daphnids were fed the standard US EPA amount of food for only four hours a day.
3. Highlighted cells indicate areas of significant interest. No statistical analyses were done.
4. Number of replicates per given treatment.

Table 94-15 presents the Mosher Slough and Smith Canal 7-day *Ceriodaphnia* Phase I TIE results, which show that Mosher Slough killed all *Ceriodaphnia* within 4 days; however, the addition of 200 µg/L PBO eliminated this toxicity. Somewhat similar results were obtained for Smith Canal for the November 6 sample over the 7-day period. There was a smaller reduction in toxicity. The Smith Canal sample taken on November 9 killed 100 percent of the *Ceriodaphnia* within 5 days.

Table 94-16 presents the results of the *Selenastrum* toxicity test conducted on November 6 and November 8, 1994. Again, as with the October samples, there was no toxicity to *Selenastrum*.

Table 94-15
Mosher Slough 11/6/94 and Smith Canal 11/6/94, 11/9/94
7-day *Ceriodaphnia* Phase I TIE[1,2]

Set up on 11/12/94

Treatment	% Mortality for each day of the test							Conclusions	Final pH @ 48 hrs
	1	2	3	4	5	6	7		
Dilute EI							6.0	Control met US EPA criteria for test acceptability.	8.6
Dilute EI + 200µg/L PBO							0.0	No artifactual toxicity in control blank.	8.5
Mosher Slough		80	100	100+				Toxicity detected.	8.3
Mosher Slough + 200µg/L PBO				0+				Significant decrease in mortality relative to ambient water suggests that an OP pesticide is responsible for toxicity.	8.3
Smith Canal (11/6)				33.3	93.3	100	100	Toxicity detected.	8.1
Smith Canal (11/6) + 200µg/L PBO							86.7	The delay in mortality suggests that an OP pesticide may, in part, be responsible for toxicity. However, high mortality suggests a second toxicant may also exist.	8.0
Smith Canal (11/9)				60	100	100	100	Toxicity detected.	8.2

1. Three replicates with 18 ml of sample and five *Ceriodaphnia* each.
2. Daphnids were fed the standard US EPA amount of food for only four hours a day.
3. Highlighted cells indicate areas of significant interest. No statistical analyses were done.
\+ These treatments were taken down at 96 hours.

Table 94-16

Stockton Urban Run-off 11/6/94 and 11/8/94
96-hour *Selenastrum* Test[1]

Set up on 11/9/94

Treatment	Cell Count (x 10^4) (2)		Final pH @ 96 hrs
	Mean	standard error	
Glass Distilled	66.7P	1.7	9.0
Dilute EI	90.3	2.3	8.7
5-Mile Slough 11/6	75.8	7.8	9.0
Calaveras River 11/6	108	9.6	9.1
Mosher Slough 11/6	96.6	8.5	9.0
Smith Canal 11/6	79.6	0.5	8.9
Smith Canal 11/8	139	10.2	9.3
Walker Slough 11/6	102	8.9	9.2

P. The glass distilled control met all US EPA criteria for test acceptability. The coefficient of variation was 4.5% in this treatment.
1. Three replicate flasks with 100 ml of sample in each flask.
2. Highlighted cells indicate areas of significant interest. Cell counts were analyzed using Dunnett's Test ($p<0.05$).

The chemical characteristics of the November 6 and 8, 1994, samples are presented in Table 94-17. The concentrations of diazinon found in samples from Five-Mile Slough, Calaveras River, Smith Canal and Walker Slough would be less than that expected to be acutely toxic within 4 days; however, the Mosher Slough sample had 499 ng/L diazinon, which would be expected to be acutely toxic to *Ceriodaphnia* within 4 days. These results are in accord with the results presented in 94-15. It is possible that, at least for Smith Canal samples, which had about 186 ng/L diazinon, as expected, chlorpyrifos, in this case, is a significant contributor to the toxicity found. The LC_{50} for *Ceriodaphnia* for chlorpyrifos is 80 ng/L. Based on the concentrations of chlorpyrifos and diazinon found in the November 6 samples, there would be expected to be about 1 TUa of *Ceriodaphnia* toxicity. It is of interest to find the Smith Canal sample taken on November 8 had non-detectable chlorpyrifos and diazinon, and this is in accord with the lack of toxicity found in that sample. This demonstrates that the toxicity associated with a rainfall event is a short-term phenomenon and does not carry over to the following day after the runoff has occurred.

Table 94-17
Chemical Characteristics of Water
Stockton Urban Run-Off Sites 11/6/94 and 11/8/94

Set up on 11/9/94

Treatment	pH	DO (mg/L)	EC (µmhos/cm)	Total Hardness (mg/L as $CaCO_3$)	Calcium Hardness (mg/L as $CaCO_3$)	Alkalinity (mg/L as $CaCO_3$)	Chlorpyrifos (ng/L)	Diazinon (ng/L)
Glass Distilled	8.8	-	0	-	-	-	-	-
Dilute EI	8.3	8.5	200	92	-	-	-	-
SSEPAMH	8.4	8.5	205	80	-	-	-	-
5-mile Slough 11/6	7.5	8.5	373	116	72	90	ND	80
Calaveras River 11/6	7.7	8.6	384	132	72	116	88	199
Mosher Slough 11/6	7.7	8.5	201	84	48	84	ND	499
Smith Canal 11/6	7.4	8.4	349	128	76	88	123	186
Smith Canal 11/6	8.0	7.1	360	128	76	88	123	186
Smith Canal 11/8	8.1	8.5	650	192	-	-	ND	ND
Walker Slough 11/6	7.6	8.6	498	172	96	148	ND	ND

ND Not detected. Detection limits for ELISA kits are 80 ng/L for chlorpyrifos and 30 ng/L for diazinon.

November 9 and 25, and December 4, 1994

Table 94-18 presents the results of 7-day *Ceriodaphnia* toxicity tests for Smith Canal obtained on November 9 and 25 and December 4. These results show that the November 9 sample killed 100 percent of the *Ceriodaphnia* within 7 days, and there was little toxicity on November 25 or December 4. The available rainfall data indicate that there was no precipitation on November 9, and 0.33 inch on November 25. No rainfall data are available for December 4.

Table 94-19 presents the results of the 7-day *Ceriodaphnia* Phase I TIE test for the Smith Canal samples obtained on November 9, 1994.

Table 94-20 presents the Smith Canal toxicity test results for the fathead minnow larvae. These results show that there was no toxicity to fathead minnow larvae over the 7-day test period.

Table 94-21 presents the toxicity test results for the Smith Canal samples obtained on November 9 and 25 and December 4, 1994, using *Selenastrum* as the test organism. The Smith Canal samples were not toxic to *Selenastrum*; in fact, it appears from the data that they stimulated *Selenastrum* growth.

Table 94-18
Smith Canal 11/9/94, 11/25/94 and 12/4/94
7-day *Ceriodaphnia* Test[1,2]

Set up on 12/7/94

Treatment	Reproduction[3] (neonates/adult)		Mortality (%)	Final pH @ 24 hrs
	x	s.e.		
Dilute EI	26.6[P]	1.3	0.0[P]	8.6
SSEPAMH	13.4	1.8	10.0	8.5
Smith Canal 11/9	17.8	3.3	100.0 (7)	8.3
Smith Canal 11/25	48.3	1.0	20.0	8.1
Smith Canal 12/4	59.0	1.9	0.0	8.2

P. The Dilute EI control met all US EPA criteria for test acceptability. 90.0% of the daphnids had a third brood.
1. Ten replicates with 15 mls of sample and one *Ceriodaphnia* each.
2. Standard US EPA feeding procedures were used during this test.
(#) Number in parenthesis denotes days to 100% mortality.
Highlighted areas indicate a significant reduction in reproduction or increase in mortality relative to the Dilute EI control water. The reproductive endpoint was analyzed using Dunnett's Test (p<.05) and the mortality endpoint was analyzed using Fisher's Exact Test.

Table 94-19
Smith Canal 11/9/94 7-day *Ceriodaphnia* Phase I TIE[1,2]

Set up on 12/6/94

Treatment	% Mortality for each day of the test[3]							Conclusions	Final pH @ 48 hrs
	1	2	3	4	5	6	7		
Dilute EI							0	Control water met all US EPA criteria for test acceptability.	8.4
Dilute EI + PBO		20	53	53	53	53	53	Toxicity detected in method blank.	8.2

Smith Canal						7	7		8.0
Smith Canal + PBO							0	No toxicity detected.	7.9

1. Three replicates with 18 mls of sample and five *Ceriodaphnia* each.
2. Daphnids were fed the standard US EPA amount of food for only four hours a day.

Highlighted cells indicate areas of significant interest. No statistical analyses were done.

Table 94-20
Smith Canal 11/9/94, 11/25/94 and 12/4/94
7-day *Pimephales* Test[1,2]

Set up on 12/7/94

Treatment	Mortality (%)[3]		Final pH @ 24 hrs
	X	s.e.	
Dilute EI	0.0[P]	0.0	8.2
SSEPAMH	0.0	0.0	7.7
Smith Canal 11/9	6.7	6.7	7.5
Smith Canal 11/25	6.7	6.7	7.7
Smith Canal 12/4	0.0	0.0	7.8

P. The Dilute EI control met all US EPA criteria for test acceptability.
1. Three replicate beakers with 250 ml of sample and 10 minnows in each replicate.
2. Minnows were fed three times daily.
3. Highlighted areas indicate a significant increase in mortality or decrease in growth when compared to the Dilute EI control. The mortality endpoint was analyzed with Dunnett's Test ($p<.05$).

Table 94-21
Smith Canal 11/9/94, 11/25/94 and 12/4/94
96-Hour *Selenastrum* Test[1]

Set up on 12/7/94

Treatment	Cell Count[2] ($x 10^4$)		Final pH @ 96 hrs
	X	s.e.	
Glass Distilled	55.0[P]	4.6	7.7
Dilute EI	94.4	4.1	8.5
SSEPAMH	63.1	9.2	8.5
Smith Canal 11/9	251.6	6.6	9.5
Smith Canal 11/25	214.2	8.1	9.3
Smith Canal 12/4	246.1	15.8	9.5

P. The glass distilled control met all US EPA criteria for test acceptability. The coefficient of variation was 16.8% in this treatment.
1. Four replicate flasks with 100 ml of sample in each flask, except for the Smith Canal treatments which had three replicates.

Highlighted areas show a significant reduction in growth compared to the glass distilled control. Cell counts were analyzed using Dunnett's Test ($p<.05$).

Table 94-22 presents the chemical characteristic data for samples taken from Smith Canal on November 9 and 25 and December 4, 1994. The data presented in Table 94-22 show that there were readily detectable amounts of diazinon present in Smith Canal on November 9 and November 25; however, these concentrations were well below the LC_{50} for *Ceriodaphnia*. There were no detectable amounts of chlorpyrifos present in the samples using a detection limit of 80 ng/L. These results indicate that no toxicity would be expected to *Ceriodaphnia* from these samples.

Table 94-22
Water Chemical Characteristics for Smith Canal 11/9/94, 11/25/94 and 12/4/94

Set up on 12/7/94

Treatment	pH	DO (mg/L)	EC (µmhos/cm)	Total Hardness (mg/L as $CaCO_3$)	Calcium Hardness (mg/L as $CaCO_3$)	Alkalinity (mg/L as $CaCO_3$)	NH_3 (mg/L)	Chlorpyrifos (ng/L)	Diazinon (ng/L)
Glass Distilled	8.6	-	10	0	-	-	0.0	-	-
Dilute EI	8.1	8.6	200	92	-	-	-	-	-
SSEPAMH	7.8	8.7	220	84	-	-	-	-	-
Smith Canal 11/9	7.8	8.3	325	108	68	.132	0.5	ND	166
Smith Canal 11/25	8.2	7.8	122	48	28	32	0.2	ND	106*
Smith Canal 12/4	7.8	8.4	450	128	88	88	0.5	ND	ND

* This sample was stored for almost 2 months before it was analyzed for diazinon.

ND Non Detect Detection limits for ELISA kits are 80 ng/L for chlorpyrifos and 30 ng/L for diazinon.

1994 Summary. In summary, the 1994 testing showed that stormwater runoff events were acutely toxic to *Ceriodaphnia* and were nontoxic to fathead minnow larvae and the alga *Selenastrum*. The level of toxicity was about 1 TUa. It was primarily due to diazinon, but, in some samples, chlorpyrifos was an important, if not the dominant, cause of toxicity.

1995 Studies

The CVRWQCB conducted sampling of several of the City of Stockton sloughs, as well as several creeks or stormwater drains in Sacramento on April 28, 1995, and May 1, 1995. Table 95-1 presents the results of the 7-day *Ceriodaphnia* test. The Mosher Slough sample taken on May 1, 1995, was nontoxic. On the other hand, Arcade Creek, Elder Creek and Sump 104, located in the City of Sacramento, were 100 percent toxic to *Ceriodaphnia* in 1 to 5 days. Precipitation data for the City of Stockton shows 0.33 inch for May 1. The lack of toxicity in Mosher Slough for the May 1 sample is unusual for this magnitude of rainfall.

The Mosher Slough sample taken on May 1, 1995, was subjected to a Phase III TIE. Table 95-2 presents the results of a 3-day *Ceriodaphnia* Phase III TIE. This test of the May 1 runoff event showed toxicity to *Ceriodaphnia*. It is not clear why there was no toxicity found in the 7-day *Ceriodaphnia* test. The Phase III TIE confirmed that the diazinon and chlorpyrifos measured in the sampled collected from Mosher Slough on 5/1/95 were the chemicals causing the observed toxicity. The C8 solid phase extracted water (indicated as PCCP in this table) was spiked with the same amount of diazinon and chlorpyrifos as was detected in the ambient sample. Then the spiked and ambient samples were set up in side-by-side dilution series to confirm that the organism response was the same in both samples.

Similarly, Table 95-3 presents a Mosher Slough May 1, 1995, sample additivity study. This experiment was conducted to show that diazinon and chlorpyrifos act additively when present in a sample together. In the dilution series of chlorpyrifos alone and diazinon alone the *Ceriodaphnia* mortality was less than 100 percent in 3 days (in the 100% dilution), however, when present together 100 percent *Ceriodaphnia* mortality occurs in 2 days.

Table 95-1
Urban Runoff 4/28/95 to 5/1/95
7-day *Ceriodaphnia* Test[1,2]

Set up on 5/2/95

Treatment	Reproduction[3] (neonates/adult)		Mortality (%)	Final pH @ 24 hrs
	x	s.e.		
Dilute EI	n=9 19.9[P]	2.0	0[P]	8.2
SSEPAMH	n=9 21.1	1.6	10	8.4
Arcade Creek 5/1/95	0.0	0.0	100 (1)	7.8
Elder Creek 4/29/95	4.0	0.8	100 (4)	8.0
Sump 104 4/28/95	6.7	1.1	100 (5)	8.4
Sump 111 4/28/95	10.7	2.2	20	7.8
Mosher Slough 5/1/95	27.3	0.6	0	8.0

P. The Dilute EI control met all US EPA criteria for test acceptability. 88.9% of the daphnids had a third brood.
1. Ten replicates with 15 mls of sample and one *Ceriodaphnia* each.
2. Standard US EPA feeding procedures were used during this test.
3. Highlighted areas indicate a significant reduction in reproduction or increase in mortality relative to the Dilute EI control water. The reproductive endpoint was analyzed using Dunn's Test ($p<.05$) and the mortality endpoint was analyzed using Fisher's Exact Test.
(#) Number in parenthesis represents days to 100% mortality.

Table 95-2
Mosher Slough 5/1/95
3-Day *Ceriodaphnia* Phase III TIE[1,2]

Set up on 5/17/95

Treatment[4,5]	% Mortality for each day of the test[3]			Chlorpyrifos (ng/L)	Diazinon (ng/L)	Final pH @ 48hrs
	1	2	3			
Dilute EI			20			8.0
Dilute EI C8 Blank for Mosher Slough			13			8.2
Spiked PCCP @ 200%	100	100	100			7.9*
Mosher 5/1 @ 100%	20	100	100	ND (78)	420	7.6
Spiked PCCP @ 100%	33	100	100	89	416	7.6
Mosher 5/1 @ 75%		13	100			8.0
Spiked PCCP @ 75%		26	100			7.9
Mosher 5/1 @ 50%			13			8.1
Spiked PCCP @ 50%			0			7.8
Mosher 5/1 @ 25%			6.7			8.1
Spiked PCCP @ 25%			0			7.9
Unspiked PCCP			0	ND	ND	8.0
Unspiked PCCP + 200 µg/L PBO			0			8.2

1. Three replicates with 18 mls of sample and five *Ceriodaphnia* each.
2. Daphnids were not fed.
3. Highlighted cells indicate areas of significant interest. No statistical analyses were done.
4. 1800 ml of Sample water was run through a C8 SPE column at a rate of 10 ml/min.
5. PCCP Sample water Post C8 SPE Column Passage
ND Non Detect Detection limits for ELISA kits are 80 ng/L for chlorpyrifos and 30 ng/L for diazinon.

+ Final pH taken at 24 hours.

Table 95-3
Mosher Slough 5/1/95 Additivity Study 3-Day *Ceriodaphnia* Test[1,2]

Set up on 6/17/95

Treatment[4,5]	% Mortality for each day of the test[3]			Chlorpyrifos	Diazinon	Final pH
	1	2	3	(ng/L)	(ng/L)	@ 48hrs
Dilute EI			0			7.6
Dilute EI C8 Blank for Mosher Slough			0			8.0
200% spiked Diazinon and Chlorpyrifos	100	100	100	119	896	7.6+
100% spiked Diazinon and Chlorpyrifos	60	100	100	41	493	7.1
75% spiked Diazinon and Chlorpyrifos		87	100			7.1
50% spiked Diazinon and Chlorpyrifos		6.7	100			7.8
25% spiked Diazinon and Chlorpyrifos			0			7.7
200% spiked Chlorpyrifos	40	100	100	148		7.5
100% spiked Chlorpyrifos			47	32		7.8
75% spiked Chlorpyrifos			0			7.7
50% spiked Chlorpyrifos			0			7.7
25% spiked Chlorpyrifos			0			7.7
200% spiked Diazinon	87	100	100		1,132	7.9+
100% spiked Diazinon		47	73		255	7.9
75% spiked Diazinon			27			7.7
50% spiked Diazinon			0			7.7
25% spiked Diazinon			0			7.8
Mosher Slough 5/1/95 PCCP*			0			8.0

1. Three replicates with 18 mls of sample and five *Ceriodaphnia* each.
2. Daphnids were not fed.
3. Highlighted cells indicate areas of significant interest. No statistical analyses were done.
4. 1800 ml of Sample water was run through a C8 SPE column at a rate of 10 ml/min.

+ Final pH taken at 24 hours.
* PCCP sample water Post C8 SPE Column Passage

ND Non Detect Detection limits for ELISA kits are 50 ng/L for chlorpyrifos and 30 ng/L for diazinon.

The Arcade Creek/Mosher Slough samples obtained on May 1, 1995, were subjected to a 4-day *Ceriodaphnia* toxicity test in which PBO was added to some of the tests. The data presented in Table 95-4 shows that the addition of PBO significantly reduced the toxicity measured over the 4-day period for both Arcade Creek and Mosher Slough. This is an indication of an organophosphate pesticide being responsible for the toxicity. The 50 percent dilution of the Arcade Creek sample still showed some toxicity, indicating that the level of toxicity present in the sample was about 2 TUa.

The chemical characteristic data for the April 27-May 1, 1995, City of Stockton and Sacramento samples are shown in Table 95-5. These data show that the chlorpyrifos and diazinon concentrations in the samples were sufficient to cause toxicity to *Ceriodaphnia* in all samples except the Sump 111 sample taken on April 28. That sample was, as expected, nontoxic, based on the low concentrations of diazinon and chlorpyrifos (see Table 95-1).

Table 95-4
Arcade Creek, Mosher Slough 5/1/95
4-Day *Ceriodaphnia* PBO Test[1,2]

Set up on 5/3/95

Treatment[4]	% Mortality for each day of the test[3]				Conclusions	Final pH @ 48hrs
	1	2	3	4		
Dilute EI				0	Control met all US EPA criteria for test acceptability.	8.4
Dilute EI + 200 µg/L PBO		5	95	95	Increase in mortality relative to control water suggests that the addition of PBO may be negatively affecting the daphnids.	8.3
Arcade Creek 100%	100	100	100	100		7.7*
Arcade Creek 100% + 200 µg/L PBO	5	5	25	25	Toxicity detected up to the 50% dilution.	7.7
Arcade Creek 50%			75	90	Addition of PBO resulted in a significant decrease in mortality suggesting toxicity may be due to organophosphate pesticide(s).	8.1
Arcade Creek 50% + 200 µg/L PBO	5	5	10	10		8.0
Arcade Creek 25%				0		8.3
Arcade Creek 12.5%				0		8.4
Mosher Slough		100	100	100	Toxicity detected.	7.9
Mosher Slough + 200 µg/L PBO				0	Significant decrease in mortality relative to ambient water suggests that an organophosphate pesticide is responsible for the toxicity.	8.0

1. Four replicates with 18 mls of sample and five *Ceriodaphnia* each.
2. Daphnids were fed the standard US EPA amount of food for only four hours a day.
3. Highlighted cells indicate areas of significant interest. No statistical analyses were done.
* Final pH taken at 24 hours.

Table 95-5
Urban Run-Off 4/27-5/1/95 Water Chemical Characteristics

Treatment	Initial pH	EC (µmhos / cm)	Total Hardness (mg/L as $CaCO_3$)	Ca Hardness (mg/L as $CaCO_3$)	Alkalinity (mg/L as $CaCO_3$)	TSS (mg/L)	Chlorpyrifos (ng/L)	Diazinon (ng/L)
Glass Distilled	9.0	5	0	-	-	3.3	-	-
Dilute EI	8.2	210	88	-	-	-	-	-
SSEPAMH	8.2	235		-	-	-	-	-
Arcade Creek 5/1	8.2	50	22	14	18	355.4	ND[67]	334
Elder Creek 4/29	8.1	100	46	26	44	496.7	90	216
Strong Ranch 4/27			22	14	22	210.4	116	424
Sump 104 4/28	8.0	310	122	78	104	15.5	ND [75]	170
Sump 111 4/28	8.0	100	36	26	30	16.5	145	ND
Mosher Slough 5/1	7.9	95	32	-	-		120	417

ND Non Detect Detection limits for ELISA kits are 80 ng/L for chlorpyrifos and 30 ng/L for diazinon.
[#] numbers in brackets are calculated ELISA values for chlorpyrifos non detects

December 11, 1995

The sample of Duck Creek, obtained on December 11, 1995, was tested for *Ceriodaphnia* toxicity under conditions where some of the tests were exposed to UV light and others were exposed to white light. Table 95-6 presents the results of this study. There was no rainfall reported at the rain gage in Stockton for this date. Comparing the results for the 100 percent sample and various dilutions of the Duck Creek sample with white light or UV light shows that the UV light did not affect toxicity. The dilution series on this sample showed that there were about 5 TUa of *Ceriodaphnia* toxicity over a 7-day period. This is one of the more toxic samples obtained in the study of the creeks/sloughs in the Stockton area. Duck Creek receives drainage from upstream agricultural sources, which could have been the source responsible for part of this elevated toxicity.

Table 95-6
Duck Creek 12/11/95 7-Day *Ceriodaphnia* in & out of UV Light TIE[1,2]

Set up on 12/29/95

Treatment	% Mortality for each day of the test[3]							Final pH @ 24 hrs
	1	2	3	4	5	6	7	
Dilute EI							0	8.0
Dilute EI in UV light							0	8.0
100% Duck Cr in white light	13	100	100	100	100	100	100	8.0
100% Duck Cr in UV light	7	100	100	100	100	100	100	7.9
80% Duck Cr in white light		80	100	100	100	100	100	8.0
80% Duck Cr in UV light		73	100	100	100	100	100	8.0
60% Duck Cr in white light		7	27	100	100	100	100	8.1
60% Duck Cr in UV light				100	100	100	100	8.0
40% Duck Cr in white light		7	7	7	29	57	64	8.1
40% Duck Cr in UV light						20	33	8.1
20% Duck Cr in white light							0	8.0
20% Duck Cr in UV light							0	8.1

1. Three replicates with 18 mls of sample and five *Ceriodaphnia* each.
2. Standard US EPA feeding procedures were used during this test.
3. Highlighted cells indicate areas of significant interest. No statistical analyses were done.

1996 Studies

Beginning in 1996, the DeltaKeeper assumed the responsibility for sampling of the Stockton Slough stormwater runoff.

A sample of the various Stockton sloughs' stormwater runoff was collected on October 29, 1996. Precipitation on this date in the Stockton area was 1.28 inches. *Ceriodaphnia* toxicity test results for this sample, which was the first runoff event of the season, are presented in Table 96-1. The data in this table show that Mosher Slough, even with the addition of 100 µg/L PBO, killed 100 percent of the *Ceriodaphnia* in 7 days. Five-Mile Slough also killed 100 percent of the test organisms in this period; however, the Five-Mile Slough sample with 100 µg/L PBO was nontoxic. The Calaveras River and Duck Creek samples were nontoxic on this sampling day, while the Smith Canal sample killed 100 percent of the *Ceriodaphnia* in 7 days. However, with the addition of 100 µg/L PBO, there was no toxicity.

Table 96-1

7-day *Ceriodaphnia* Test Conducted on Samples Collected 10/29/96[1,2]

Set up on 10/30/96

Treatment	Reproduction[3] (neonates/adult)		Mortality (%)	Initial pH	Final pH @ 24 hrs	EC (µmhos/cm)	Hardness (mg/L)	TSS (mg/L)
	x	s.e.						
SSEPAMH	19.4[P]	2.6	0[P]	8.3	8.3	275	92	
SSEPAMH + 100 µg/L PBO	17.2	3.2	0					

Mosher Slough	0	0	100	7.6	7.3	105	36	288.0
Mosher + 100 µg/L PBO	0	0	100					
Five Mile Slough	0	0	100	7.9	7.5	200	56	79.0
Five Mile + 100 µg/L PBO	22.7	1.2	0					
Calaveras River	33.0	0.8	0	8.2	8.3	280	88	23.1
Calaveras + 100 µg/L PBO	33.5	1.8	0					
Smith Canal	9.8	1.6	100	8.1	7.8	490	132	55.5
Smith + 100 µg/L PBO	13.3	0.7	0					
Duck Creek	32.2	1.4	0	8.0	7.8	200	56	82.7
Duck + 100 µg/L PBO	27.5	1.8	0					

P. The Dilute EI control met all US EPA criteria for test acceptability. 70% of the daphnids had a third brood.
1. Ten replicates with 15 mls of sample and one *Ceriodaphnia* each.
2. Standard US EPA feeding procedures were used during this test.
3. *Highlighted areas indicate a significant reduction in reproduction or increase in mortality relative to the Dilute EI control water.* The reproductive endpoint was analyzed using Dunnett's Test ($p<.05$) and the mortality endpoint was analyzed using Fisher's Exact Test.

The Mosher Slough sample obtained on October 29, 1996, was subjected to a 96-hour Phase I TIE, using *Ceriodaphnia* as the test organism. The data presented in Table 96-2 show that there were about 2 TUa of 4-day *Ceriodaphnia* acute toxicity and that the presence of PBO reduced this toxicity. However, the addition of EDTA at either 15 or 30 mg/L did not affect the toxicity, indicating that the toxicity was not likely due to a heavy metal.

Table 96-3 presents the fathead minnow larvae test results for the October 29, 1996, samples. The samples of Mosher Slough, Five-Mile Slough, Calaveras River, Smith Canal and Duck Creek were all nontoxic to fathead minnow larvae.

Table 96-4 presents the results of the *Selenastrum* testing for the October 29, 1996, samples, which also showed no toxicity to this organism.

Table 96-5 presents the chemical characteristics of the 10/29/96 samples. From the data presented in Table 96-5, the Mosher Slough sample taken on October 29, 1996, had 486 ng/L diazinon and 103 ng/L chlorpyrifos. These concentrations would be expected to contain about 2 TUa of *Ceriodaphnia* acute toxicity. This is similar to what was found in the test, indicating that the toxicity could be accounted for based on diazinon and chlorpyrifos. The Five-Mile Slough sample would be expected to have some toxicity, which is estimated to be about 1.5 TUa, based on diazinon and chlorpyrifos concentrations. Calaveras River, Smith Canal and Duck Creek would not be expected to be toxic based on diazinon and chlorpyrifos concentrations. This was what was found in the toxicity testing for the Calaveras River and Duck Creek; however, the Smith Canal sample showed 100 percent kill of *Ceriodaphnia* in 7 days. It is possible, then, that there were other toxicants in the Smith Canal sample, which would cause the sample to be toxic, but not have sufficient diazinon and chlorpyrifos to account for the magnitude of the toxicity found.

Table 96-2
Mosher Slough 10/29/96 96-Hour *Ceriodaphnia* Phase I Test[1]

Set up on 11/9/96

Treatment[2]	ELISA values		# of Reps	% Mortality for each day of test				Conclusion[3]	Final pH @ 24h
	Diazinon	Chlorpyrifos		1	2	3	4		

Lab Control (SSEPAMH), Hardness 80			4				0	Controls met all US EPA criteria for test acceptability.	8.4
Lab Control, Hardness 36 (H36)			4				5		8.1
Lab Control + 100 µg/L PBO			4			5	20	Toxicity in the PBO manipulation suggests that 200 µg/L may be too high.	8.3
Lab Control + 200 µg/L PBO			4			53	84		8.3
Lab Control H36 + 15 mg/L EDTA			4		5	5	5	No artifactual toxicity in these control blanks.	8.0
Lab Control H 36 + 30 mg/L EDTA			4	5	5	5	5		8.0
Mosher 10/29/96 100% (H36)			3	100	100	100	100	The dilution series suggests that toxicant(s) may be present at approximately two toxic units. Significant reduction in toxicity with the addition of PBO suggests toxicity may be due to metabolically activated organophosphorous pesticide(s).	7.6
Mosher 50%			3		33	53	80		7.6
Mosher 50% + 100 µg/L PBO			3				0		7.5
Mosher 50% + 200 µg/L PBO			3		7	13	13		7.3
Mosher 25%			3				0		7.6
Mosher 25% + 100 µg/L PBO			3				0		7.4
Mosher 25% + 200 µg/L PBO			3		7	27	27		7.5
Mosher 12.5%			3				7		7.6
Mosher + 15 mg/L EDTA			3	93	100	100	100	No reduction in toxicity with the addition of EDTA suggests toxicity is not due to metals.	7.5
Mosher + 30 mg/L EDTA			3	100	100	100	100		7.5

1. Each replicate vial with 15 ml of sample and 5 daphnids.
2. 4-hr feeding
3. Highlighted cells show areas of interest. No statistical analyses were conducted.

Table 96-3

Pimephales Toxicity Test Conducted on Samples Collected 10/29/96[1,2]

Set up on 10/31/96

Treatment[3]	Growth (mg)		Mortality (%)[4]		Initial pH	Final pH	EC
	x	Se	X	s.e.		@ 24 hrs	(µmhos/cm)
SSEPAMH	0.44[P]	0.02	0.0[P]	0	8.3	8.0	275
Mosher Slough	0.37	0.02	5.0	0.03	7.6	7.0	105
Five Mile Slough	0.46	0.02	42.5	0.19	7.9	7.3	200
Calaveras River	0.46	0.03	2.5	0.03	8.2	7.9	280
~~Smith Canal~~	~~0.48~~	~~0.03~~	~~2.5~~	~~0.03~~	~~8.1~~	~~7.5~~	~~490~~
Duck Creek	0.41	0.01	0	0	8.0	7.5	200

P. The Dilute EI control met the criteria for test acceptability.

1. Three replicate beakers with 250 ml of sample and 10 minnows in each replicate.
2. Minnows were three times daily.
4. Highlighted areas indicate a significant increase in mortality or decrease in growth when compared to the Dilute EI control. The growth and mortality endpoints were analyzed with Dunnett's Test (p<.05).

Table 96-4
96-Hour *Selenastrum* Test Conducted on Samples Collected 10/29/96[1]

Set up on 10/30/96

Treatment	Cell Count[2] (x 10^4)		Initial pH	Final pH	EC	Hardness	TSS
	x	s.e.		@ 96 hrs	(μmhos/cm)	(mg/L)	(mg/L)
Glass Distilled	202.7[P]	19.1	8.0	7.8	70	0	
Duck Creek	370.8	6.8	7.8	10.2	210	56	82.7
Smith Canal	355.2	19.3	8.1	9.5	455	132	55.5
Calaveras River	328.5	38.8	8.0	9.7	275	88	23.1
Five Mile Slough	392.3	9.4	7.9	10.0	225	56	79.0
Mosher Slough	364.2	6.3	8.0	9.9	155	36	288.0

P. The glass distilled control met all US EPA criteria for test acceptability. The coefficient of variation was 18.8% in this treatment.
1. Four replicate flasks with 100 ml of sample in each flask.
2. Highlighted areas show a significant reduction in growth compared to the glass distilled control. Cell counts were analyzed using Dunnett's Test (p<.05).

Table 96-5
10/29/96 Water Chemical Characteristics

Treatment	Diazinon[5] (ng/L)	Chlorpyrifos[5] (ng/L)	Diuron (ng/L)	EC (μmhos/cm)	Hardness (mg/L as $CaCO_3$)	TSS (x±se mg/L)
Lab Control for *Ceriodaphnia*	-	-	-	275	92	-
Lab Control for *Pimephales*	-	-	-	275	92	-
Lab Control for *Selenastrum*	-	-	-	70	0	-.316±.017
Mosher Slough 10/29/96	486[1]	103[1]	ND[3]	155	36	288.0±11.5
Five Mile Slough 10/29/96	304[2]	84[1]	ND[3]	225	56	79.0±4.3
Calaveras River 10/29/96	36[2]	ND[1]	ND[3]	275	88	23.1±0.2
Smith Canal 10/29/96	129[2]	ND[1]	ND[3]	455	132	55.5±0.3
Duck Creek 10/29/96	96[2]	65[1]	ND[3]	210	56	82.7±3.6

The DeltaKeeper took several rainfall samples during October and November 1996. The data for diazinon and chlorpyrifos in these samples are presented in Table 96-6. The concentrations of chlorpyrifos found in the rainfall samples at the various locations were less than the detection limit of 50 ng/L. Diazinon concentrations in the rainfall samples at the various locations in October and November 1996 ranged from about 42 to 97 ng/L.

Table 96-6
DeltaKeeper Backyard Rainwater Sampling ELISA Values

Site or Collector ID	Diazinon[5] (ng/L)	Chlorpyrifos[5] (ng/L)
2352 Dry Creek Way 10/29/96 (Emilie Reyes, UCDATL)	42[1]	ND[3]
Weston Ranch in South Stockton 10/29/96 (Stephen Clark, UCDATL)	46[1]	ND[3]

John Newbold 10/29/96	ND[1]	ND[1]
1924 Meadow 11/16/96	97[4]	ND[4]
2230 Kensington 11/17/96	32[4]	ND[4]
Collector WB 11/17/96	ND[4]	ND[4]
2925 Princeton 11/18/96	91[4]	ND[4]

1 ELISA conducted on 11/2/96.
2 ELISA conducted on 10/30/96.
3 ELISA conducted on 11/3/96.
4 ELISA conducted on 11/20/96.
5 UCDATL LC_{50} values for *Ceriodaphnia dubia* are 400-500 ng/L for diazinon and 80-100 ng/L for chlorpyrifos. Values obtained using ELISA method.
ND Non Detect-detection limits for diazinon, chlorpyrifos and diuron ELISA are 30 ng/L, 50 ng/L and 30 ng/L, respectively.

1997 Studies

The DeltaKeeper collected stormwater runoff from Mosher Slough and Five-Mile Slough on November 13, 1997. Rainfall in the Stockton area measured for that date was 0.12 inch. Table 97-1 presents the results of the 7-day *Ceriodaphnia* test for these samples. Mosher Slough was found to be 100 percent toxic, even with PBO, in the 7 days. The Five-Mile Slough sample was 100 percent toxic within 5 days and nontoxic within 7 days, with PBO.

Table 97-1
Stockton Urban Runoff 11/13/97
7-day *Ceriodaphnia* Test[1,2]

Set up on 11/14/97

Treatment	Reproduction[3] (neonates/adult)		Mortality (%)	Final pH @ 24 hrs
	x	s.e.		
Laboratory Control	27.4[P]	0.1	0[P]	8.6
Laboratory Control + PBO	16.67	1.1	0	8.5
Mosher Slough	*	*	100 (3)	8.1
Mosher Slough + PBO	*	*	90	7.9
5-Mile Slough	*	*	100 (5)	7.7
5-Mile Slough + PBO	29.3	0.1	0	7.6

P. The laboratory control met all US EPA criteria for test acceptability. 100% of the daphnids had a third brood.
1. Ten replicates with 15 ml of sample and one *Ceriodaphnia* each.
2. Standard US EPA feeding procedures were used during this test.
3. Highlighted cells indicate areas of significant interest. No statistical analyses were done.
(#) Denotes days to 100% mortality.

Table 97-2 presents the fathead minnow larvae tests for the Mosher Slough and Five-Mile Slough samples collected on November 13, 1997. The Mosher Slough sample was nontoxic, while the Five-Mile Slough sample did show mortalities to the fathead minnow larvae over the 7-day test period.

Table 97-3 presents the results of the toxicity tests for the November 13, 1997, samples taken of Mosher Slough and Five-Mile Slough for *Selenastrum*. The samples were nontoxic to this alga during the test period.

Table 97-4 presents the chemical characteristic data for the November 13, 1997, sample. The data in Table 97-4 show that Mosher Slough contained 460 ng/L of diazinon, while Five-Mile Slough had about 360 ng/L of diazinon. Both samples contained between 50 and 60 ng/L of chlorpyrifos. These concentrations of diazinon and chlorpyrifos would be expected to be toxic to *Ceriodaphnia*. This is what was found, as shown in Table 97-1. The toxicity to fathead minnow larvae shown for Five-Mile Slough is due to unknown causes.

Table 97-2
7-day *Pimephales* Test[1,2]

Set up on 11/14/97

Treatment	Growth (mg)		Mortality (%)[3]		Final pH @ 24 hrs
	x	Se	x	s.e.	
Laboratory Control	0.274[P]	0.009	0[P]	0	8.0
Mosher Slough	0.318	0.041	22.5	19.3	7.7
5-Mile Slough	0.1710	0.031	75.0	8.66	7.6

P. The laboratory control met all US EPA criteria for test acceptability.
1. Four replicate beakers with 250 ml of sample and 10 minnows in each replicate.
2. Minnows were fed three times daily.
3. Highlighted areas indicate a significant increase in mortality or decrease in growth when compared to the laboratory control. The growth and mortality endpoints were analyzed with Dunnett's Test ($p<.05$).

Table 97-3
96-Hour *Selenastrum* Test[1]

Set up on 11/14/97

Treatment	Cell Count[1] (x 10^4)		% CV	Final pH @ 96 hrs
	x	s.e.		
Laboratory Control	133.5	15.5	23.2[NP]	7.5
Mosher Slough	161.9	9.9	6.1	9.3
5-Mile Slough	207.0	2.9	1.4	9.7

NP. The glass distilled control did not meet all US EPA criteria for test acceptability. The coefficient of variation was 23.2% in this treatment.
1. Four replicate flasks with 100 ml of sample in each flask.
2. Highlighted areas show a significant reduction in growth compared to the glass distilled control. Cell counts were analyzed using Dunnett's Test ($p<.05$).

Table 97-4
Chemical characteristics for Stockton Urban Runoff samples collected 13 November 1997

Treatment	Diazinon[1] ELISA value (ng/L)	Chlorpyrifos[1] ELISA value (ng/L)	Lab pH	Lab EC[2] (µmhos/cm)	Lab DO (mg/L)	Total Hardness (mg/L as $CaCO_3$)	Ammonia (mg/L as NH_4)	Alkalinity (mg/L as $CaCO_3$)
Lab Control (EPAMH)			8.4	260	8.2	80		58
Lab Control (Glass Distilled)			7.9	91			0	
Lab Control (SSEPAMH)			8.4	209	8.3	84		66
Lab Control (GDEPAMH)			8.4	267	8.0			
Mosher Slough 11/13/97	461	59	7.9	99	8.3	42	0.5	46
5-Mile Slough 11/13/97	359	52	7.5	118	7.8	46	1.2	48

1. Detection limits for ELISA diazinon and chlorpyrifos are 30 ng/L and 50 ng/L, respectively. Diazinon and chlorpyrifos ELISA were conducted on 11/14/97.
2. All EC values reported in this column were taken at 25° C.

1998 Studies

DeltaKeeper collected a sample of Walker Slough and Mosher Slough stormwater runoff on September 9, 1998. According to the rainfall data available, there was no rainfall on that date in Stockton.

Table 98-1 presents the 7-day *Ceriodaphnia* toxicity test results for that sample, which show that neither Walker Slough nor Mosher Slough was toxic to *Ceriodaphnia.* Table 98-2 shows that similar results for the fathead minnow larvae were found for the sample collected on September 9, 1998, in which there was no toxicity found. This was also the result for the *Selenastrum* testing for that sample (see Table 98-3). There was appreciable stimulation of *Selenastrum* growth in the Walker Slough and Mosher Slough samples. The chemical characteristic data for the September 9, 1998, samples are presented in Table 98-4. No data are available for ELISA tests on these samples.

Table 98-1

Summary of 7-day *Ceriodaphnia* toxicity test conducted during September 1998.[2]

Treatment	Reproduction[1] (neonates/adult)		Mortality[1] (%)	Final pH at 24 hours
	x	se		
Laboratory Control	18.9^{P}	1.1	0^{P}	8.4
Walker Slough	18.2	1.9	0	8.3
Mosher Slough at Mariners	29.1	1.2	0	8.4

P. The laboratory control met all US EPA criteria for test acceptability. 90% of the daphnids had a third brood.
1. Highlighted cells indicate a significant reduction in reproduction or increase in mortality relative to the laboratory control water. The mortality endpoint was analyzed using Fisher's Exact Test. The reproductive endpoint was analyzed using Dunnett's test (p<0.05).
2. The samples were collected on 9 September 1998. This test was set up on 10 September 1998.

Table 98-2

Summary of 7-day *Pimephales* toxicity test conducted during September 1998.[2]

Treatment	Growth[1] (mg/indiv)		Mortality (%)[1]		Final pH at 24 hours
	x	se	x	se	
Laboratory Control	0.355^{P}	0.020	5.0^{P}	3.0	7.8
Walker Slough	0.429	0.035	5.0	5.0	7.7
Mosher Slough at Mariners	0.436	0.016	0.0	0.0	7.8

P. The laboratory control met the criteria for test acceptability.
1. Highlighted areas indicate a significant increase in mortality or decrease in growth when compared to the laboratory control. The growth and mortality endpoints were analyzed with Dunnett's Test (p<.05).

2. The samples were collected on 9 September 1998. This test was set up on 10 September 1998.

Table 98-3
Summary of 96-hr *Selenastrum* toxicity test conducted during September 1998[2]

Treatment	Cell Count (x 10^4)[1]		% CV	Final pH
	x	se		at 96 hours
Laboratory Control	185.4[P]	16.7	18.0	8.5
Walker Slough	500.9	10.8	4.3	10.2
Mosher Slough at Mariners	429.9	12.5	5.8	10.2

P. The laboratory control met all US EPA criteria for test acceptability. The coefficient of variation was 18.0% in this treatment.
1. Highlighted areas indicate a significant reduction in growth compared to the laboratory control. Cell counts were analyzed using Dunnett's Test (p<.05).
2. Samples were collected on 9 September 1998. This toxicity test was set up on 10 September 1998.

Table 98-4
Water Chemical Characteristic Data for Stockton Urban Runoff Samples Collected 9 September 1998

Treatment	Lab pH	Lab EC (µmhos/cm)	Lab DO (mg/L)	Total Hardness (mg/L as $CaCO_3$)	Alkalinity (mg/L as $CaCO_3$)
Lab Control (EPAMH)	8.0	287	8.3	88	86
Lab Control (SSEPAMH)	8.0	233	8.5	96	82
Lab Control (Glass Distilled)					
Walker Slough	7.7	137	8.4	60	62
Mosher Slough at Mariners	7.8	166	8.3	72	82

October 24, 1998

A sample of stormwater runoff was obtained by the DeltaKeeper for October 24, 1998 from several of the Stockton sloughs. The rainfall data for that date for the City of Stockton show that there was 0.67 inch of precipitation.

Table 98-5 presents the results of the 7-day *Ceriodaphnia* toxicity test. Both Mosher Slough and Walker Slough showed 100 percent mortality of the *Ceriodaphnia* in 3 and 2 days, respectively. This toxicity was essentially eliminated through the addition of 100 µg/L PBO. Five-Mile Slough, Calaveras River and Smith Canal samples taken on October 24, 1998, did not show toxicity to *Ceriodaphnia* over the 7-day test.

Tables 98-6 and 98-7 show the fathead minnow larvae and *Selenastrum* toxicity test data for the October 24, 1998, sample. No toxicity was observed to either of these organisms in Five-Mile Slough, Calaveras River, Smith Canal, Mosher Slough and Walker Slough.

The data in Table 98-8 show that Mosher Slough had 310 ng/L diazinon, while Walker Slough had 170 ng/L diazinon. There is no indication as to whether chlorpyrifos was measured on these samples. Since both samples showed high levels of acute toxicity to *Ceriodaphnia* over 7 days, it appears that there may be diazinon or other toxicants present to account for the toxicity measured.

Table 98-5
Summary of 7-day *Ceriodaphnia* toxicity test conducted during October 1998[2]

Treatment	Reproduction[1] (neonates/adult)	Mortality[1] (%)	Final pH at 24 hours

	x	se		
Laboratory Control	21.5[P]	1.1	0.0[P]	8.5
Laboratory Control + PBO	16.0	2.8	10	8.5
5-Mile Slough	34.9	1.3	0	8.0
5-Mile Slough + PBO	30.3	3.7	10	8.0
Calaveras River	28.2	2.0	10	7.9
Calaveras River + PBO	24.9	1.2	0	7.9
~~Smith Canal~~	~~25.3~~	~~2.4~~	~~0~~	~~7.7~~
~~Smith Canal + PBO~~	~~22.8~~	~~1.2~~	~~0~~	~~7.6~~
Mosher Slough	*	*	100 (3)	7.7
Mosher Slough + PBO	14.7	2.5	20	7.6
Walker Slough	*	*	100 (2)	7.4
Walker Slough + PBO	12.1	1.0	0	7.4

P. The laboratory control met all US EPA criteria for test acceptability. 90% of the daphnids had a third brood.
1. Highlighted cells indicate a significant reduction in reproduction or increase in mortality relative to the laboratory control water. The mortality endpoint was analyzed using Fisher's Exact Test. The reproductive endpoint was analyzed using Dunnett's test ($p<0.05$).
2. The samples were collected on 24 October 1998. This test was set up on 25 October 1998.
* Due to significant mortality observed in this sample, reproduction was not calculated.
(#) Number in parentheses represents days to 100% mortality.

Table 98-6
Summary of 7-day *Pimephales* toxicity test conducted during October 1998[2]

Treatment	Growth[1] (mg/indiv)		Mortality (%)[1]		Final pH at 24 hours
	x	se	x	se	
Laboratory Control	0.476[P]	0.016	0.0[P]	0.0	8.1
5 Mile Slough	0.473	0.029	0.0	0.0	7.6
Calaveras River	0.528	0.028	2.5	3.0	7.4
~~Smith Canal~~	~~0.424~~	~~0.010~~	~~0.0~~	~~0.0~~	~~7.2~~
Mosher Slough	0.486	0.017	2.5	3.0	7.3
Walker Slough	0.435	0.022	10.0	4.0	7.2

P. The laboratory control met the criteria for test acceptability.
1. Highlighted areas indicate a significant increase in mortality or decrease in growth when compared to the laboratory control. The growth and mortality endpoints were analyzed with Dunnett's Test ($p<.05$).
2. The samples were collected on 24 October 1998. This test was set up on 28 October 1998.

Table 98-7
Summary of 96-hr *Selenastrum* toxicity test conducted during October 1998[2]

Treatment	Cell Count ($x\ 10^4$)[1]		% CV	Final pH at 96 hours
	x	se		
Laboratory Control	187.3[P]	9.3	9.9	8.0
5-Mile Slough	364.1	24.6	13.5	9.8
Calaveras River	337.0	11.0	6.5	10.1
~~Smith Canal~~	~~268.2~~	~~2.6~~	~~1.9~~	~~9.4~~
Mosher Slough	376.9	10.0	5.3	9.8
Walker Slough	279.6	10.4	7.4	9.6

P. The laboratory control met all US EPA criteria for test acceptability. The coefficient of variation was 9.9% in this treatment.
1. Highlighted areas indicate a significant reduction in growth compared to the laboratory control. Cell counts were analyzed using Dunnett's Test ($p<.05$).
2. The samples were collected on 24 October 1998. This test was set up on 25 October 1998.

Table 98-8

Summary of water chemical characteristic measurements on samples collected on 24 October 1998

Treatment	Field Temp (°C)	Field pH	Field EC (µmhos/cm)	Lab pH	Lab EC (µmhos/cm)	Lab DO (mg/L)	Total Hardness (mg/L as $CaCO_3$)	Alkalinity (mg/L as $CaCO_3$)
Lab Control (EPAMH)				8.3	284	8.3	88	60
Lab Control (SSEPAMH)				8.3	221	8.2	88	66
Lab Control (Glass Distilled)				7.8	90	8.7		
5 Mile Slough				7.6	236	7.5	70	63
Calaveras River	*	*	89	7.6	103	7.9	42	40
Smith Canal	*	*	164	7.2	178	6.1	56	44
Mosher Slough	*	*	91	7.2	110	6.4	44	41
Walker Slough				7.3	140	7.1	48	28

* These values are not available due to a lack of available field equipment.

Treatment	Diazinon (ng/L)
Mosher Slough	310
Walker Slough	170

December 7, 1998

DeltaKeeper collected samples of Walker Slough and Mosher Slough on December 7, 1998. There was no rainfall on that day. Table 98-9 shows that, while Walker Slough was nontoxic to *Ceriodaphnia* during the 7-day period, Mosher Slough showed 60 percent mortality over that period. Blind duplicates on the Walker Slough samples showed similar results. Table 98-10 shows that the addition of 100 µg/L PBO eliminated the toxicity that was found to *Ceriodaphnia* over the 7-day test.

The December 7 sample was found to be nontoxic to fathead minnow larvae and to *Selenastrum*. These data are presented in Tables 98-11 and 98-12. While there was an apparent decrease in the cell count for the Walker Slough sample collected on December 7, 1998, this decrease was not statistically significant. A partial TIE was conducted on the Walker Slough sample collected on December 7, 1998, using *Selenastrum* as the test organism (Table 98-13). The cell count in this sample for Walker Slough was statistically significantly depressed. Passing the sample through a C8 column extracted water eliminated the toxicity.

Table 98-9

Summary of 7-day *Ceriodaphnia* toxicity test (chronic) conducted during December 1998[2]

Treatment	Reproduction[1] (neonates/adult) x	se	Mortality[1] (%)	Final pH at 24 hours
Laboratory Control	21.8[P]	2.8	0[P]	8.3
Walker Slough	24.4	0.8	0	8.3
Mosher Slough at Mariners	*	*	60	8.2

Quality Assurance Samples

Blind Duplicate	Reproduction[1] (neonates/adult) x	se	Mortality (%)	Final pH at 24 hours
Walker Slough	24.4	0.8	0	8.3
Walker Slough duplicate	25.0	1.3	0	8.2

P. The laboratory control met all US EPA criteria for test acceptability. 78% of the daphnids had a third brood.

1. Highlighted cells indicate a significant reduction in reproduction or increase in mortality relative to the laboratory control water. The mortality endpoint was analyzed using Fisher's Exact Test. The reproductive

endpoint was analyzed using Dunnett's test (p<0.05).
2. The samples were collected on 7 December 1998. This test was set up on 8 December 1998.
* Due to significant mortality observed in these samples, reproduction was not calculated.

Table 98-10
Summary of 7-day *Ceriodaphnia* toxicity test (TIE) conducted during December 1998[2]

Treatment	Reproduction[1] (neonates/adult)		Mortality[1] (%)	Final pH at 24 hours
	x	se		
Laboratory Control	24.8[P]	1.1	0[P]	8.4
Laboratory Control + PBO	17.9	0.9	0	8.4
Mosher Slough	*	*	90	8.3
Mosher Slough + PBO	29.6	0.5	0	8.3

P. The laboratory control met all EPA criteria for test acceptability. 89% of the daphnids had a third brood.
1. Highlighted cells indicate a significant reduction in reproduction or increase in mortality relative to the laboratory control water. The mortality endpoint was analyzed using Fisher's Exact Test. The reproductive endpoint was analyzed using Dunnett's test (p<0.05).
2. The samples were collected on 7 December 1998. This test was set up on 16 December 1998.
* Due to significant mortality observed in this sample, reproduction was not calculated.

Table 98-11
Summary of 7-day *Pimephales* toxicity test conducted during December 1998[2]

Treatment	Growth[1] (mg/indiv)		Mortality (%)[1]		Final pH at 24 hours
	x	se	x	se	
Laboratory Control	0.446[P]	0.063	2.5[P]	3.0	8.1
Walker Slough	0.383	0.014	0.0	0.0	8.1
Mosher Slough at Mariners	0.380	0.008	0.0	0.0	8.1

Quality Assurance Samples

Blind Duplicate	Growth[1] (mg/indiv)		Mortality (%)[1]		Final pH at 24 hours
	x	se	x	se	
Walker Slough	0.383	0.014	0.0	0.0	8.1
Walker Slough duplicate	0.416	0.020	12.5	8.0	8.0

P. The laboratory control met the criteria for test acceptability.
1. Highlighted areas indicate a significant increase in mortality or decrease in growth when compared to the laboratory control. The growth and mortality endpoints were analyzed with Dunnett's Test (p<.05).
2. The samples were collected on 7 December 1998. This test was set up on 8 December 1998.

Table 98-12
Summary of 96-hr *Selenastrum* toxicity test (chronic) conducted during December 1998[2]

Treatment	Cell Count ($x 10^4$)[1]		% CV	Final pH at 96 hours
	x	se		
Laboratory Control	206.4[P]	11.2	10.8	7.5
Walker Slough	65.8	11.3	34.3	8.9
Mosher Slough at Mariners	123.6	3.0	4.8	9.5

Quality Assurance Samples

Blind Duplicates	Cell Count ($x 10^4$)[1]		% CV	Final pH at 96 hours
	x	se		
Walker Slough	65.8	11.3	34.3	8.9
Walker Slough duplicate	59.2	6.0	20.1	8.8

P. The laboratory control met all US EPA criteria for test acceptability. The coefficient of variation was 10.8% in this treatment.
Highlighted areas indicate a significant reduction in growth compared to the laboratory control. Cell counts were analyzed using Dunnett's Test (p<.05).

2. Samples were collected on 7 December 1998. This test was set up on 8 December 1998.

Table 98-13
Summary of 96-hr *Selenastrum* toxicity test (TIE) conducted during December 1998[2]

Treatment	Cell Count (x 10^4)[1]		% CV	Final pH
	x	se		at 96 hours
Laboratory Control	200.5[P]	8.9	8.8	8.8
Laboratory Control C8 method blank	75.8	5.1	13.5	8.5
Walker Slough 12/7/98	69.2	4.1	11.8	8.9
Walker Slough 12/7/98 C8 solid phase extracted water	209.5	5.0	4.8	10.0
Re-sampled Walker Slough 12/14/98	188.9	6.3	6.6	10.0

P. The laboratory control met all US EPA criteria for test acceptability. The coefficient of variation was 8.8% in this treatment.
1. Highlighted areas indicate a significant reduction in growth compared to the laboratory control or increase in growth (in the solid phase extracted water) compared to the ambient sample. Cell counts were analyzed using Dunnett's Test ($p<.05$).
2. The samples were collected on the dates indicated in the table. This test was set up on 16 December 1998.

Walker Slough was re-sampled on December 14, and was not found to be toxic. While there is no information on whether there was precipitation on December 14, it appears that the toxicity found on December 7 was transitory, associated with a runoff event, and it did not persist for a week until it was re-sampled.

The chemical characteristic data for the December 7 sample are presented in Table 98-14. No ELISA results were available, since the samples were nontoxic. This test is only run when toxicity is found.

Table 98-14
Summary of water chemical characteristics of samples collected on 7 December 1998

Treatment	Field Temp (^0C)	Field pH	Field EC (µmhos/cm)	Lab pH	Lab EC (µmhos/cm)	Lab DO (mg/L)	Total Hardness (mg/L as $CaCO_3$)	Alkalinity (mg/L as $CaCO_3$)
Lab Control (EPAMH)				8.2	291	8.4	84	36
Lab Control (SSEPAMH)				8.3	227	8.4	88	70
Lab Control (Glass Distilled)				8.4	90	8.4		
Walker Slough	7.9	7.1	105	8.2	161	8.4	56	21
Mosher Slough at Mariners	10.4	7.5		8.1	195	8.3	88	18

Quality Assurance Samples

Blind Duplicate	Field Temp (^0C)	Field pH	Field EC (µmhos/cm)	Lab pH	Lab EC (µmhos/cm)	Lab DO (mg/L)	Total Hardness (mg/L as $CaCO_3$)	Alkalinity (mg/L as $CaCO_3$)
Walker Slough				8.2	161	8.4	56	21
Walker Slough duplicate				8.2	158	8.4	58	13

1999 Studies

The DeltaKeeper collected samples from Mosher Slough on January 20, 1999. There was no rain on the day of collection. The data from the 7-day *Ceriodaphnia* toxicity test are presented in Table 99-1. Mosher Slough water caused 100 percent mortality within 1 day. The addition of 100 µg/L PBO extended the time to 6 days for 100 percent mortality.

Table 99-2 presents the toxicity test results with *Selenastrum* for the January 20 sample. The Mosher Slough sample was not toxic to *Selenastrum*.

The data presented in Table 99-3 for the chemical characteristics show that there were 50 ng/L chlorpyrifos and 1,200 ng/L diazinon. This sample would be expected to be highly toxic. It is somewhat surprising that Mosher Slough had that level of toxicity in a non-runoff situation. While the day of sampling had no rainfall, the day before (1/19/99) had 0.56 inch of rain. Evidently, there was sufficient carryover from one day to the next in this case to cause Mosher Slough to be toxic the day after a rainfall event. This situation is somewhat different from what has been found in the past; however, the other samples did not have such high levels of diazinon as this sample.

Table 99-1
Summary of 7-day *Ceriodaphnia* toxicity test conducted during January 1999[2]

Treatment	Reproduction[1] (neonates/adult)		Mortality[1] (%)	Final pH at 24 hours
	x	se		
Laboratory Control	22.3[P]	0.3	0[P]	8.4
Laboratory Control + PBO	16.2	1.0	0	8.4
Mosher Slough	*	*	100 (1)	8.1
Mosher Slough + PBO	*	*	100 (6)	8.0

P. The laboratory control met all US EPA criteria for test acceptability. 100% of the daphnids had a third brood.
1. Highlighted cells indicate a significant reduction in reproduction or increase in mortality relative to the laboratory control water. The mortality endpoint was analyzed using Fisher's Exact Test. The reproductive endpoint was analyzed using Dunnett's test ($p<0.05$).
2. The samples were collected on 20 January 1999. This test was set up on 21 January 1999.

Table 99-2
Summary of 96-hr *Selenastrum* toxicity test conducted during January 1999[2]

Treatment	Cell Count (x 10^4)[1]		% CV	Final pH at 96 hours
	x	se		
Laboratory Control	221.3[P]	11.2	6.0	8.4
Laboratory Control C8 Blank	73.6	1.7	4.5	8.2
Mosher Slough	287.0	10.0	7.0	8.3

P. The laboratory control met all US EPA criteria for test acceptability. The coefficient of variation was 6.0% in this treatment.
1. Highlighted areas indicate a significant reduction in growth compared to the laboratory control. Cell counts were analyzed using Dunnett's Test ($p<.05$).
2. Samples were collected on 19-20 January 1999. This test was set up on 21 January 1999.

Table 99-3
Summary of water chemical characteristics of samples collected during January 1999

Treatment	Field Temp (°C)	Field pH	Field EC (µmhos/cm)	Lab pH	Lab EC (µmhos/cm)	Lab DO (mg/L)	Total Hardness (mg/L as $CaCO_3$)	Alkalinity (mg/L as $CaCO_3$)

Lab Control (SSEPAMH)				8.4	217	8.4	84	70
Lab Control (Glass Distilled)				7.7	95	8.3	0	4
Mosher Slough				8.2	102	8.3	24	36

Treatment	Chemical Concentration (ng/L)			
	Chlorpyrifos	Diazinon	Simazine	Diuron
Mosher Slough	50	1,200	440	2,500

February 8, 1999

DeltaKeeper took a sample of Mosher Slough on February 8, 1999. There was 0.16 inch of rain on that day in Stockton. Mosher Slough was sampled at both I-5 and Don Avenue. As shown in Table 99-4, both samples showed 100 percent mortality within 1 day to *Ceriodaphnia*. Duplicates of the I-5 sample showed the same results.

A 96-hour series of toxicity tests using *Ceriodaphnia*, with or without PBO, were conducted on the February 8, 1999, samples taken from Mosher Slough. The Mosher Slough sample taken at Don Avenue showed 100 percent mortality within 1 day. The addition of 100 µg/L PBO essentially eliminated this toxicity over 4 days. Based on the data presented in Table 99-5, there were approximately 3 to 4 TUa of *Ceriodaphnia* toxicity in the February 8, 1999, sample of Mosher Slough water.

Table 99-6 presents the 7-day fathead minnow larvae test results for the February 8 sample. There was no toxicity to fathead minnow larvae in this runoff event.

Table 99-7 presents the results of the toxicity tests with *Selenastrum* for the February 8, 1999, samples taken from Mosher Slough. The Mosher Slough samples were toxic to *Selenastrum*. The cause of this toxicity was not determined.

Table 99-4
Summary of 7-day *Ceriodaphnia* toxicity test conducted during February 1999[2]

Treatment	Reproduction[1] (neonates/adult)		Mortality[1] (%)	Final pH at 24 hours
	x	se		
Laboratory Control	20.5[P]	0.6	0[P]	8.5
Mosher Slough at I-5	*	*	100 (1)	8.0
Mosher Slough at Don Avenue	*	*	100 (1)	8.1

Quality Assurance Samples

Blind Duplicate	Reproduction[1] (neonates/adult)		Mortality (%)	Final pH at 24 hours
	x	se		
Mosher Slough at I-5	*	*	100 (1)	8.0
Mosher Slough at I-5 duplicate	*	*	100 (1)	8.0

Trip Blank	Reproduction[1] (neonates/adult)		Mortality (%)	Final pH at 24 hours
	x	se		
Laboratory Control Trip Blank	21.1	1.2	0	8.5

P. The laboratory control met all US EPA criteria for test acceptability. 100% of the daphnids had a third brood.
1. Highlighted cells indicate a significant reduction in reproduction or increase in mortality relative to the

laboratory control water. The mortality endpoint was analyzed using Fisher's Exact Test. The reproductive endpoint was analyzed using Dunnett's test ($p<0.05$).

2. The samples were collected on 8 February 1999. This test was set up on 9 February 1999.

Table 99-5
Summary of *Ceriodaphnia* 96-hour PBO TIE and dilution series conducted during February 1999[1,2,4]

Treatment	Mortality for each day of the test[3]				Conclusions	Final pH at 24 hrs
	1	2	3	4		
Laboratory Control				0	Control met all US EPA criteria for test acceptability.	8.3
Laboratory Control + PBO				0	No artifactual toxicity present in control blanks.	8.4
100% Mosher Slough at I-5	100	100	100	100	Toxicity detected.	8.0
100% Mosher Slough at I-5 + PBO				0	Toxicity alleviated by the addition of PBO suggests that toxicity was due to a metabolically activated OP pesticide.	7.9
50% Mosher Slough at I-5	50	100	100	100	Toxicity detected.	8.2
25% Mosher Slough at I-5				0	No toxicity detected.	8.3
25% Mosher Slough at I-5 + PBO				0		8.2
12.5% Mosher Slough at I-5				0		8.3
100% Mosher Slough at Don Ave.	100	100	100	100	Toxicity detected.	8.0
100% Mosher Slough at Don Ave. + PBO			5	5	Toxicity alleviated by the addition of PBO suggests that toxicity was due to a metabolically activated OP pesticide.	8.2
50% Mosher Slough at Don Ave.	100	100	100	100	Toxicity detected.	8.0
25% Mosher Slough at Don Ave.				0	No toxicity detected.	8.3
25% Mosher Slough at Don Ave. + PBO				0		8.4
12.5% Mosher Slough at Don Ave.		5	5	5		8.2

1. Four replicates with 18 mls of sample and 5 *Ceriodaphnia* each.
2. Daphnids were fed the standard US EPA amount of food for only four hours a day.
3. Highlighted cells indicate areas of significant interest. No statistical analyses were done.
4. The site was sampled on 8 February 1999. This test was set up on 12 February 1999.

Table 99-6
Summary of 7-day *Pimephales* toxicity test conducted during February 1999[2]

Treatment	Growth[1] (mg/indiv)		Mortality (%)[1]		Final pH at 24 hours
	x	se	x	se	
Laboratory Control	0.413[P]	0.022	0[P]	0.0	8.0
Mosher Slough at I-5	0.466	0.024	5.0	5.0	7.4
Mosher Slough at Don Avenue	0.482	0.024	10.0	4.0	7.5

Quality Assurance Samples

Blind Duplicate	Growth[1] (mg/indiv)		Mortality (%)[1]		Final pH at 24 hours
	x	se	x	se	
Mosher Slough at I-5	0.466	0.024	5.0	5.0	7.4
Mosher Slough at I-5 duplicate	0.438	0.033	5.0	3.0	7.5

Trip Blank	Growth[1] (mg/indiv)		Mortality (%)[1]		Final pH at 24 hours
	x	se	x	se	
Laboratory Control Trip Blank	0.423	0.019	7.5	5.0	8.1

P. The laboratory control met the criteria for test acceptability.

1. Highlighted areas indicate a significant increase in mortality or decrease in growth when compared to the laboratory control. The growth and mortality endpoints were analyzed with Dunnett's Test (p<.05).
2. The samples were collected on 8 February 1999. This test was set up on 9 February 1999.

Table 99-7
Summary of 96-hr *Selenastrum* toxicity test conducted during February 1999[2]

Treatment	Cell Count (x 10^4)[1]		% CV	Final pH at 96 hours
	x	se		
Laboratory Control	207.6[P]	8.6	8.3	8.4
Mosher Slough at I-5	13.0	0.7	11.3	8.2
Mosher Slough at Don Avenue	71.3	0.8	2.1	8.2

Quality Assurance Samples

Blind Duplicate	Cell Count (x 10^4)[1]		% CV	Final pH at 96 hours
	x	se		
Mosher Slough at I-5	13.0	0.7	11.3	8.2
Mosher Slough at I-5 duplicate	13.0	0.3	3.9	8.2

Trip blank	Cell Count (x 10^4)[1]		% CV	Final pH at 96 hours
	x	se		
Laboratory Control Trip Blank	102.6	7.9	15.5	8.4

P. The laboratory control met all US EPA criteria for test acceptability. The coefficient of variation was 8.3% in this treatment.
1. Highlighted areas indicate a significant reduction in growth compared to the laboratory control. Cell counts were analyzed using Dunnett's Test (p<.05).
2. Samples were collected on 8 February 1999. This test was set up on 9 February 1999.

Table 99-8 presents the chemical characteristic data for the February 8, 1999, sample. This sample was found to contain from 30 to 40 ng/L chlorpyrifos and 860 ng/L diazinon. These concentrations of these two pesticides would be expected to be highly toxic to *Ceriodaphnia*. This is in accord with the toxicity test results.

Table 99-8
Summary of water chemical characteristics of samples collected during February 1999

Treatment	Field Temp (°C)	Field pH	Field EC (µmhos/cm)	Lab pH	Lab EC (µmhos/cm)	Lab DO (mg/L)	Total Hardness (mg/L as $CaCO_3$)	Alkalinity (mg/L as $CaCO_3$)
Lab Control (EPAMH)				7.8	260	8.6	96	60
Lab Control (SSEPAMH)				8.2	234	8.6	88	66
Lab Control (Glass Distilled)				9.0	94	8.4		
Mosher Slough at I-5				7.8	91	8.6	36	30
Mosher Slough at Don Avenue				7.9	91	8.7	36	34

Quality Assurance Samples

Blind Duplicate	Field Temp (°C)	Field pH	Field EC (µmhos/cm)	Lab pH	Lab EC (µmhos/cm)	Lab DO (mg/L)	Total Hardness (mg/L as $CaCO_3$)	Alkalinity (mg/L as $CaCO_3$)
Mosher Slough at I-5				7.8	91	8.6	36	30
Mosher Slough at I-5 duplicate				7.8	87	8.7	36	30

Trip Blank	Field Temp (°C)	Field pH	Field EC (µmhos/cm)	Lab pH	Lab EC (µmhos/cm)	Lab DO (mg/L)	Total Hardness (mg/L as $CaCO_3$)	Alkalinity (mg/L as $CaCO_3$)
Laboratory Control Trip Blank				8.2	224	8.5	88	66

Treatment	Chemical Concentration (ng/L)			
	Chlorpyrifos	Diazinon	Prowl	Simazine
Mosher Slough at I-5	40	820	100	5,500
Mosher Slough at Don Avenue	30	860	60	5,300

March 1999

On March 8, 1999, a set of samples was collected from several of the City of Stockton sloughs, as well as other waterbodies in the Delta. The Stockton rainfall gage reported 0.20 inch of precipitation on that date. Tables 99-9 through 99-12 present the results of the toxicity testing and chemical characteristic measurements on this set of samples. Review of the data in these tables shows that Walker Slough and Mosher Slough were nontoxic to *Ceriodaphnia*, fathead minnow larvae and *Selenastrum*. The data obtained from other waterbodies in the region, such as the San Joaquin River at Vernalis, Mokelumne River at New Hope, French Camp Slough at El Dorado, Old River at Tracy, etc., also showed no toxicity to the test organisms. Table 99-13 presents a summary of the toxicity test results obtained for the March 8, 1999, sample.

Table 99-9

Summary of 7-day *Ceriodaphnia* toxicity test conducted on samples collected from the Sacramento-San Joaquin River Delta on 8 March 1999

Set up on 3/9/99

Treatment	Reproduction[1] (neonates/adult)		Mortality[1] (%)	Final pH at 24 hours
	x	se		
Laboratory Control	21.7[P]	0.6	0[P]	8.2
San Joaquin River at Vernalis	24.6	1.8	10	8.2
Mokelumne River at New Hope	10.6	1.2	0	7.9
~~Paradise Cut~~	~~36.1~~	~~1.3~~	~~0~~	~~8.3~~
French Camp Slough at El Dorado	26.9	0.6	0	8.3
Walker Slough	33.9	0.8	0	8.2
Mosher Slough at Mariners	33.1	1.0	30	8.5
Stockton Treatment Plant	24.5	1.1	0	8.2
White Slough	25.0	1.0	0	8.1
Old River at Tracy	29.8	0.7	0	8.2
Quality Assurance Samples				
Mosher Slough	33.1	1.0	30	8.5
Mosher Slough duplicate	32.7	1.2	0	8.5
Stockton Treatment Plant	24.5	1.1	0	8.2
Stockton Treatment Plant duplicate	26.9	1.3	0	8.2
Stockton Treatment Plant duplicate	27.9	0.8	0	8.1

P. The laboratory control met all US EPA criteria for test acceptability. 100% of the daphnids had a third brood.

1. Highlighted cells indicate a significant reduction in reproduction or increase in mortality relative to the laboratory control water. The mortality endpoint was analyzed using Fisher's Exact Test. The reproductive endpoint was analyzed using Dunnett's test ($p<0.05$).

Table 99-10

Summary of 7-day *Pimephales* toxicity test conducted on samples collected from the Sacramento-San Joaquin River Delta on 8 March 1999.

Set up on 3/9/99

Treatment	Growth[1] (mg/indiv)		Mortality (%)[1]		Final pH at 24 hours
	x	se	x	se	
Laboratory Control	0.407[P]	0.009	0[P]	0.0	7.9
San Joaquin River at Vernalis	0.381	0.002	0.0	0.0	7.8
Mokelumne River at New Hope	0.292	0.079	25.0	3.0	7.5
Paradise Cut	0.426	0.023	5.0	5.0	7.9
French Camp Slough at El Dorado	0.379	0.042	25.0	18.0	7.9
Walker Slough	0.424	0.015	5.0	3.0	7.7
Mosher Slough at Mariners	0.414	0.005	0.0	0.0	8.1
Stockton Treatment Plant	0.402	0.021	0.0	0.0	7.8
White Slough	0.395	0.015	5.0	3.0	7.7
Old River at Tracy	0.396	0.011	0.0	0.0	7.8
Quality Assurance Samples					
Mosher Slough	0.414	0.005	0.0	0.0	8.1
Mosher Slough Duplicate	0.438	0.025	2.5	3.0	8.2
Stockton Treatment Plant	0.402	0.021	0.0	0.0	7.8
Stockton Treatment Plant duplicate	0.395	0.017	2.5	3.0	7.8
Stockton Treatment Plant duplicate	0.411	0.006	7.5	5.0	7.8

P. The laboratory control met all US EPA criteria for test acceptability.

1. Highlighted areas indicate a significant increase in mortality or decrease in growth when compared to the laboratory control. The growth and mortality endpoints were analyzed with Dunnett's Test ($p<.05$).

Table 99-11

Summary of 7-day *Selenastrum* toxicity test conducted on samples collected from the Sacramento-San Joaquin River Delta on 8 March 1999

Set up on 3/9/99

Treatment	Cell Count (x 10^4)[1]		% CV	Final pH at 96 hours
	x	se		
Laboratory Control	218.4[P]	3.2	2.9	8.6
San Joaquin River at Vernalis	232.3	19.2	16.5	9.8
Mokelumne River at New Hope	275.3	10.6	7.7	9.4
Paradise Cut	158.9	35.8	45.1	8.6
French Camp Slough at El Dorado	305.6	15.5	10.2	9.8
Walker Slough	295.6	18.9	12.8	9.9
Mosher Slough at Mariners	306.0	21.3	13.9	9.9
Stockton Treatment Plant	284.1	8.0	5.6	9.9
White Slough	308.9	20.1	13.0	9.8
Old River at Tracy	279.8	19.9	14.3	9.9
Quality Assurance Samples				
Mosher Slough	306.0	21.3	13.9	9.9
Mosher Slough duplicate	270.1	9.4	6.9	9.7
Stockton Treatment Plant	284.1	8.0	5.6	9.9
Stockton Treatment Plant duplicate	264.1	22.0	16.7	9.9
Stockton Treatment Plant duplicate	289.9	11.6	8.0	9.8

P. The laboratory control met all US EPA criteria for test acceptability. The coefficient of variation was 2.9% in this treatment.

1. Highlighted areas indicate a significant reduction in growth compared to the laboratory control. Cell counts were analyzed using Dunnett's Test ($p<.05$).

Table 99-12
Summary of chemical characteristic measurements on samples collected from the Sacramento-San Joaquin River Delta on 8 March 1999

Treatment	Field Temp (°C)	Field pH	Field EC (µmhos/cm)	Lab pH	Lab EC (µmhos/cm)	Lab DO (mg/L)	Total Hardness (mg/L as $CaCO_3$)	Alkalinity (mg/L as $CaCO_3$)
ıb Control (DIEPAMH)				8.1	223	8.6	80	62
ıb Control (SSEPAMH)				8.2	222	8.2	86	68
ab Control (Glass Distilled)								
ın Joaquin River at Vernalis	10.8	6.7	241	8.1	319	8.4	82	56
okelumne River at New Hope	9.6	7.6	32	7.9	50	8.3	20	44
ıradise Cut	11.6	7.4	965	8.2	865	8.4	272	102
ench Camp Slough at El Dorado	11.5	8.3	207	8.2	202	8.4	80	
'alker Slough	11.5	7.4	109	8.2	142	8.3	56	60
osher Slough at Mariners	12.3	7.5	426	8.4	375	8.3	140	60
ockton Treatment Plant	11.0	8.2	326	8.1	305	8.3	76	56
'hite Slough	11.2	7.4	152	8.0	136	8.4	50	44
ld River at Tracy	11.0	7.6	258	8.1	333	8.4	86	58
uality Assurance Samples								
osher Slough				8.4	375	8.3	140	60
osher Slough duplicate				8.5	382	8.3	142	
ockton Treatment Plant				8.1	305	8.3	76	56
ockton Treatment Plant ıplicate				8.1	309	8.2	76	54
ockton Treatment Plant ıplicate				8.1	309	8.2	80	

Table 99-13
Summary of toxicity test results for the third quarterly sampling from the Sacramento-San Joaquin Delta collected on 8 March 1999

Set up on 3/9/99

Treatment	*Ceriodaphnia*		*Pimephales*		*Selenastrum*
	Reproduction	Mortality	Growth	Mortality	Cell Count
	Neonate/adult	%	mg/indiv	%	$x10^4$
Laboratory Control	21.7	0	0.407	0.0	218.4
San Joaquin River at Vernalis	24.6	10	0.381	0.0	232.3
Mokelumne River at New Hope	10.6	0	0.292	25.0	275.3
Paradise Cut	36.1	0	0.426	5.0	158.9
French Camp Slough at El Dorado	26.9	0	0.379	25.0	305.6
Walker Slough	33.9	0	0.424	5.0	295.6
Mosher Slough at Mariners	33.1	30	0.414	0.0	306.0
Stockton Treatment Plant	24.5	0	0.402	0.0	284.1
White Slough	25.0	0	0.395	5.0	308.9
Old River at Tracy	29.8	0	0.396	0.0	279.8

1. Highlighted cells indicate a significant reduction in reproduction, growth or cell count or increase in mortality relative to the laboratory control water. The *Ceriodaphnia* mortality endpoint was analyzed using Fisher's Exact Test. The reproductive endpoint, fish growth and mortality, and cell counts were analyzed using Dunnett's Test ($p<.05$).

June 7, 1999

A set of dry weather flow samples was collected from Walker Slough, Mosher Slough, as well as several other waterbodies in the region of the South and Central Delta. The Stockton Slough samples showed no toxicity to *Ceriodaphnia* (Tables 99-14 and 99-15); however, there was toxicity of Mosher Slough water to fathead minnow larvae (Table 99-16), with about 20 percent mortality over the period of the seven-day test. There was no toxicity to *Selenastrum* for the June 7 sample (Table 99-17). Paradise

Cut, located within the South Delta near Tracy, did show toxicity to *Ceriodaphnia*. It was not toxic to fathead minnow larvae; however, Mokelumne River was toxic to fathead minnow larvae.

Table 99-18 presents a summary of the toxicity test results for samples collected on June 7, 1999.

Treatment	Reproduction[1] (neonates/adult)		Mortality[1] (%)	Final pH at 24 hours
	x	se		
Laboratory Control	18.5[P]	1.2	0[P]	8.4
San Joaquin River at Vernalis	23.7	2.8	10	8.3
Mokelumne River at New Hope	22.0	2.6	10	8.4
Paradise Cut	*	*	70	8.5
French Camp Slough at El Dorado	22.6	0.7	0	8.3
Walker Slough	22.4	1.1	0	8.4
Mosher Slough at Mariners	21.5	2.5	10	8.5
Stockton Treatment Plant	22.1	1.0	0	8.3
White Slough	27.0	0.6	10	8.4
Old River at Tracy	27.2	3.2	10	8.4
Quality Assurance Samples – Blind Duplicate				
San Joaquin River at Vernalis	23.7	2.8	10	8.3
San Joaquin River at Vernalis duplicate	27.7	1.0	0	8.4

P. The laboratory control met all US EPA criteria for test acceptability. 90% of the daphnids had a third brood.

1. Highlighted cells indicate a significant reduction in reproduction or increase in mortality relative to the laboratory control water. The mortality endpoint was analyzed using Fisher's Exact Test. The reproductive endpoint was analyzed using Dunnett's test ($p<0.05$).

* Due to significant mortality observed in this sample, reproduction was not calculated.

The sample of the San Joaquin River at Vernalis was nontoxic to *Ceriodaphnia*, fathead minnow larvae and *Selenastrum*. The sample of the Mokelumne River at New Hope was nontoxic to *Ceriodaphnia* and *Selenastrum*, but caused about 58 percent mortality to fathead minnow larvae. The Paradise Cut sample showed 70 percent mortality to *Ceriodaphnia* and was toxic to *Selenastrum*. It was nontoxic to fathead minnow larvae. The June 7 samples collected from French Camp Slough, Walker Slough, White Slough and Old River at Tracy were all nontoxic to the three test species. The Stockton Wastewater Treatment Plant and Mosher Slough samples were nontoxic to *Ceriodaphnia* and *Selenastrum*; however, they did show low levels of toxicity to fathead minnow larvae.

Table 99-19 presents information on the chemical characteristics of the samples collected on June 7 and 16, 1999. No data were provided on diazinon and chlorpyrifos concentrations in the samples.

Table 99-14

Summary of 7-day *Ceriodaphnia* toxicity test conducted on samples collected from the Sacramento-San Joaquin Delta on 7 June 1999

Set up on 6/8/00

Table 99-15

Summary of 7-day *Ceriodaphnia* PBO TIE conducted on samples collected from Paradise Cut and 5-Mile Slough on 7 and 16 June 1999

Set up on 6/8/99

Treatment	Reproduction[1] (neonates/adult)		Mortality[1] (%)	Final pH at 24 hours
	x	se		
Laboratory Control	21.7[P]	2.1	10[P]	8.4
Laboratory Control + PBO	22.0	1.1	0	8.4
Paradise Cut 6/7/99	*	*	50	8.5
Paradise Cut 6/7/99 + PBO	31.6	1.1	0	8.4
Paradise Cut 6/16/99	33.6	0.6	0	8.5
5-Mile Slough 6/16/99	18.8	1.2	0	8.6

P. The laboratory control met all US EPA criteria for test acceptability. 90% of the daphnids had a third brood.

1. Highlighted cells indicate a significant reduction in reproduction or increase in mortality relative to the laboratory control water. The mortality endpoint was analyzed using Fisher's Exact Test. The reproductive endpoint was analyzed using Dunnett's test (p<0.05).

* Due to significant mortality observed in this sample, reproduction was not calculated.

Table 99-16

Summary of 7-day *Pimephales* toxicity test conducted on samples collected from the Sacramento-San Joaquin Delta on 7 June 1999

Set up on 6/8/99

Treatment	Growth[1] (mg/indiv)		Mortality (%)[1]		Final pH at 24 hours
	x	se	x	se	
Laboratory Control	0.313[P]	0.011	1.25[P]	1.3	8.2
San Joaquin River at Vernalis	0.333	0.012	0.0	0.0	8.2
Mokelumne River at New Hope	0.395	0.040	57.5	18.9	8.0
Paradise Cut	0.374	0.020	2.5	2.5	8.3
French Camp Slough at El Dorado	0.369	0.012	7.5	4.8	8.0
Walker Slough	0.313	0.011	4.3	4.3	8.0
Mosher Slough at Mariners	0.349	0.021	20.0	13.5	8.2
Stockton Treatment Plant	0.399	0.025	17.5	7.5	8.2
White Slough	0.356	0.030	27.5	17.0	8.0
Old River at Tracy	0.360	0.014	0.0	0.0	8.3
Quality Assurance Samples – Blind Duplicate					
San Joaquin River at Vernalis	0.333	0.012	0.0	0.0	8.2
San Joaquin River at Vernalis duplicate	0.339	0.014	2.5	2.5	8.2

P. The laboratory control met the criteria for test acceptability.

1. Highlighted areas indicate a significant increase in mortality or decrease in growth when compared to the laboratory control. The growth and mortality endpoints were analyzed with Dunnett's Test (p<.05).

Table 99-17

Summary of 96-hr *Selenastrum* toxicity test conducted on samples collected from the Sacramento-San Joaquin Delta on 7 June 1999

Set up on 6/8/99

Treatment	Cell Count (x 10^4)[1]		% CV	Final pH
	x	se		at 96 hours
Laboratory Control	75.6[P]	3.8	10.0	7.8
San Joaquin River at Vernalis	139.5	17.3	24.8	8.5
Mokelumne River at New Hope	184.2	15.2	16.6	9.5
Paradise Cut	23.4	5.9	50.2	8.6
French Camp Slough at El Dorado	164.6	5.4	6.6	9.7
Walker Slough	218.2	10.0	9.2	10.0
Mosher Slough at Mariners	144.3	5.4	7.5	9.6
Stockton Treatment Plant	149.0	20.0	26.8	8.6
White Slough	196.9	10.9	10.7	9.7
Old River at Tracy	51.3	5.1	19.7	8.5
Quality Assurance Samples				
San Joaquin River at Vernalis	139.5	17.3	24.8	8.5
San Joaquin River at Vernalis duplicate	142.7	15.3	21.5	8.5

P. The laboratory control met all US EPA criteria for test acceptability. The coefficient of variation was 10% in this treatment.

1. Highlighted areas indicate a significant reduction in growth compared to the laboratory control. Cell counts were analyzed using Dunnett's Test (p<.05).

Table 99-18
Summary of toxicity test results for samples from the Sacramento - San Joaquin Delta collected on 7 June 1999

Set up on 6/8/99

Treatment	*Ceriodaphnia*		*Pimephales*		*Selenastrum*
	Reproduction	Mortality	Growth	Mortality	Cell Count
	neonate/adult	%	mg/indiv	%	x10^4
Laboratory Control	18.5[P]	0[P]	0.313[P]	1.25[P]	75.6[P]
San Joaquin River at Vernalis	23.7	10	0.333	0.0	139.5
Mokelumne River at New Hope	22.0	10	0.395	57.5	184.2
Paradise Cut	[illegible]	70	0.374	2.5	23.4
French Camp Slough at El Dorado	22.6	0	0.369	7.5	164.6
Walker Slough	22.4	0	0.313	4.3	218.2
Mosher Slough at Mariners	21.5	10	0.349	20.0	144.3
Stockton Treatment Plant	22.1	0	0.399	17.5	149.0
White Slough	27.0	10	0.356	27.5	196.9
Old River at Tracy	27.2	10	0.360	0.0	51.3

1. Highlighted cells indicate a significant reduction in reproduction, growth or cell count or increase in mortality relative to the laboratory control water. The *Ceriodaphnia* mortality endpoint was analyzed using Fisher's Exact Test. The reproductive endpoint, fish growth and mortality, and cell counts were analyzed using Dunnett's Test (p<.05).

Table 99-19
Summary of chemical characteristic measurements on samples collected from the Sacramento-San Joaquin Delta on 7 and 16 June 1999

Treatment	Field Temp (°C)	Field pH	Field EC (µmhos/cm)	Lab pH	Lab EC (µmhos/cm)	Lab DO (mg/L)	Total Hardness (mg/L as $CaCO_3$)	Alkalinity (mg/L as $CaCO_3$)
Lab Control (DIEPAMH)				8.2	318	7.6	84	60

Lab Control (SSEPAMH)				8.3	260	8.1	92	76
Lab Control (Glass Distilled)				8.1	106	8.1		
San Joaquin River at Vernalis	19.0	7.8	502	8.3	490	8.1	112	76
[illegible]elumne River at New Hope	16.4	8.1	78	8.0	100	8.0	44	24
[illegible]dise Cut	NA	NA	NA	8.4	945	8.1	256	120
French Camp Slough at El Dorado	20.5	8.1	135	8.1	179	8.7	64	50
Walker Slough	22.7	8.0	283	8.1	174	8.1	32	60
Mosher Slough at Mariners	22.6	7.8	177	8.2	189	8.0	84	64
Stockton Treatment Plant	19.9	6.6	437	8.4	486	8.0	124	80
White Slough	20.5	7.4	137	8.8	160	7.8	56	46
Old River at Tracy	NA	NA	NA	8.1	614	8.0	168	90
Paradise Cut 6/16/99	19.8	7.2	1746	8.2	1000	7.9	292	122
Old River at Tracy 6/16/99	20.6	7.9	1054	8.3	644	7.9	152	87
5-Mile Slough 6/16/99				8.4	349	7.9	96	93

Quality Assurance Samples

San Joaquin River at Vernalis	19.0	7.8	502	8.3	490	8.1	112	76
San Joaquin River at Vernalis duplicate	19.0	7.8	502	8.3	471	8.0	108	74

September 22, 1999

On September 22, 1999, DeltaKeeper collected samples from Walker Slough, Mosher Slough, and 5 Mile Slough. Table 99-20 showed that the Mosher Slough and 5 Mile Slough samples killed 100 % of the *Ceriodaphnia* in six and seven days, respectively. The Walker Slough sample was non-toxic to *Ceriodaphnia*. Table 99-21 shows that the addition of 100 µg/L PBO reduced the toxicity for Mosher Slough to 20 % mortality over seven days. Table 99-22 shows that the addition of 100 µg/L of PBO caused the 5 Mile Slough sample to be non-toxic to *Ceriodaphnia*. However, the re-setup of the 5 Mile Slough sample collected on September 22, 1999, shown in Table 99-22 was non-toxic over the seven-day test period. As shown in Table 99-20, the 5 Mile Slough sample killed 100 % of the *Ceriodaphnia* in seven days. The Table 99-22 tests were set up on October 1, some nine days after the sample was originally collected on September 22. Evidently, during this period, some of the toxicity that was found for 5 Mile Slough for the tests that were set up the day following collection, was lost in the sample.

Table 99-23 presents the chemical analysis of the samples collected on September 22, 1999. The parameters analyzed are in accord with what would be expected. No analysis were conducted for the OP pesticides, diazinon and chlorpyrifos.

Insert Tables 99-20 through 99-23

ACRONYMS AND ABBREVIATIONS

CVRWQCB	Central Valley Regional Water Quality Control Board
DIEPAMH	US EPA deionized moderately hard control water
Dilute EI	UCD Institute of Ecology Well Water diluted to an EC of approx. 200 µmhos/cm
DO	dissolved oxygen
EC	electrical conductivity
EDTA	ethylene diamine tetraacetic acid
ELISA	enzyme linked immuno sorbent assay
EPAMH	US EPA moderately hard control water
GDEPAMH	glass distilled water amended with salts to EPA moderately hard standards
LC_{50}	lethal concentration that kills 50 percent
NPDES	national pollutant discharge elimination system
OP	organophosphate
PBO	piperonyl butoxide
PCCP	Post C8 SPE Column Passage
SSEPAMH	Sierra Spring US EPA moderately hard control water
TIE	toxicity investigation evaluation
TUa	acute toxic units
UCD ATL	University of California, Davis, Aquatic Toxicology Laboratory
US EPA	United States Environmental Protection Agency