AQUATIC ECOSYSTEMS ANALYSIS LABORATORY UCDAVIS

Monitoring Discharges from Irrigated Lands – Central Valley Regional Water Quality Control Board

Final Report: Activities from 2004 - 2007

Prepared for the Central Valley Regional Water Quality Control Board

By

Aquatic Ecosystems Analysis Laboratory
John Muir Institute of the Environment
University of California, Davis

January 2009

TABLE OF CONTENTS

TABLE OF TABLES

TABLE OF FIGURES

List of Acronyms

AEAL	Aquatic Ecosystems Analysis Laboratory
ANOVA	Analysis of Variance
CD	Compact Disc
CDFG	California Department of Fish and Game
COC	Chain of Custody
CRM	Certified Reverence Material
CS	Central Sacramento
CVRWQCB	Central Valley Regional Water Quality Control Board
CWC	Clean Water Code
D	Delta
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
DF	Dilution factor
DFG	California Department of Fish and Game
DFG-ATL	California Department of Fish and Game – Aquatic Toxicology Laboratory
DI	Deionized
DL	Detection Limit
DO	Dissolved Oxygen
DoW	Depth of Water
DQO	Data Quality Objective
DS	Dormant Season
EPA	Environmental Protection Agency
FB	Field Blank
FD	Field Duplicate
FT	Fresno-Tulare
IS	Irrigation Season
LCS	Laboratory Control Spike
LCSD	Laboratory Control Spike Duplicate
MDL	Minimum Detection Limit
MS	Matrix Spike
MSD	Matrix Spike Duplicate
NA	Not Applicable
ND	Not Detected
NPDES	National Pollutant Discharge Elimination System
NS	North Sacramento
NSJ	North San Joaquin
NTU	Nephelometric Turbidity Units
OP	Organophosphate
OCH	Organochlorine Pesticides
pH	Power of Hydrogen
PR	Percent Recovery

PTFE	Polytetraflouroethylene (Teflon™)
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RL	Reporting Limit
ROWD	Report of Waste Discharge
RPD	Relative Percent Difference
SC	Specific Conductivity
SM	Standard Method
SOP	Standard Operating Procedure
SS	South Sacramento
SSJ	South San Joaquin
SWAMP	Surface Water Ambient Monitoring Program
TDS	Total Dissolved Solids
THM	Trihalomethane
TIE	Toxicity Identification Evaluation
TOC	Total Organic Carbon
UCD	University of California Davis
USGS	United States Geological Service
WDR	Waste Discharge Requirements
WQTL	Water Quality Trigger Limit
WT	Wet Season

EXECUTIVE SUMMARY

The CVRWQCB executed an interagency agreement with the Aquatic Ecosystem Analysis Laboratory (AEAL) to conduct an evaluation of water quality of agricultural drains throughout the Central Valley as the Phase II monitoring for the Irrigated Lands Program. Phase II included characterizing water quality by using chemical analysis and toxicity testing, identifying the causes (e.g. sediment, contaminants, salt, pesticides) of any water quality impairment, determining the sources of contaminants based on the identified causes of impairments, and using the data and information for recommending specific management practices and future assessments of agricultural runoff. Phase II sites were sampled for chemicals (organic, inorganic, and metals), water and sediment toxicity during winter storms (December-March) and irrigation months (March-September) from July 2004 to September 2007.

The Valley was divided into several subregions and regions for analysis. For statistical comparisons, the regions were the Sacramento Valley, Delta, San Joaquin Valley, and Fresno-Tulare. Exceedances of water quality objectives for field parameters (DO, pH, temperature, EC) were commonplace throughout the Central Valley and across the entire period of sampling. The Sacramento Valley experienced fewer exceedances than the San Joaquin Valley, Delta, or the Fresno-Tulare regions. DO, EC, and pH exceedances were most common in the Delta, followed by the San Joaquin Valley. Water temperature was similar across all regions. All nitrogen (ammonia, nitrate+nitrite, nitrite) was found in greatest concentration in the Delta compared to the other regions, and mean orthophosphate concentration was also significantly greater in the Delta.

Detections of metals were common during the entire period of monitoring. Selenium and cadmium were the least detected elements but were detected in approximately 70% of the samples analyzed. Other metals were detected in nearly 100% of the samples including zinc and copper.

The most common detections of chemicals were for organophosphate pesticides, primarily diazinon and chlorpyrifos. While other classes of pesticides, e.g. carbamates, experienced detections at less than 5% of the samples, diazinon and chlorpyrifos pesticides were detected in as many as 30% of the samples. Other organophosphate pesticides, e.g. dimethoate were detected in over 10% of the samples collected. Not unexpectedly, the results of the TIEs for toxicity tests indicated that organophosphate pesticides were the cause of toxicity to *Ceriodaphnia* in a majority of the cases. Carbamates were found as a contributing factor in three of the TIEs and pyrethroids and metals were each found as the cause in a single TIE. Atrazine, simazine, and diuron were the most frequently detected herbicides with atrazine more commonly detected in the San Joaquin Valley, and diuron detected more commonly in the Sacramento Valley.

The primary pesticides that are the most problematic in the Valley with respect to the frequency of detection, and the concentrations of the constituents in the samples, are chlorpyrifos, diazinon, atrazine, simazine, and diuron. They share a low K_{oc} value (1800-6000 depending on the source, 1000, 100, 130, 480 respectively) indicating that they are highly soluble and readily mobilized by storm water or irrigation return flows. The three herbicides account for 58% of all detections of herbicides during the entire period of sampling, and the two organophosphate pesticides account for 59% of all organophosphate, carbamate, and fungicide detections. Eliminating these five chemicals from runoff would eliminate nearly 60% of the pesticides from surface waters of the Valley. Based on the results of the TIEs, eliminating these five constituents could also potentially eliminate over 75% of the toxicity observed.

BACKGROUND

The California Water Code (CWC) requires that any discharges, or proposed discharges, to surface waters that could affect water quality be described in a Report of Waste Discharge (ROWD). In the past, the Central Valley Regional Water Quality Control Board (CRWQCB) has regulated these waste discharges primarily through the issuance of Waste Discharge Requirements (WDR) and National Pollutant Discharge Elimination System (NPDES) permits. NPDES permits are issued for point source and municipal storm water discharges, but irrigation return flows and storm water discharges from irrigated lands have been excluded from the program as a result of Resolution No. 82-036: *Waiving Waste Discharge Requirements for Specific Types of Discharge* which was adopted by the CRWQCB in 1982. This resolution exempted both irrigation return flows and storm water runoff from agricultural lands from permitting requirements. Due to insufficient resources, verification that dischargers were complying with the conditions of the waiver was not conducted and thus the 1982 waiver was largely a passive program.

In 1999, Senate Bill 390 changed the section of the California Water Code that authorized waivers of Waste Discharge Requirements (WDR) specifying that all discharge waivers in place on January 1 2000 would end January 1 2003 if the Regional Board did not readopt them.

In July 2003, the Regional Board adopted Resolution R5-2003-0105. This resolution includes two conditional waivers, one for agricultural coalition groups that form on behalf of individual dischargers and the other for individual dischargers, to facilitate compliance with the California Water Code and the plans and policies of the Regional Boards. R5-2003-0105 stipulates that the agricultural coalition groups must develop waste monitoring programs to assess the sources and impacts of waste in discharges from irrigated lands and, if necessary, track progress in reducing the amount of waste discharge that affects the quality of the waters of the state and its beneficial uses. Coalitions had until January 2005 to start their own monitoring programs. The goal of the two-year interim Waiver was to build capacity of local coalitions, engage with individual dischargers, and initiate data collection, all of which are aspects of the foundation for the long-term program (CVRWQCB 2003).

INTRODUCTION

The CVRWQCB executed an interagency agreement with the UC Davis Aquatic Toxicology Laboratory in November 2002 to conduct an evaluation of water quality of agricultural drains throughout the Central Valley. In Phase I of the Irrigated Lands Program, water quality was evaluated primarily through the use of water column toxicity testing in a limited number of agricultural drains in the San Joaquin River and Sacramento River watersheds. Phase II of the program was contracted to the UC Davis Aquatic Ecosystem Analysis Laboratory (AEAL) and the California Department of Fish and Game (CDFG).

Phase II included the following objectives:

- Characterize water quality by using chemical analysis and toxicity testing in a number of agricultural drains in the Central Valley
- Identify the causes (e.g. sediment, contaminants, salt, pesticides) of any water quality impairment
- Determine the sources of contaminants based on the identified causes of impairments
- Use data and information gained in this program for recommending specific management practices and future assessments of agricultural runoff.

Ninety two sites were sampled at least once for water quality analyses and 100 sites were sampled at least one time for sediment toxicity evaluation (Table 1). The primary criteria for site selection were:

- Upstream drainage was dominated by agricultural irrigation return flow or storm water runoff
- Land use surrounding the site was predominantly agricultural, and
- Sampling could take place at locations where agricultural drainage water is discharged into a creek or river.

MONITORING PLAN SUMMARY

Selected Phase II sites were sampled for chemicals (organics, inorganics and metals), water and sediment toxicity during winter storms (Dec-Mar) and irrigation months (Mar-Sept) from July 2004 to November 2007. Samples were only analyzed for trihalomethanes (THMs) during the 2004 Irrigation season. Due to infrequent detections in samples, analyses for THMs were eliminated. For the purposes of this report the monitoring efforts will be referred to by the time periods during which they occurred:

- 2004 Irrigation Season (IS 2004): July 8 – September 16, 2004
- 2005 Dormant Season (DS 2005): January 26 – February 23, 2005
- 2005 Wet Season (WT 2005): between DS 2005 storm events
- 2005 Irrigation Season (IS 2005): June 13 – August 10, 2005

- 2006 Dormant Season (DS 2006): January 15 – March 1, 2006
- 2007 Irrigation Season (IS 2007): June 27, 2007 – November 28, 2007.

In addition, several sampling events involving split samples took place in September 2004, and February and October 2005. Those events involve simultaneous sampling by the AEAL and selected coalition groups. In this report the split sampling efforts will be referred to as the NA 2004 Season and NA 2005 Season.

SAMPLING SITE SELECTION

In order to achieve the broadest representation of land use types and geographic distribution, sampling sites were selected from seven arbitrarily created regions. The sites encompassed a geographic area spanning from north of Red Bluff to as far south as Visalia and bounded to the east and west by the confines of the Sacramento and San Joaquin valley floors (Table 1). The seven geographic regions were North Sacramento (NS), Central Sacramento (CS), South Sacramento (SS), Delta (D), North San Joaquin (NSJ), South San Joaquin (SSJ), and the Fresno-Tulare region (FT).

Sampling site identification codes (site IDs) were created for new sites using a letter code for each region name followed by a two digit numerical reference beginning with 01. For example, NS01 was the first site selected in the North Sacramento (NS) region. Some of the sites chosen for this program had been previously monitored by the CVRWQCB or other agencies. In those instances, the site identifications created by the previous monitoring agency were used. Table 1 is a comprehensive list of all locations, site names and site IDs monitored for this project.

Sediment samples were collected by AEAL and UC Berkeley staff during the 2004 & 2005 irrigation seasons and the 2005 dormant season. Some sediment samples were collected at the same locations as water samples (Table 2). Sediment was not collected at all sites due to the absence of soft sediment, lack of water, or inaccessibility. Sites where no sediment was sampled are listed under the “Not Applicable” column in Table 2.

Table 1. Surface water monitoring sites during Phase II

Site ID	Site Name	County	Target Latitude	Target Longitude	2004 Irrigation	2004 NA	2005 Dormant	2005 Irrigation	2005 NA	2006 Dormant	2007 Irrigation
NS04	Antelope Creek at Kansas Avenue	Tehama	40.12483	-121.1147	X		X				
NS07	China Slough at Tehema and Vina Road	Tehama	39.93724	-122.04963	X						
NS08	Keefer Slough at Hwy 99	Butte	39.80799	-121.91081	X*						
CS01	Tributary Home Colony Canal	Tehama/Glenn	39.78425	-122.19659				X			
CS03	Stony Creek on Hwy 45 near Road 24	Glenn	39.70981	-122.00221	X						
CS06	Comanche Creek (Angel Slough) at Dayton Road	Butte	39.70014	-121.84878				X			
CS07	Butte Creek on Durham Dayton Hwy	Butte	39.64593	-121.78492			X				
CS09	Simmerly Slough at Ellis Avenue	Yuba	39.19807	-121.57696	X						
CS10	Yankee Slough at Swanson Road	Sutter	38.96777	-121.51452	X						
CS11	Bear River at Pleasant Grove Road	Sutter	38.98464	-121.48647				X			
CS12	Unnamed Drain of Walker Creek on County Road 28	Glenn	39.66846	-122.22385	X			X			
CS13	Unnamed Canal at Hwy 45	Colusa	38.96886	-121.86087	X						
CS15	Spring Creek at Walnut Creek	Colusa	39.11975	-122.19318	X		X	X			X
CS21	Hamilton Slough at Hwy 99	Butte	39.42279	-121.68722	X						
CS22	Drain to Walker Creek at County Road D	Glenn	39.68472	-122.25194				X*			
CS23	Spring Creek at East Camp Road	Colusa	39.10878	-122.21082				X			
CS24	Drain to Walker Creek at County Road F	Glenn	39.67449	-122.23312				X			
CS25	Jack Slough at Jack Slough Road	Yuba	39.18038	-121.57108					X	X	
CS26	Butte Slough at Lower Pass Road	Sutter	39.18718	-121.90904					X	X	
CS27	Colusa Basin Drain above Knights Landing	Yolo	38.81212	-121.72433					X	X	
CS28	Colusa Basin Drain #5	Colusa	39.18325	-122.05143					X	X	
CS30	Butte Creek at Gridley Road	Butte	39.3619	-121.9098						X	
CS31	Main Drainage Canal at Colusa Highway	Butte	39.36214	-121.82305						X	X
CS32	Mud Creek at Sacramento Avenue	Butte	39.72904	-121.93191						X	
CS33	Stony Creek at Highway 45	Glenn	39.71087	-122.02605						X	
CS34	Salt Creek at Old Hwy 99	Colusa	39.16874	-122.15644							X
CS35	Lurline Creek at Old Hwy 99	Colusa	39.21216	-122.18309							X
CS36	Hunters Creek at Four Mile Road	Colusa	39.36518	-122.11617							X
CS37	Howard Sloughat Afton Road	Glenn	39.4201	-121.8928							X
LSAC29	Stone Corral Creek at Four Mile Road/Excelsior Road	Colusa	39.29363	-122.11562							X
SSLNK	Sacramento Slough near Karnak	Sutter	38.785	-121.6533					X		
SS03	Willow Slough at Road 99	Yolo	38.60471	-121.78422	X						
SS04	Unnamed Ditch at SW corner of Levee Road and Riego Road	Sutter	38.75116	-121.4937	X						
SS05	North Main Canal at Sankey Road	Sutter	38.77978	-121.53259				X			
SS06	Winters Canal at Road 86A	Yolo	38.66366	-122.01609			X				
SS07	West Adams Canal at Road 89	Yolo	38.70488	-121.96093	X						
SS09	N-S Ditch along Natomas Road	Sutter	38.74504	-121.4938				X			
D01	Drain to San Joaquin River off South Manthey Road	San Joaquin	37.8234	-121.2985	X		X				
D02	Drain to Grant Line off Wing Levee Road	San Joaquin	37.8205	-121.4035	X		X				
D03	Drain to North Canal at South Bonetti Road	San Joaquin	37.8715	-121.5256	X		X				
D04	Sycamore Slough at Cotta Road (near Guard Road)	San Joaquin	38.13794	-121.42144							X
ULCABR	Ulatis Creek at Brown Road	Solano	38.307	-121.7942							X

* Dry site

Site ID	Site Name	County	Target Latitude	Target Longitude	2004 Irrigation	2004 NA	2005 Dormant	2005 Irrigation	2005 NA	2006 Dormant	2007 Irrigation
LTCJR	Lone Tree Creek at Jack Tone Rd	San Joaquin	37.8376	-121.14376		X					
NSJ03	Unnamed Canal at west end of Woodbridge Road	San Joaquin	38.15266	-121.4986	X						
NSJ04	Calaveras River at Clements Road	San Joaquin	38.04563	-121.07661				X			
NSJ06	Mormon Slough on Jack Tone Road	San Joaquin	37.96505	-121.14793	X						
NSJ18	Orestimba Creek at Kilburn Road	Stanislaus	37.39918	-121.03168	X						
NSJ24	Dry Creek at J9	Stanislaus	37.65894	-120.77867	X						
NSJ26	Ingalsbe Slough at J17	Merced	37.49167	-120.5564	X						
NSJ28	Pixley Slough at Eightmile Road	San Joaquin	38.05765	-121.3135	X		X	X			X
NSJ29	Stevison Lower Lateral at intersection of Faith Home Road and Turner Road	Merced	37.3724	-120.92194	X						
NSJ31	Calaveras River at Pezzi Road	San Joaquin	38.04536	-121.19982			X	X			X
NSJ32	Bear Creek at Alpine Road	San Joaquin	38.07402	-121.21093			X	X			X
NSJ34	Bear Creek at Harney Lane	San Joaquin	38.10171	-121.17643				X			
NSJ36	Pixley Slough at Ham Lane	San Joaquin	38.07474	-121.2863				X			
NSJ38	Paddy Creek at Jack Tone Road	San Joaquin	38.1179	-121.14973				X			
SJC516	Unnamed Canal at Howard Rd	San Joaquin	37.87696	-121.37656				X			
SJC517	Mid Roberts Island Drain at Woodsbro Road	San Joaquin	37.94163	-121.3693				X			
SSJ01	Cottonwood Creek at Hwy 145 in Madera County	Madera	36.90021	-120.05489	X						
SSJ03	Berenda Creek at Avenue 17.5 west of Madera	Madera	37.00448	-120.23746			X	X			
SSJ04	Island Field Drain on Catrina Road	Merced	37.06142	-120.57228				X			
SSJ07	Boundary Drain at Henry Miller Avenue	Merced	37.09884	-120.77777				X			
SSJ08	Poso Drain at NE corner of Turner Island Road and Palazzo Road	Merced	37.12854	-120.70565	X						
LCAJR	Littlejohns Creek at Jack Tone Rd	San Joaquin	37.88962	-121.14605					X		
DSAGR	Duck Slough @ Gurr Rd	Merced	37.21423	-120.55958		x					
SSJ10	Owens Creek at Gurr Road	Merced	37.23534	-120.55953				X			
SSJ12	Duck Slough at Arboleda Drive	Merced	37.56072	-120.37818	X		X				
SSJ15	Livingston Canal at Cressey Way	Merced	37.47864	-121.40605							X
SSJ16	TID Lateral #2 on Service Road	Stanislaus	37.58013	-120.87577							X
SSJ17	Lateral 5 at Paradise Road	Stanislaus	37.61453	-121.1438							X
SSJ18	Lower Lateral 2 at Grayson Road	Stanislaus	37.56522	-121.13846							X
SSJ19	Lateral 6 at Central Avenue	Merced	37.40163	-120.95913							X
SSJ20	El Nido Canal at W. Washington Road	Merced	37.11292	-120.43459							X
SSJ21	Fairfield Canal at Olive Avenue	Merced	37.31795	-120.39669							X
SSJ22	Ceres Main Canal at Faith Home and Hatch Road	Stainislaus	37.609	-120.92043							X
STC042	Hospital Creek at River Road	Stainislaus	37.61055556	-121.2286111		X					
FT03	Elbow Creek on Rd 112 N of Visalia	Tulare	36.40293	-119.32213			X	X			
FT05	Button Ditch on Ave 368 west of Alta Avenue	Tulare	36.45856	-119.39828	X			X			
FT08	West Reedley Ditch at East Adams Avenue	Fresno	36.63328	-119.44552	X						
FT13	Kings River at Jackson Avenue Bridge	Kings	36.25584	-119.85412	X						
FT14	Tule River at Popular Avenue	Tulare	36.05001	-119.50499	X		X				
FT15	Calloway Canal at Hwy 46	Kern	35.60171	-119.26294	X						
FT16	Kings River at Reed Avenue	Fresno	36.58692	-119.45639			X				
FT18	Drain to Fink Ditch at Central Avenue	Fresno	36.69134	-119.46542				X			
FT19	Drain to Wooten Creek along Hill Road at Wooten Circle	Fresno	36.38505	-119.27781				X			
FT23	St. Johns River at Road 108	Tulare	36.37453	-119.33127				X			
FT24	Elk Bayou at Road 96.	Tulare	36.12429	-119.35671				X			
FT25	Melga Canal at Jersey Avenue	Kings	36.24044	-119.62431				X			
FT31	Peoples Ditch at Elder Avenue	Kings	36.38668	-119.63774				X			
FT32	Fresno Slough at Huntsman Avenue	Fresno	36.58081	-120.20284						X	
FT33	Cantua Creek at South Stanislaus Avenue	Fresno	36.42895	-120.33738						X	
FT34	Los Gatos Creek at El Dorado Avenue	Fresno	36.16644	-120.20959						X*	

* Dry site

Table 2. Sediment sites during Phase II

Site ID	Site Name	County	Latitude	Longitude	2004 Irrigation	2005 Dormant	2005 Irrigation	2006 Dormant	Not Applicable
CS02	Unnamed Canal at Cutting Road between County Road P and 6th Avenue	Tehama/Glenn	39.79770	-122.13170	X				
CS03	Stony Creek on Hwy 45 near Road 24	Glenn	39.70981	-122.00221	X				
CS06	Comanche Creek (Angel Slough) at Dayton Road	Butte	39.70014	-121.84878			X		
CS07	Butte Creek on Durham Dayton Hwy	Butte	39.64593	-121.78492		X			
CS09	Simmerly Slough at Ellis Avenue	Yuba	39.19807	-121.57696	X				
CS10	Yankee Slough at Swanson Road	Sutter	38.96777	-121.51452	X				
CS11	Bear River at Pleasant Grove Road	Sutter	38.98464	-121.48647			X		
CS12	Unnamed Drain of Walker Creek on County Road 28	Glenn	39.66846	-122.22385	X		X		
CS13	Unnamed Canal at Hwy 45	Colusa	38.96886	-121.86087	X				
CS15	Spring Creek at Walnut Drive	Colusa	39.11975	-122.19318	X	X	X		
CS21	Hamilton Slough at Hwy 99	Butte	39.42279	-121.68722	X				
D01	Drain to San Joaquin River off South Manthey Road	San Joaquin	37.82340	-121.29850	NA				
D02	Drain to Grant Line Canal off Wing Levee Road	San Joaquin	37.82050	-121.40350	X				
D03	Drain to North Canal at South Bonetti Road	San Joaquin	37.87150	-121.52560	NA				
GLSZR1	Gilsizer Slough at Bogue Road	Sutter	39.09841	-121.63878					X
GLSZR3	Gilsizer Slough at Oswald Road	Sutter	39.06879	-121.64317					X
GLSZR4	Gilsizer Slough at O'Banion Road	Sutter	39.02533	-121.65913					X
GLSZR5	Gilsizer Slough at Hutchison Road	Sutter	39.03979	-121.64622					X
GLSZR6	Gilsizer Slough at Lincoln Road	Sutter	39.11285	-121.63599					X
FT03	Elbow Creek on Road 112 N of Visalia	Tulare	36.40293	-119.32213		X	X		
FT05	Button Ditch on Avenue 368 west of Alta Avenue	Tulare	36.45856	-119.39828	X	X	X		
FT08	West Reedley Ditch at East Adams Avenue	Fresno	36.63328	-119.44552	X				
FT13	Kings River at Jackson Avenue Bridge	Kings	36.25584	-119.85412	NA				
FT14	Tulare River at Poplar Avenue	Tulare	36.05001	-119.50499	X				
FT15	Calloway Canal at Hwy 46	Kern	35.60171	-119.26294	X				
FT18	Drain to Fink Ditch at Central Avenue	Fresno	36.69138	-119.46543			X		
FT19	Drain to Wooten Creek along Hill Road at Wooten Circle	Fresno	36.38505	-119.27781			X		
FT23	St. Johns River at Road 108	Tulare	36.37453	-119.33127			X		
FT24	Elk Bayou at Road 96	Tulare	36.12429	-119.35671			X		
FT25	Melga Canal at Jersey Avenue	Kings	36.24044	-119.62431			X		
FT31	Peoples Ditch at Elder Avenue	Kings	36.38668	-119.63774			X		
NS04	Antelope Creek at Kansas Avenue	Tehama	40.12483	-122.11470	NA				
NS07	China Slough at Tehema and Vina Road	Tehama	39.93724	-122.04963	X				
NSJ03	Unnamed canal at west end of Woodbridge Road	San Joaquin	38.15266	-121.49860	NA				
NSJ06	Mormon Slough on Jack Tone Road	San Joaquin	37.96505	-121.14793	NA				
NSJ17	Del Puerto Creek at Intersection Highway 33 and Mulberry Road	Stanislaus	37.51421	-121.15875					X
NSJ18	Orestimba Creek at Kilburn Road	Stanislaus	37.39918	-121.03168	X	X			
NSJ24	Dry Creek at J9	Stanislaus	37.65894	-120.77867	X				
NSJ26	Ingalsbe Slough at J17	Merced	37.49167	-120.55640	X				
NSJ28	Pixley Slough at Eightmile Road	San Joaquin	38.05765	-121.31350	NA	X	X		
NSJ29	Stevinson Lower Lateral at intersection of Faith Home Road	Merced	37.37240	-120.92194	NA				
NSJ31	Calaveris River at Pezzi Road	San Joaquin	38.04536	-121.19982		X	X		
NSJ32	Bear Creek at Alpine Road	San Joaquin	38.07402	-121.21093		X	X		
SED03	Butte Creek at Durnel Drive	Butte	39.58390	-121.80000	X				
SED06	Juncture of Poso Drain and Pick Anderson Bypass	Merced	37.14060	-120.70720	X				
SED07	Tom Paine Slough at Paradise Road	San Joaquin	37.77160	-121.38600	X				
SED08	Unnamed Slough at Wildwood Road	San Joaquin	37.86330	-121.12820	X				
SED09	Drain to Pixley Slough at Davis Road	San Joaquin	38.05640	-121.33320	X				
SED10	Drain to Brack Dr at Woodbridge Road	San Joaquin	38.15270	-121.49890	X				
SED11	Drain to North Canal along Bonetti Drive	San Joaquin	37.86430	-121.52000	X	X			
SED12	Hospital Creek at Road 33	San Joaquin	37.61230	-121.25970	X	NA			

Site ID	Site Name	County	Latitude	Longitude	2004 Irrigation	2005 Dormant	2005 Irrigation	2006 Dormant	Not Applicable
SED15	Ditch on S. side of Utica Avenue	Kings	35.93418	-119.62700		X	X		
SED16	Deer Creek at Alila Avenue	Tulare	35.95007	-119.17570		X			
SED17	Farmer's Ditch at Rt. 137 (Tulare Avenue)	Tulare	36.20884	-119.26043		X	X		
SED18	Mill Creek at Road 168	Tulare	36.34812	-119.19781		X	X		
SED19	King Ditch at Avenue 368 and Road 60	Tulare	36.46521	-119.43875		X	X		
SED20	Knestirc Ditch at Route 201 (Avenue 400)	Tulare	36.51731	-119.43939		X	X		
SED21	Near Kings River at Reed Avenue	Fresno	36.58525	-119.46010		X			
SED22	Murphy Slough at Elm	Fresno	36.46018	-119.79870		X	X		
SED23	Turner Ditch at Marks (22nd Avenue)	Fresno	36.43824	-119.85109		X	X		
SED24	Stinson Ditch at Kamm	Fresno	36.53146	-120.11618		X	X		
SED25	PoSo Slough at Hudson	Fresno	36.97646	-120.54536		X	X		
ASED25	Poso Slough at Shain	Fresno	36.96708	NR					X
BSED25	Poso Slough at Merrill	Fresno	36.95242	-120.51951					X
CSED25	Poso Slough at Newcomb	Fresno	36.95096	-120.50906					X
DSED25	Poso Slough at Valeria	Fresno	36.98164	-120.55665					X
ESED25	Poso Slough at Evans	Fresno	36.99539	-120.57233					X
FSED25	Poso Slough at Eucalyptus	Merced	37.01076	-120.60405					X
SED26	Holland Drain at Hudson	Fresno	36.92477	-120.51830		X	X		
SED27	Stony Creek at Hwy 32	Glenn	39.74592	-122.10140		X			
SED28	Colusa Drain at Hwy 162	Glenn	39.52191	-122.04444		X			
SED29	Big Chico Creek at Grape	Butte	39.71668	-121.93079		X			
SED30	Mud Creek at Meridian	Butte	39.74741	-121.91808		X			
SED41	Del Puerto Creek at Loquat #1	Stanislaus	37.53856	-121.12389					X
SED42	Del Puerto Creek at Loquat #2	Stanislaus	37.53876	-121.12363					X
SED43	Del Puerto Creek at Vineyard Avenue	Stanislaus	37.52140	-121.14866					X
SED44	Del Puerto Creek at Frank Cox Road	Stanislaus	37.53130	-121.13805					X
SED45	Del Puerto Creek at Rogers Road	Stanislaus	37.49936	-121.17761					X
SED46	Del Puerto Creek at Zacharins Road	Stanislaus	37.49394	-121.19386					X
SED47	Del Puerto Creek at DP Canyon Road	Stanislaus	37.47398	-121.23623					X
SJC516	Unnamed Canal at Howa Road	San Joaquin	37.87696	-121.37656			X		
SJC517	Mid Roberts Island Drain at Woodsbro Road	San Joaquin	37.94163	-121.36930			X		
SLO	Live Oak Slough at Eager Road	Sutter	39.18127	-121.66233			X		
SS03	Willow Slough at Road 99	Yolo	38.60471	-121.78422	X				
SS04	Unnamed Ditch at SW corner of Levee and Riego Road	Sutter	38.75116	-121.49370	X				
SS05	North Main Canal at Sankey Road	Sutter	38.77978	-121.53259			X		
SS06	Winters Canal at Road 86A	Yolo	38.66366	-122.01609		X			
SS07	West Adams Canal at Road 89	Yolo	38.70488	-121.96093	X				
SS09	N-S Ditch along Natomas Road	Sutter	38.74504	-121.49380			X		
SSI	Unnamed Drain Along Sutter Island X Road	Sacramento	38.29572	-121.59263			X		
SSJ01	Cottonwood Creek at Hwy 145 in Madera County	Madera	36.90021	-120.05489	X				
SSJ03	Berenda Creek at Avenue 17.5 west of Madera	Madera	37.00448	-120.23746		X	X		
SSJ04	Island Field Drain at Catrina Road	Merced	37.06142	-120.57228	X		X		
SSJ05	Main Canal at Badger Flat Road	Merced	37.07120	-120.87680	X				
SSJ07	Boundary Drain at Henry Miller Avenue	Merced	37.09884	-120.77777			X		
SSJ08	Poso Drain at NE corner of Turner Island and Palazzo Road	Merced	37.12854	-120.70565	X				
SSJ09	Sand Slough on Turner Island Road West of Merced Natl. Wildlife Refuge	Merced	37.17170	-120.68340	X				
SSJ10	Owens Creek at Gurr Road	Merced	37.23534	-120.55953			X		
SSJ12	Duck Slough at Arboleda Drive	San Joaquin	37.25734	-120.37818	X	X			
STC042	Hospital Creek at River Road	Stanislaus	37.61056	-121.22861					X

NA: Sediment not analyzed for one of the following reasons 1) Hard bottom and no sediment available 2) Too deep to sample 3) dry site

NR: Latitude was not recorded

Note: No sediment samples were collected for analysis during the 2006 Dormant Season

METHODS

Methods for Phase II sampling are outlined in the Quality Assurance Project Plan for this project. Briefly, there were several categories of measurements collected including field parameters, water column toxicity, sediment toxicity, water chemistry, and sediment chemistry. Sediment toxicity testing was performed by Don Weston at the University of California, Berkeley, and sediment chemistry analyses were performed by Mike Lydy at Southern Illinois University. Methods for those analyses are included in Appendix 7.

FIELD PARAMETERS

Air and water temperature, pH, electrical conductivity (EC) and dissolved oxygen (DO) were measured using Oakton pH/Con 10 Multiparameter Meter and Oakton Accumet Dissolved Oxygen Meter. Field measurements, weather and water conditions were noted on field sheets as well as the sampling time, the number of collected environmental and quality control samples.

Velocity was measured either by using a bridgeboard or by wading. Four different current meters were used to determine the stream velocities: USGS Price Type AA Current Meter for low and normal velocities, Swoffer Current Velocity Meter Model 2100 or Marsh-McBurney Velocity Meter FLO-MATE Model 2000. Velocity values for some sites were obtained from gauges. Discharge was not measured during the 2006 dormant season or during 2007 sampling. Discharge was measured following the standard method described in USDA Technical Report RM-245. For velocity that was measured in a channel, the currently recommended mid-section method by the U.S. Geological Survey was used to compute discharge (Harrelson 1994). The failure to measure discharge with every sampling event was due to one of several reasons 1) malfunction of equipment 2) flow was too high or fast for wading 3) water level or flow was too low to take discharge measurement 4) discharge was not required.

Some sites had culverts rather than bridges and discharge was difficult to obtain. Frequently, culvert discharges were at high enough velocities to render the bridge method ineffective due to the inability to keep the line vertical on the velocity meter. Also, during periods of high discharge, wading velocity measurements made by wading across the culverts was too dangerous.

It was possible to accurately estimate discharge by taking velocity measurements at several depths and applying those velocities to horizontal sections of the water column at those depths. Culvert flows were calculated by estimating the cross-section area of the water at the point where it leaves the culvert, then multiplying this area by the velocity of the water. The water was divided into three sections by depth, with velocities taken at one point in each depth range. The depth ranges were bottom of water column to 70% depth of water (DoW); 70% DoW to 40% DoW; and 40% DoW to water surface. The velocity was recorded at 80% DoW, 60% DoW, and 20% DoW. The depths for velocity measurements were chosen based on USGS protocol for velocity estimation in a channel.

CHEMICAL ANALYSES

The water samples were collected following the Standard Operating Procedures included in the Quality Assurance Project Plan developed for the Irrigated Lands Monitoring Program. Samples were categorized as either grab or integrated grab samples. Grab samples were a single sample taken from one location. Integrated samples were a single sample taken from a composite of three different locations, for example across a bridge.

The samples for metals analyses were acidified by UCD AEAL upon return from the field and sent to the Department of Fish & Game Marine Pollution Studies Laboratory in Moss Landing. TOC samples were analyzed, in part, by the UC Davis Department of Civil and Environmental Engineering, and in part by the Department of Fish and Game Water Pollution Control Laboratory. All other samples were analyzed at the Department of Fish and Game Water Pollution Control Laboratory in Rancho Cordova.

TOXICITY TESTING

Sediment for sediment toxicity was collected following the Standard Operating Procedure developed by Dr. Don Weston using the metal scoop method. The sediment samples were picked up by Dr. Weston from the UCD AEAL and analyzed at UC Berkeley. The water and sediment samples were put on ice immediately after collection and kept on ice until delivered to the different laboratories. The Water Column Toxicity samples were delivered to either AQUA-Science Laboratory (Davis, CA) or CA Department Fish and Game Aquatic Toxicology Laboratory for toxicity testing.

RESULTS

The results presented below reflect only the samples with detections. Complete data for all constituents are provided to the CVRWQCB in electronic format. Data are also available through the UCD Regional Data Center at the AEAL. Results for sediment toxicity analyses and sediment chemistry analyses have been submitted separately by D. Weston and are included in this report as Appendix 7.

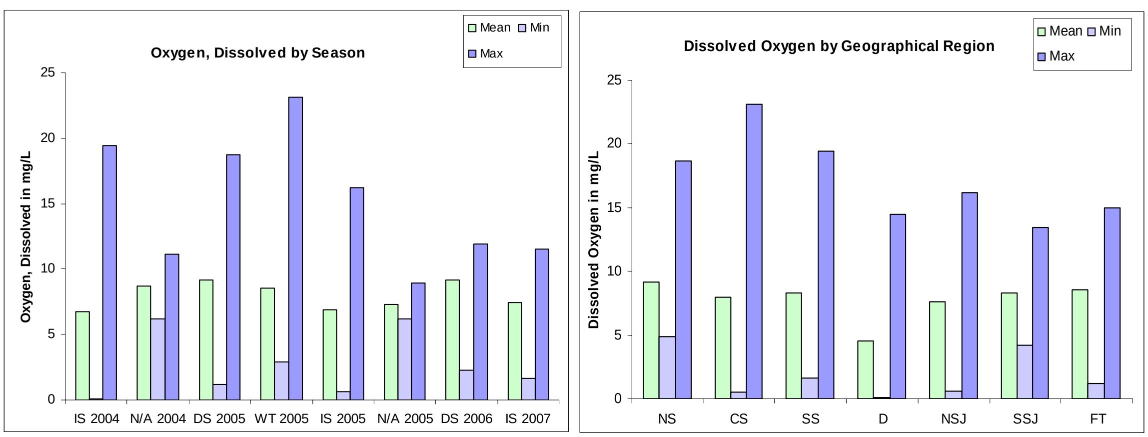
FIELD PARAMETERS

Water quality parameters were measured at the time of each sample collection. Figures 1-4 illustrate dissolved oxygen (DO), pH, specific conductivity (SC) and water temperature categorized by sampling season and geographical region.

Mean dissolved oxygen concentrations ranged from 6.75-9.17 mg/L across all seasons and geographical regions with the exception of the Delta region, which had a significantly lower mean concentration of 4.57 mg/L (Figure 1).

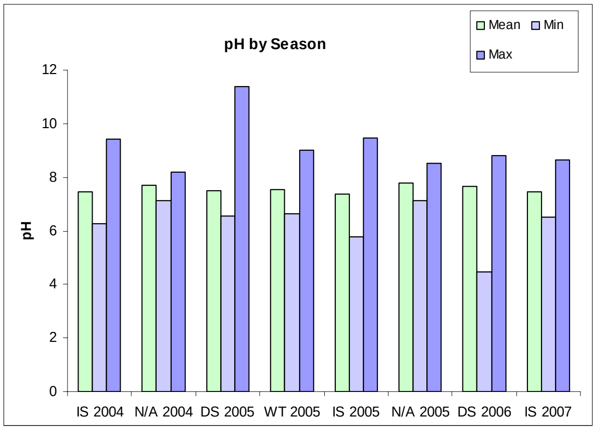
IS 2004, DS 2005, WT 2005 and IS 2005 had higher maximum DO concentrations with a peak of 23.10 mg/L for WT 2005 in the Central Sacramento region. DO maximum concentrations were lowest for the split sampling events (NA 2004 and 2005) and for the years 2006 and 2007. The lowest DO value was in the Delta region during the 2004 irrigation season at 0.10 mg/L. All minimum DO concentrations across seasons and regions were below the Water Quality Trigger Limit (WQTL) of 7 mg/L.

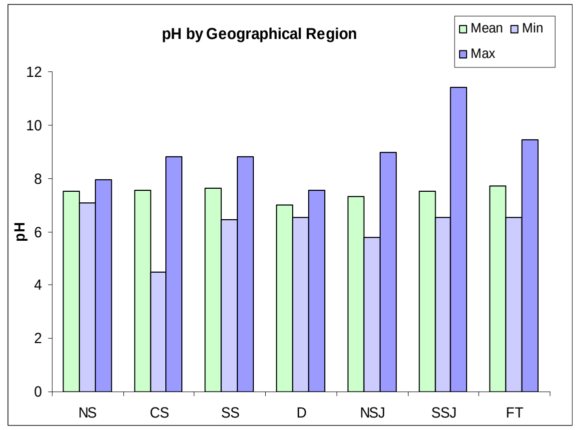
Figure 1. Dissolved oxygen mean, minimum, and maximum concentrations by season and region.



The mean seasonal pH ranged from 7.36 to 7.79 with the regional mean varying between 7.00 and 7.70. The maximum pH was 11.40 at Berenda Creek in January 2005. All seasonal maximum values except NA 2004 were above the WQTL of 8.5, as were five of the seven geographic maximums. Maximum pH for the North Sacramento and Delta regions was < pH 8.5. Minimum pH values fell below the WQTL of pH 6.5 in three regions and during three seasons: 6.28 during IS 2004 in the Central Sacramento region; 5.78 during IS 2005 in the North San Joaquin region; 4.48 and 6.44 during DS 2006 in Central Sacramento and South Sacramento regions, respectively (Figure 2).

Figure 2. pH mean, minimum, and maximum values by season and region.

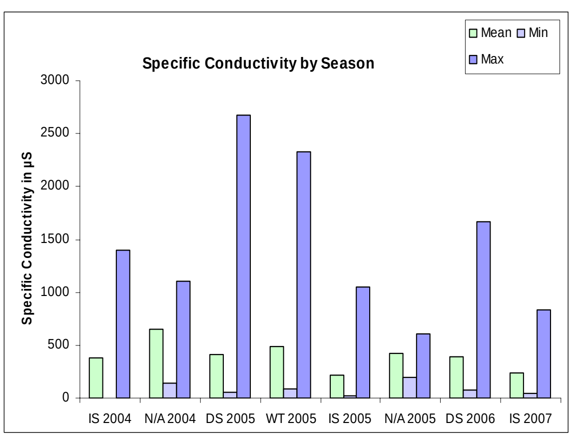


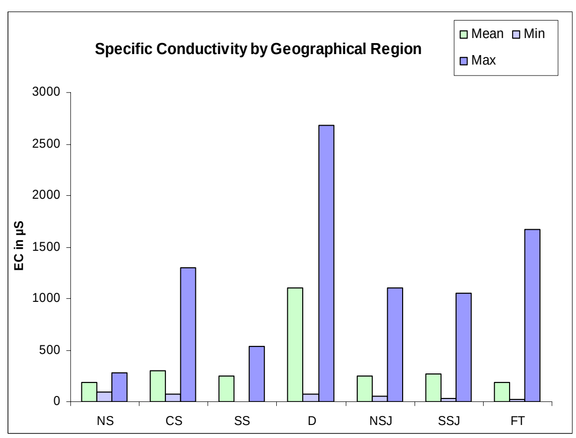


Mean specific conductivity was between 180.9-649.5 µS/cm for all sampling seasons and regions with the exception of the Delta region where the mean specific conductivity was 1099 µS/cm (Figure 3). The highest seasonal values were DS 2005 and WT 2005 with 2680 µS/cm and 2330 µS/cm, respectively.

The highest regional specific conductance value was 2680 µS/cm at SS05 in the Delta region. In general, the highest EC values were recorded during storm seasons. Twelve of fifteen maximum values exceeded the WQTL of 700 µS/cm. During the NA 2005 season all of the NS and SS sites had specific conductivity readings below 700 µS/cm. Minimum values ranged from 3.0 to 197.8 µS/cm (Figure 3).

Figure 3. Specific Conductivity mean, minimum, and maximum values by season and region.

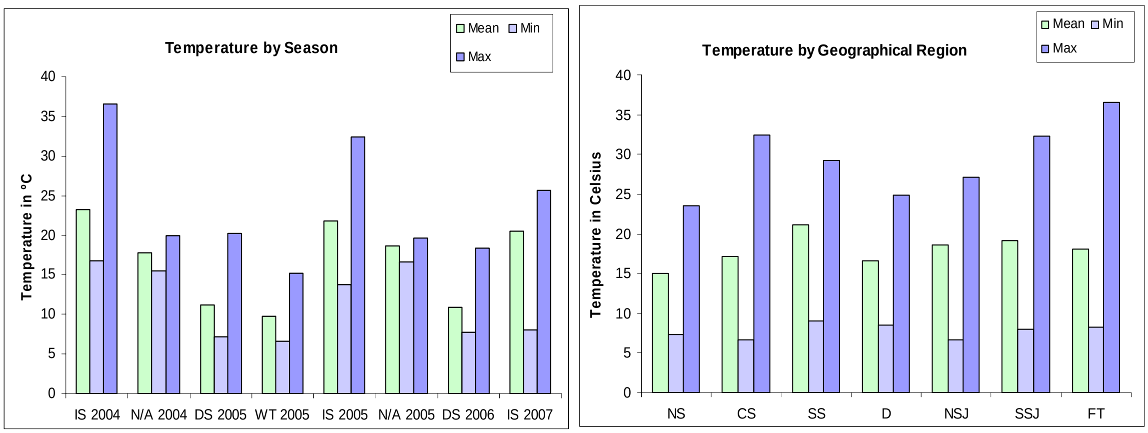




Mean water temperature ranged from 15 ºC in the North Sacramento region to 21.1 ºC in the South Sacramento region (Figure 4). The highest temperatures were found during IS 2004 in Fresno-Tulare region with 36.5ºC and during IS 2005 in the Central Sacramento region with 32.4ºC. The lowest seasonal temperature was 7.1ºC during DS

2005 while the Central Sacramento region had the lowest regional water temperature of 6.6 ºC.

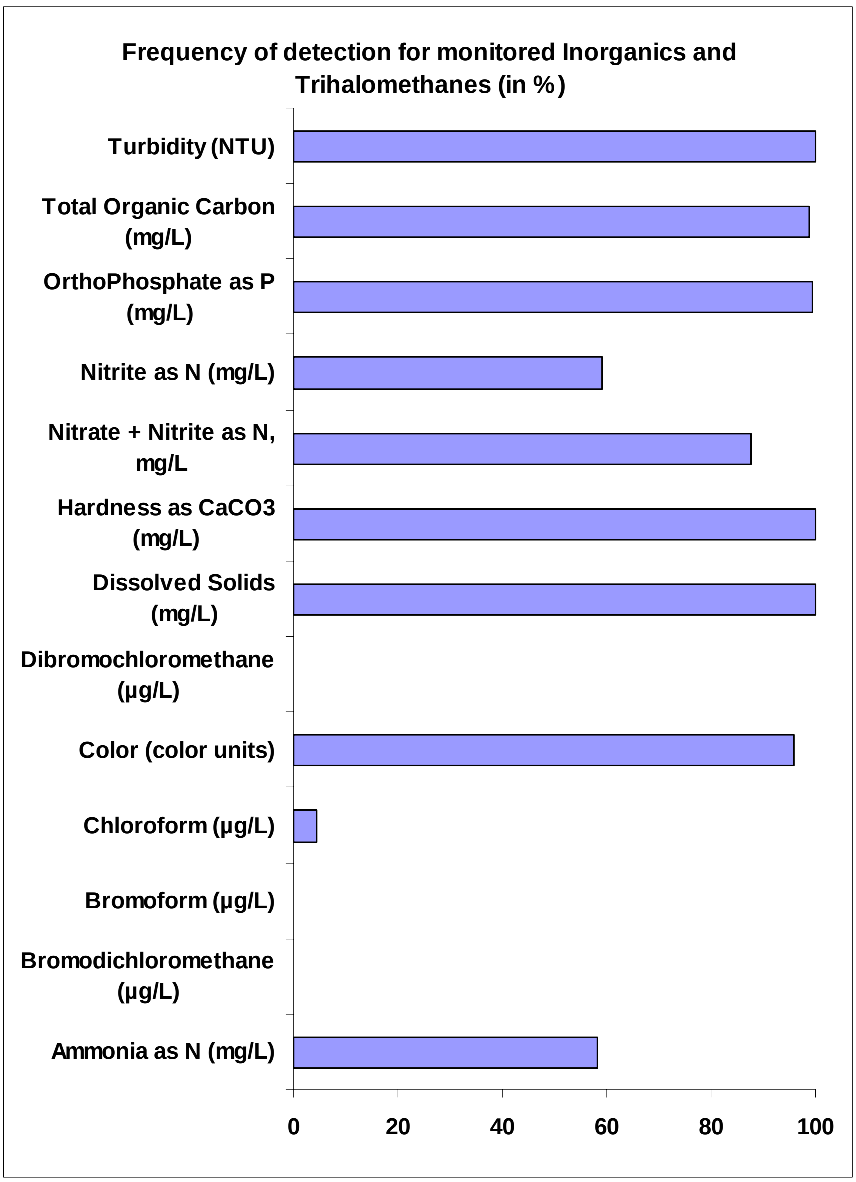
Figure 4. Mean, minimum, and maximums temperature by season and region.



Inorganics and trihalomethanes

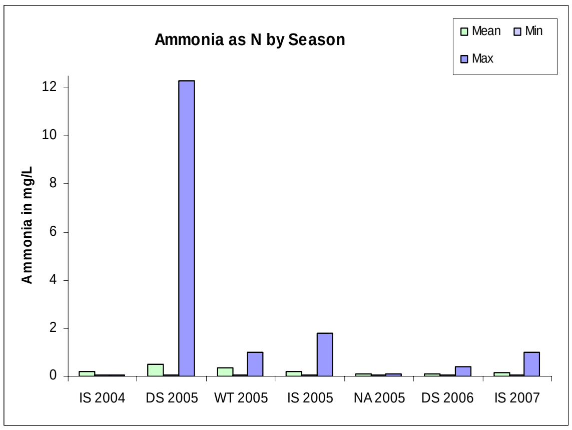
In this group of analytes the following constituents were monitored for: Ammonia as N, bromodichloromethane, bromoform, chloroform, color, dibromochloromethane, dissolved solids, hardness as $CaCO_3$, nitrate + nitrite as N, nitrite as N, orthophosphate as P, total organic carbon and turbidity. The trihalomethanes (bromodichloromethane, bromoform, chloroform and dibromochloromethane) were only monitored during the Irrigation Season 2004. Bromodichloromethane, bromoform and dibromochloromethane were never detected and are not referenced in the section below. Figure 5 provides the frequency of detection for all monitored inorganics and trihalomethanes.

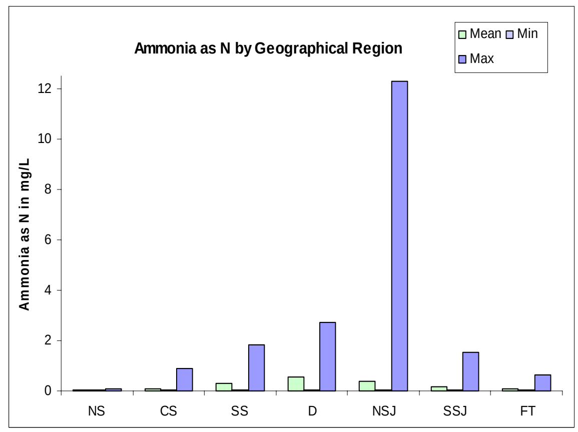
Figure 5. Frequency of detection for inorganics and trihalomethanes (percentage of total samples).



Ammonia was detected in 58% of samples (Figure 5). Average ammonia concentrations ranged between 0.06-0.57 mg/L. The highest concentration, 12.30 mg/L occurred during DS 2005 in the North San Joaquin region. The water quality trigger limit of 1.5 mg/L was exceeded 35 times with most exceedances occurring during IS 2005 in the SS, D and SSJ regions. The minimum concentrations for all seasons and regions were ≤ 0.05 mg/L (Figure 6).

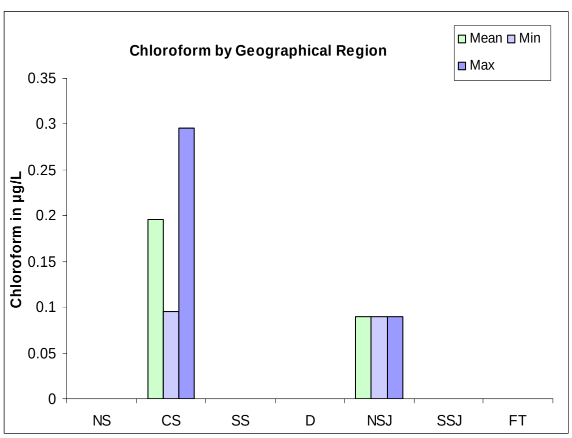
Figure 6. Ammonia as N mean, minimum, and maximum concentrations by season and region.





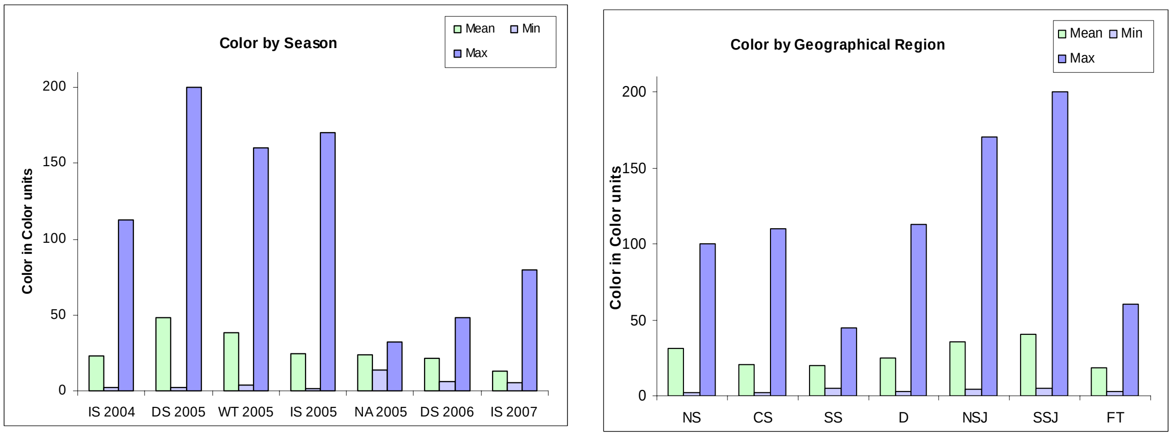
Chloroform was only monitored during the Irrigation Season 2004 and was found in 4% of samples and only in the Central Sacramento and North San Joaquin regions (Figure 7). Bromodichloromethane, bromoform and dibromochloromethane were not detected.

Figure 7. Chloroform concentration by region.



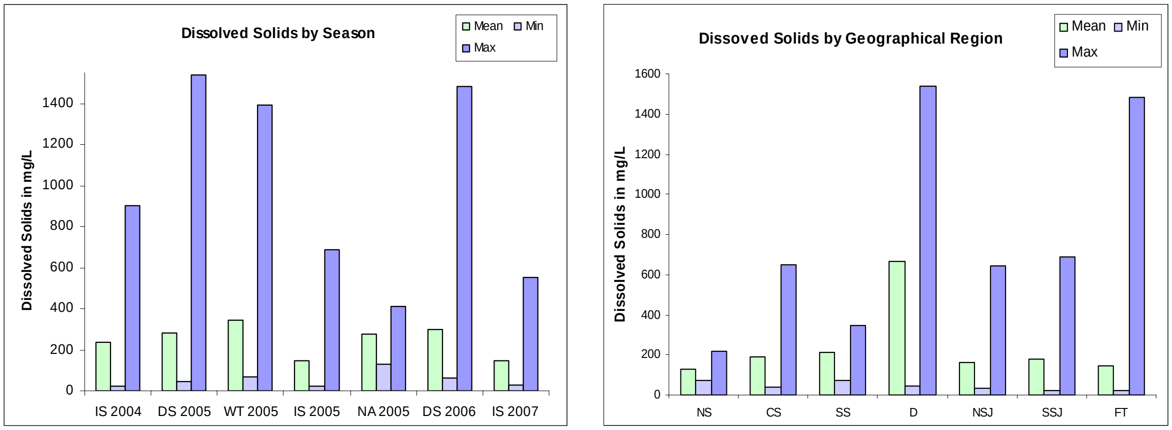
Color was present in 96% of the samples. Seasonal and regional means ranged between 12.93-48.18 color units (Figure 8). DS 2005 had the highest seasonal average with 48.18 color units. SSJ had the highest regional average with 40.17 color units. The peak maximum value was 200 color units and was recorded during DS 2005 in South San Joaquin region. The South Sacramento and Fresno-Tulare regions had lower maximum concentrations than all other regions. Minimum concentrations ranged between 1.9 and 6 color units with the exception of NA 2005, which had a value of 14 color units.

Figure 8. Mean, minimum, and maximum color by season and region.



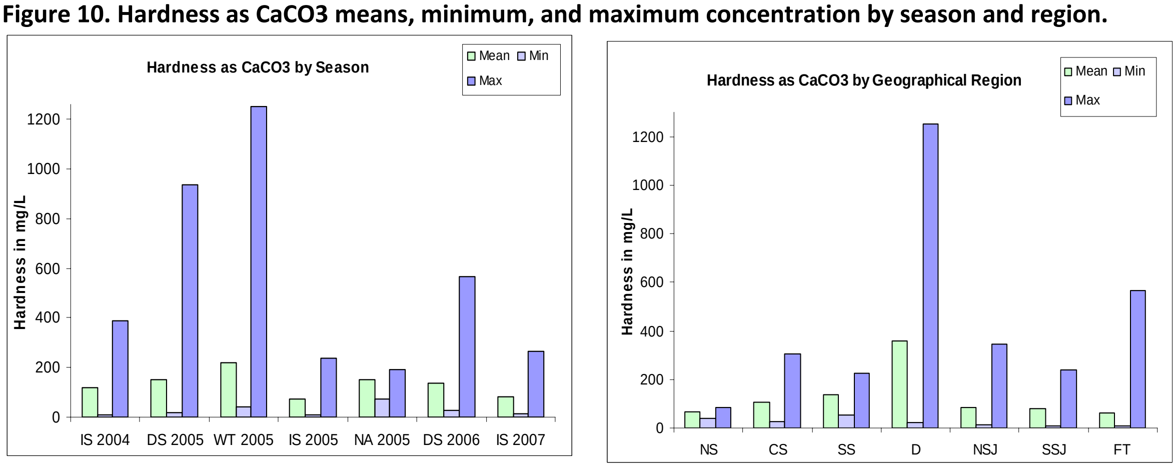
Dissolved solids were detected in every sample. Mean concentrations across both region and season ranged from 129.23-344.71 mg/L with the exception of the Delta region where the average concentration was 663.14 mg/L (Figure 9). All seasons except NA 2005 had maximum concentrations greater than the WQTL of 450 mg/L. The three highest seasonal maximum concentrations occurred during DS 2005, WT 2005 and DS 2006 (1540, 1390 and 1480 mg/L, respectively). The NS and SS regions had maximum concentrations below 450 mg/L, while all other regions had maximum concentrations exceeding the WQTL. The highest regional maximum concentrations were in the Delta and FT regions with values of 1540 and 1480 mg/L, respectively. Minimum concentrations ranged between 20 and 130 mg/L.

Figure 9. Dissolved Solid mean, minimum, and maximum concentration by season and region.



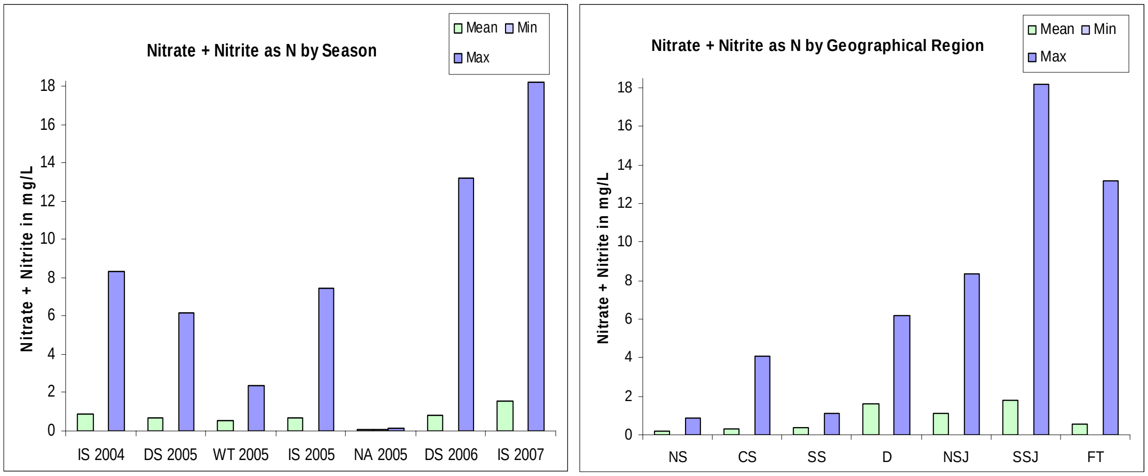
Hardness as $CaCO_3$ was detected in every sample. Mean hardness for season and region ranged from 62.03-220.20 mg/L, except the Delta region which averaged 357.26 mg/L (Figure 10). The Delta region also had the highest regional maximum of 1250 mg/L, which was recorded during WT 2005. The highest maximum concentration (936 mg/L) occurred during DS 2005. Minimum hardness ranged between 8-74.4 mg/L.

Figure 10. Hardness as CaCO3 means, minimum, and maximum concentration by season and region.



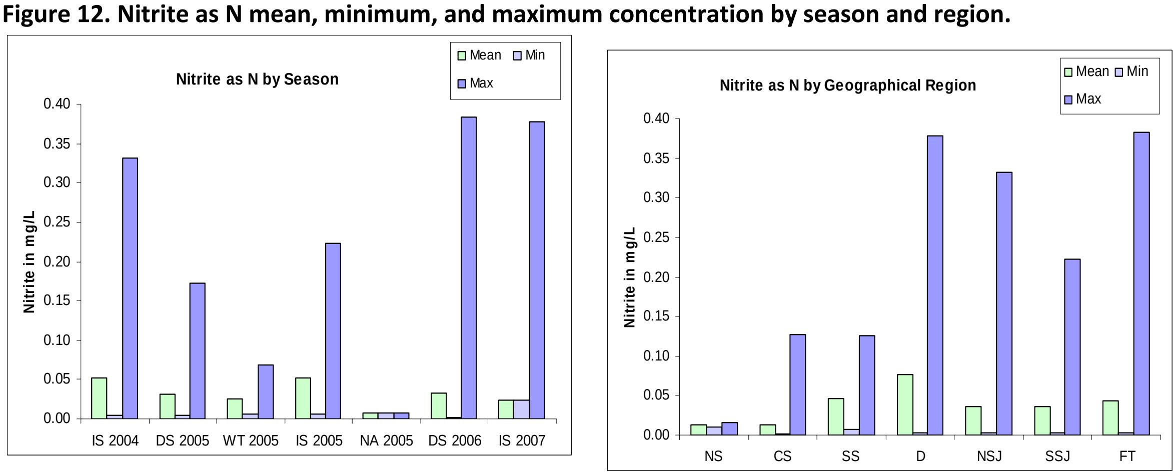
Nitrite + nitrate as N were detected in 88% of samples. Mean seasonal and regional concentrations ranged between 0.09 and 1.78 mg/L (Figure 11). The highest maximum concentrations occurred during DS 2006 (13.20 mg/L) and IS 2007 (18.20 mg/L) in the SSJ and FT regions, respectively. Minimum concentrations during all seasons and regions were below 0.08 mg/L.

Figure 11. Nitrate + Nitrite means, minimum, and maximum concentrations by season and region.



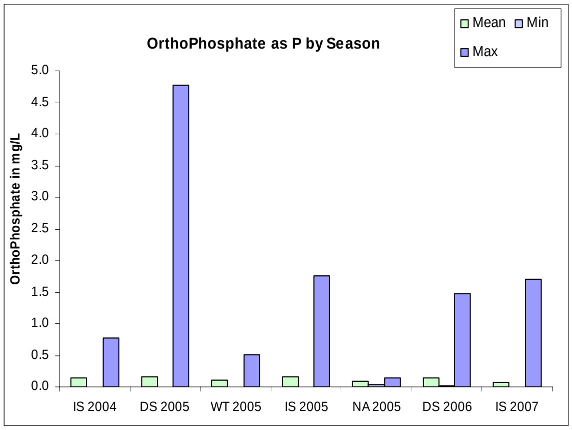
Nitrite as N was present in 59% of samples. Average nitrite as N for both season and region were between 0.01 and 0.08 mg/L (Figure 12). Seasonal maximums were highest during DS 2006 at 0.383 mg/L in the Fresno-Tulare region. The Delta and regions to the south had significantly higher maximum concentrations compared to more northern regions. Seasonal and regional nitrite as N minimum detections were ≤ 0.02 mg/L. All concentrations were below the WQTL of 1 mg/L.

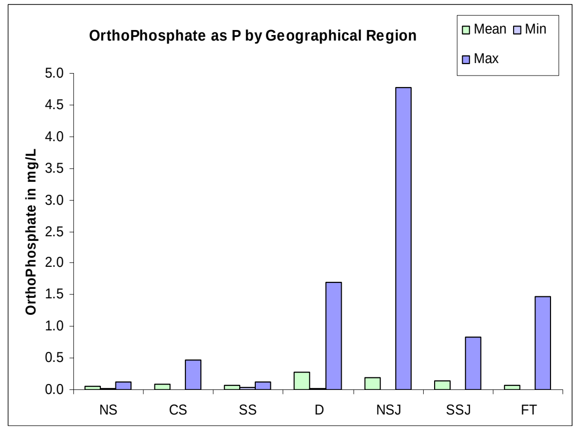
Figure 12. Nitrite as N mean, minimum, and maximum concentration by season and region.



Ninety-nine percent of the water samples contained orthophosphate as P. Mean orthophosphate concentrations for season and region ranged between 0.05 and 0.28 mg/L (Figure13). The highest maximum concentration, 4.78 mg/L, was found during DS 2005 in the North San Joaquin region. Minimum concentrations were between 0.01-0.03 mg/L.

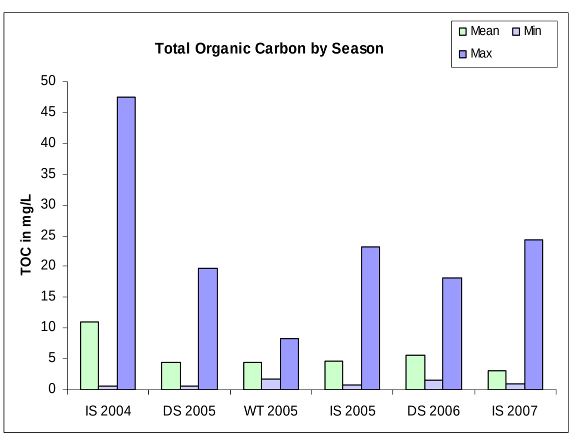
Figure 13. Orthophosphate as P mean, minimum, and maximum concentrations by season and region.

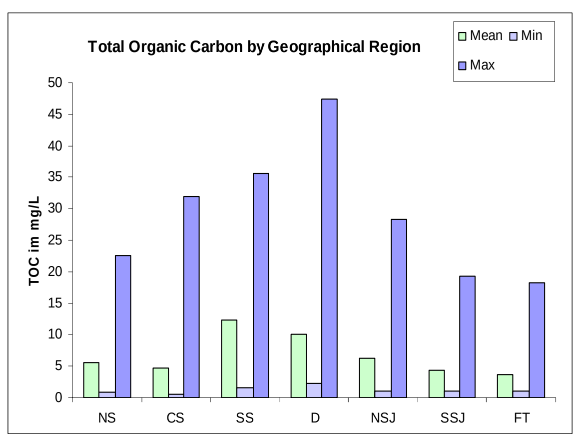




Total organic carbon (TOC) was detected in 99% of the collected samples. Mean seasonal concentrations varied between 3.12-5.56 mg/L except during IS 2004 when the average concentration was 11.05 mg/L (Figure 14). Average TOC values for the South Sacramento and Delta regions were 12.34 mg/L in SS and 10.10 mg/L, respectively. All other regions averaged between 3.65-6.22 mg/L. The highest seasonal maximum concentration of 47.46 mg/L was recorded during IS 2004 and was nearly double the maximum concentration found in any other season. Regional maximum TOC concentrations were all above 18.20 mg/L; the highest concentration was in the Delta. The minimum concentrations ranged between 0.6-2.20 mg/L.

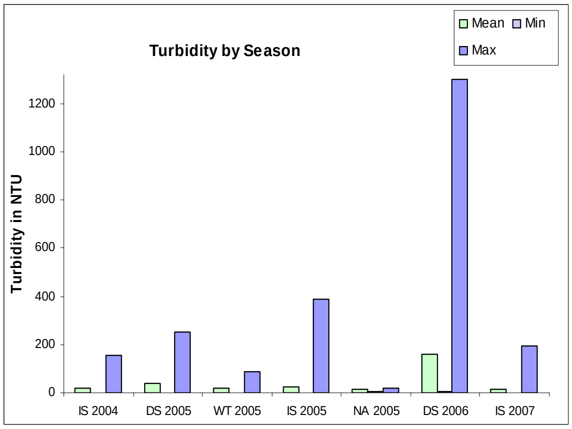
Figure 14. Total Organic Carbon mean, minimum, and maximum concentration by season and region.

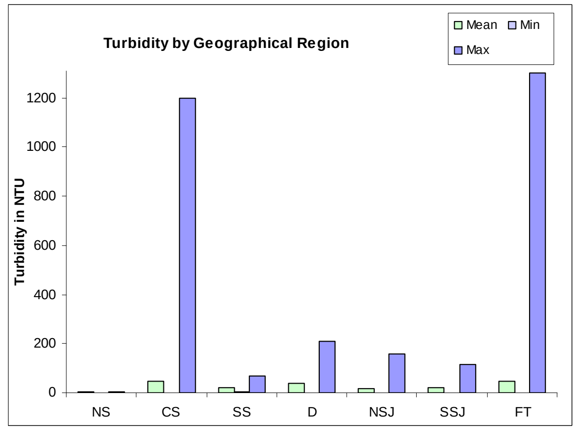




Some turbidity was measured in every water sample. Mean turbidity for all seasons and regions were below 50 nephelometric turbidity units (NTU) except for during DS 2006 where the average was 160.26 NTU; four times higher than the next closest season (Figure 15). The two highest maximum values, 1300 and 1200 NTU, were recorded during DS 2006 in the Fresno-Tulare and Central Sacramento regions, respectively. Turbidity minimum values ranged between 0.65-6.5 NTU's.

Figure 15. Mean, minimum, and maximum turbidity by season and region.





ORGANICS

Pesticide characteristics are important in determining the fate of the chemical in the environment. These characteristics include

- solubility in water (water solubility)
- tendency to bind to the organic material (K_{oc})
- persistence in the environment (half-life)

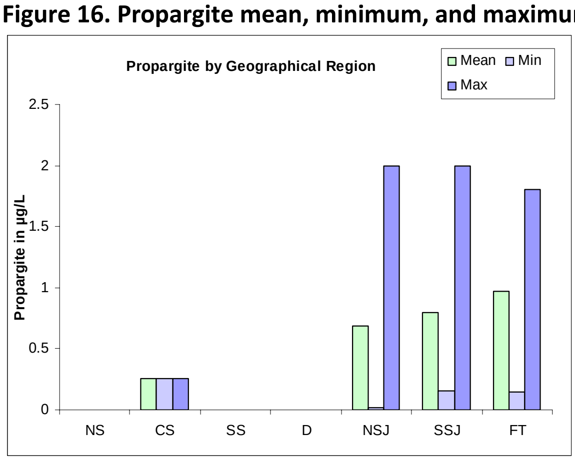
These three factors are commonly used to rate pesticides for their potential to leach or move with surface runoff after application. Pesticides with high water solubility, low tendency to adsorb to soil particles and long half-life have the highest potential to move into water.

Although physical properties vary by pesticide group (organophosphate, organochlorine, carbamate, pyrethroids, and herbicides), tendencies can be determined based on the solubility and the K_{oc} value. In general, organochlorine and pyrethroid pesticides tend to have high K_{oc} and low solubility, which makes them difficult to detect in water. Organophosphate, carbamate pesticides, and some herbicides have the opposite tendency and tend to partition to the water column.

ACARACIDES

Samples for propargite were collected only during the IS 2005. The detection frequency was 8%. Mean concentrations were between 0.256 and 0.975 µg/L (Figure 16). The highest concentration (2 µg/L) was found in two regions, NSJ and SSJ. Propargite was found in four of seven regions.

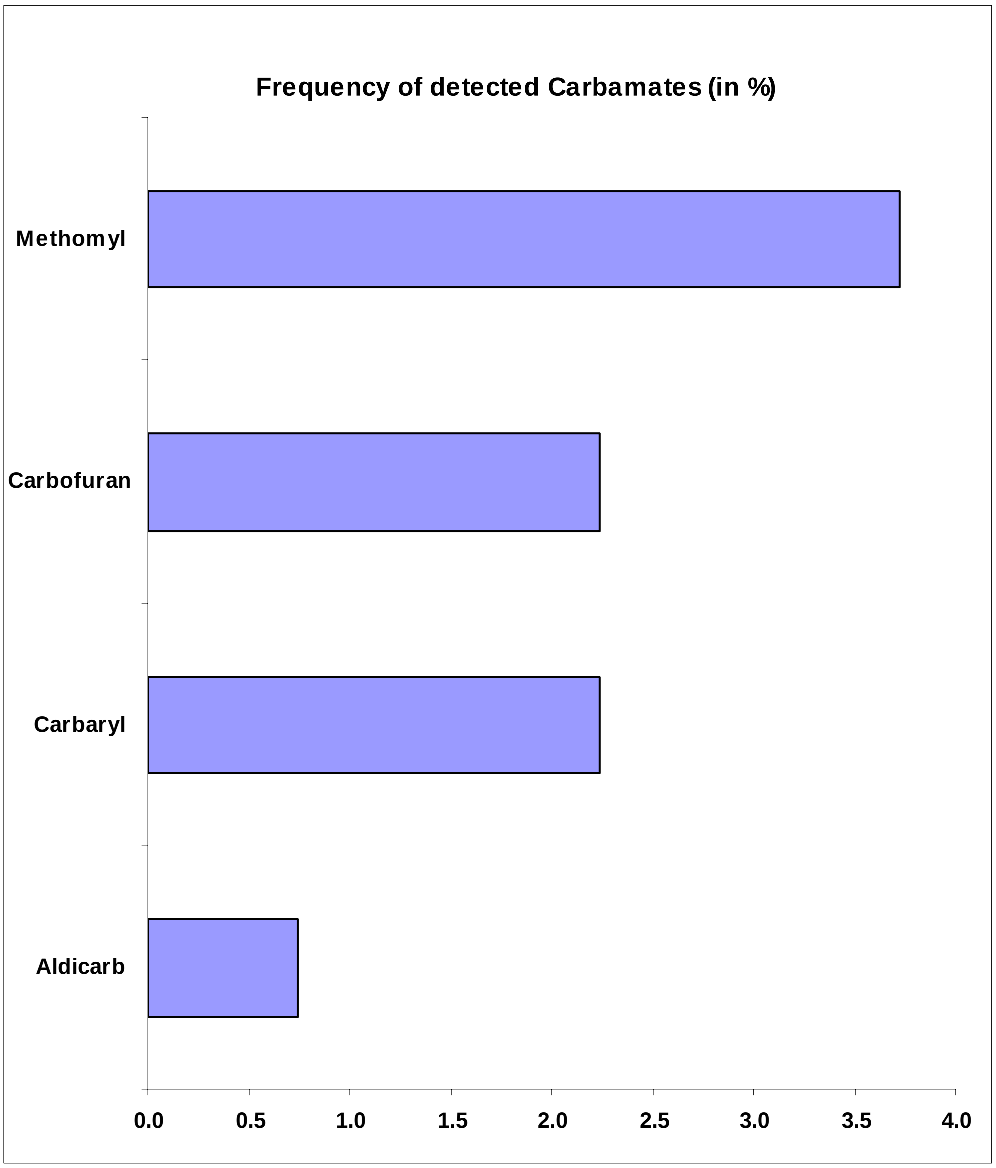
Figure 16. Propargite mean, minimum, and maximum concentrations by region.



CARBAMATE PESTICIDES (Carbamates)

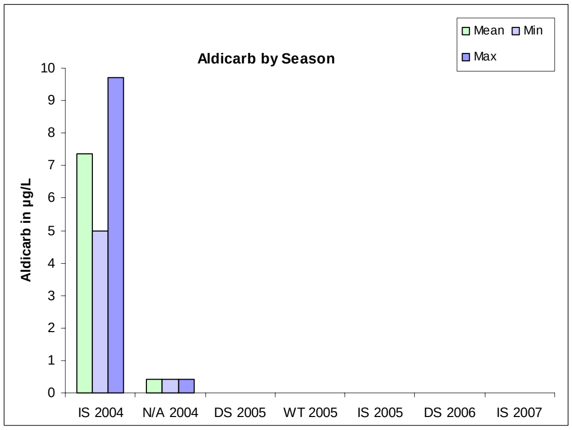
The analyzed suite of carbamates included aldicarb, carbaryl, carbofuran, methiocarb and methomyl. Methiocarb was never detected. The frequencies for the detected analytes ranged between 0.7 – 3.7% across regions and seasons (Figure 17).

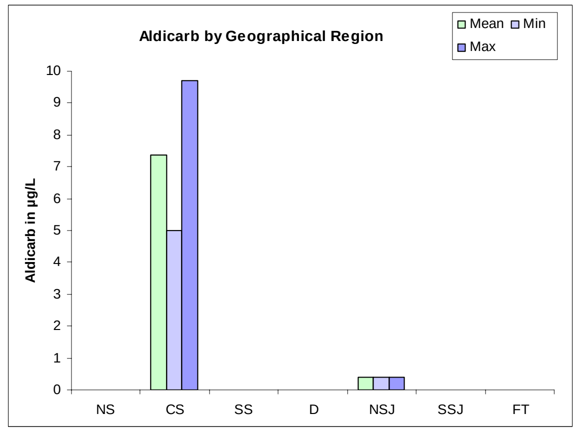
Figure 17. Frequency of detected carbamate pesticides (percentage of total samples).



Aldicarb was detected only during IS 2004 in CS and NA 2004 in NSJ (Figure 18). CS mean, minimum and maximum concentrations were above the Water Quality Trigger Limit (WQTL) of 3 µg/L. NSJ showed very low detections.

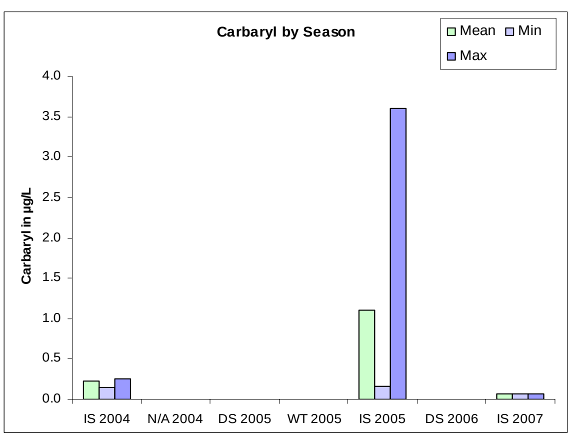
Figure 18. Aldicarb mean, minimum, and maximum concentrations by region.

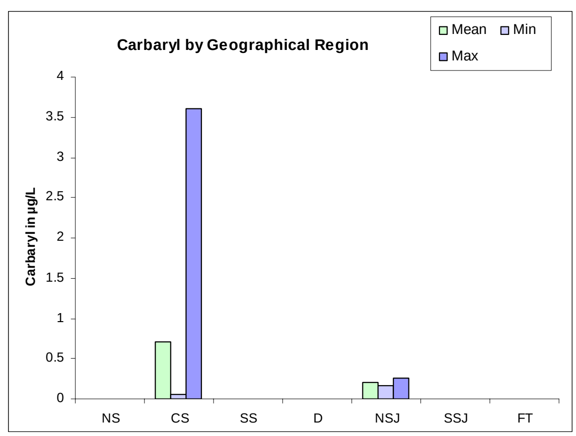




The detection frequency of carbaryl was 2.2%. Carbaryl was only found during the irrigation seasons, with a maximum concentration of 3.6 µg/L in CS during IS 2005 (Figure 19). The WQTL for carbaryl is 2.53 µg/L. Mean seasonal and regional concentrations were below 1.01 µg/L. Carbaryl was detected in the NSJ, but not in any other region.

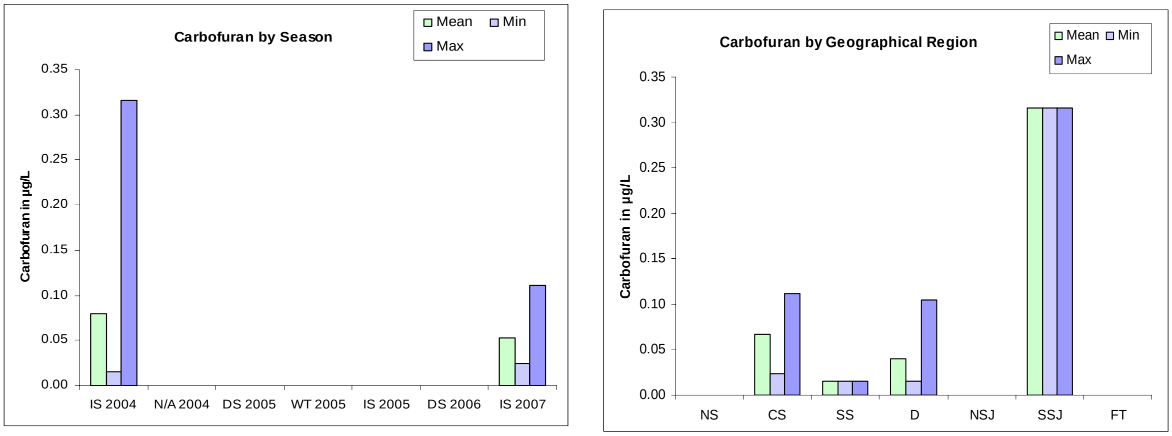
Figure 19. Carbaryl mean, minimum, and maximum concentrations by region.





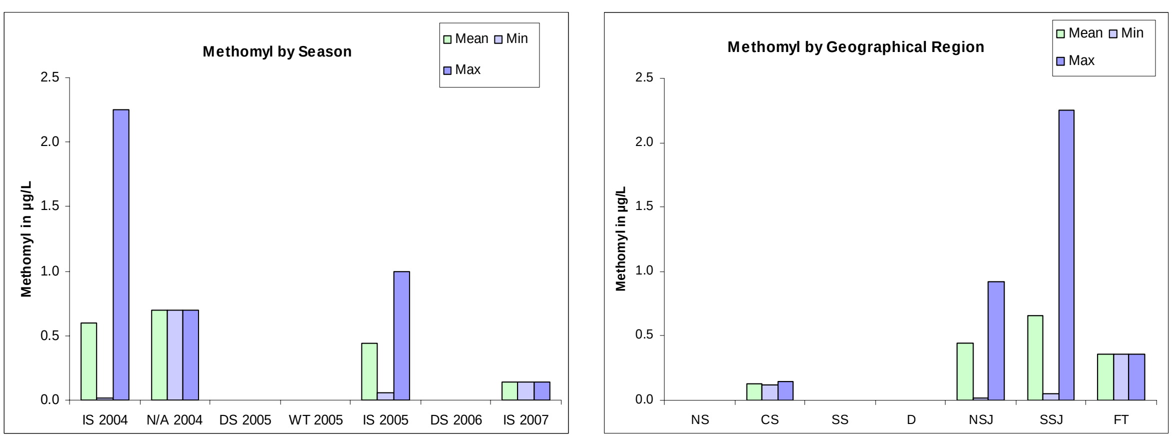
Carbofuran was found in 2.2% of all water samples, but only during IS 2004 and IS 2007. The maximum concentration (0.316 µg/L) was seen during IS 2004 in the SSJ (Figure 20). The CS, SS and D also had detections with maximum concentrations of 0.11 µ/L or lower. The WQTL for carbofuran is “ND” (= Non Detect) as carbofuran is a prohibited discharge pesticide.

Figure 20. Carbofuran mean, minimum, and maximum concentrations by region.



Methomyl was detected with a frequency of 3.7% and found during all irrigation seasons and NA 2004. The highest maximum concentration (2.25 µg/L) was seen during IS 2004 and in the SSJ (Figure 21). NA 2004 had the highest seasonal average concentration of 0.695 µg/L and SSJ showed the highest regional average concentration of 0.657 µg/L. Both of those concentrations and the mean of 0.595 µg/L in IS 2004 were above the WQTL of 0.52 µg/L for methomyl.

Figure 21. Methomyl mean, minimum, and maximum concentrations by region.



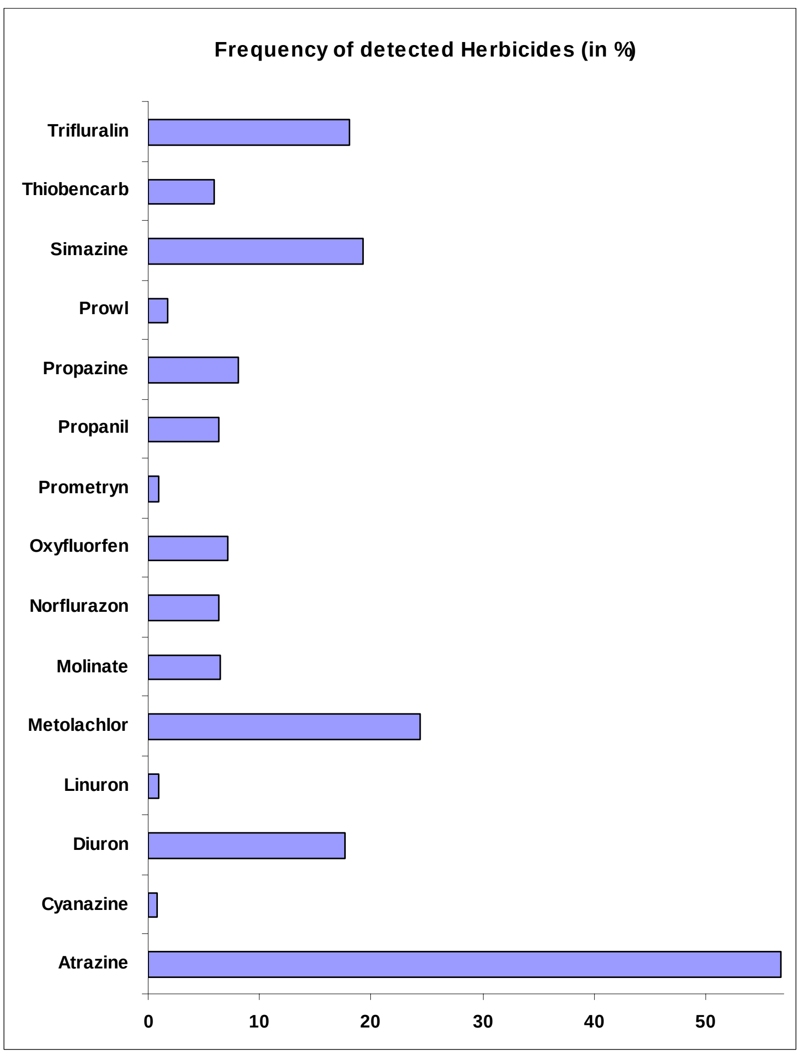
Fungicides

Captan was the only fungicide for which analyses were conducted. It was never detected.

Herbicides

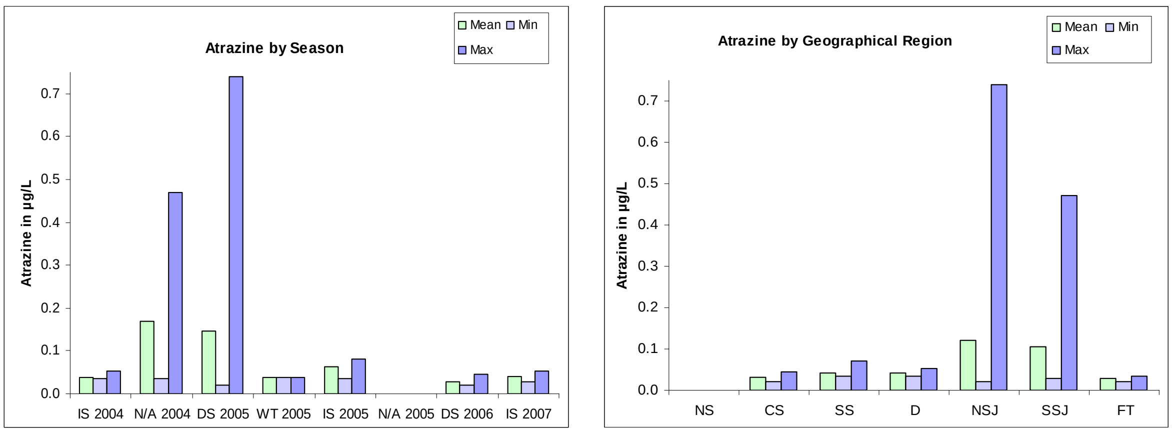
The suite of herbicides included alachlor, ametryn, atraton, atrazine, cyanazine, diuron, linuron, metolachlor, molinate, norflurazon, oxyfluorfen, prometon, prometryn, propanil, propazine, prowl (pendamethalin), secbumeton, simazine, simetryn, terbutylazine, terbutryn, thiobencarb and trifluralin. Fifteen of 23 herbicides were detected between 2004 and 2007. The presentation of the results will focus on atrazine, diuron, metolachlor, molinate, simazine, thiobencarb and trifluralin. Individual herbicide detection frequencies ranged between 1 and 57% (Figure 22).

Figure 22. Frequency of detected herbicides (percentage of total samples)



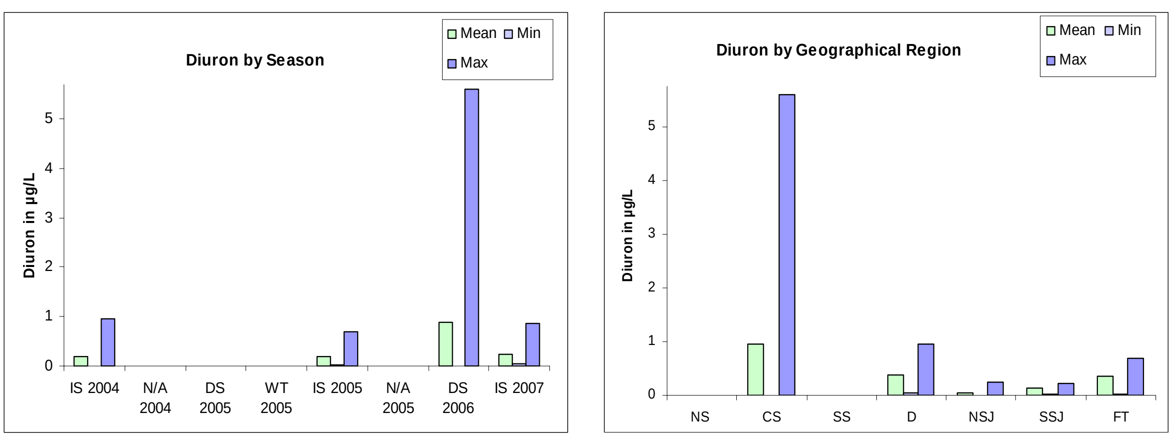
Within the fifteen detected herbicides, atrazine was detected most frequently (Figure 22). Mean seasonal and regional concentrations ranged between 0.027 and 0.170 µg/L (Figure 23). The two highest maximum concentrations (0.74 and 0.47 µg/L) occurred during DS 2005 in the NSJ and during NA 2004 in the SSJ, respectively. All detections were below the WQTL of 1.0 µg/L.

Figure 23. Atrazine mean, minimum, and maximum concentrations by season and region.



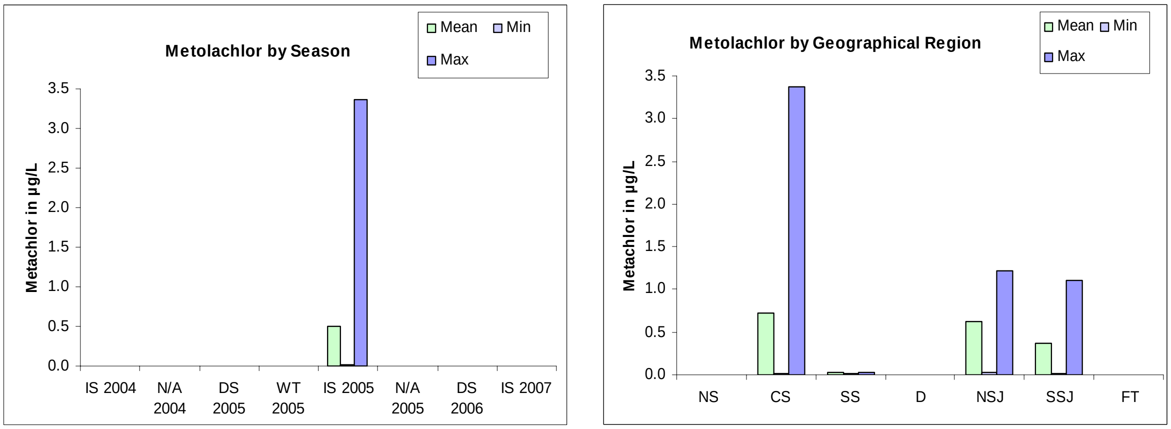
Diuron was found in 18% of all collected water samples during the irritation seasons and DS 2006. The highest maximum concentration occurred during DS 2006 in the CS (5.6 µg/L, Figure 24). All seasonal and regional average concentrations and maximum concentrations were below the WQTL of 2 µg/L.

Figure 24. Diuron mean, minimum, and maximum concentrations by season and region.



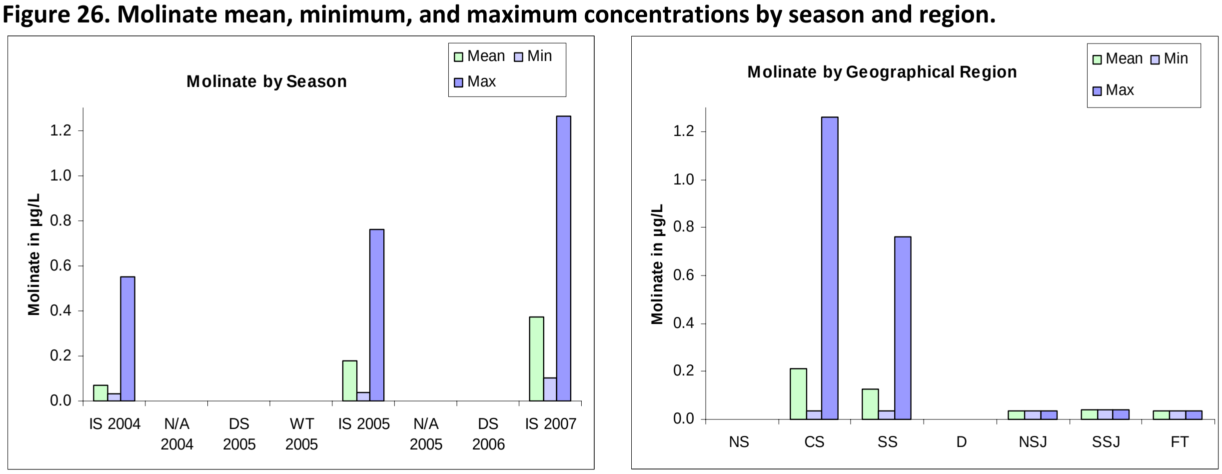
Metolachlor was the second most frequently detected herbicide (24%), but it was only found during IS 2005. The highest maximum value was in CS with 3.37 µg/L (Figure 25). The NSJ and SSJ had similar average concentrations and maximum concentrations, and the SS had very few detections. Metolachlor has no current WQTL.

Figure 25. Metolachlor mean, minimum, and maximum concentrations by season and region.



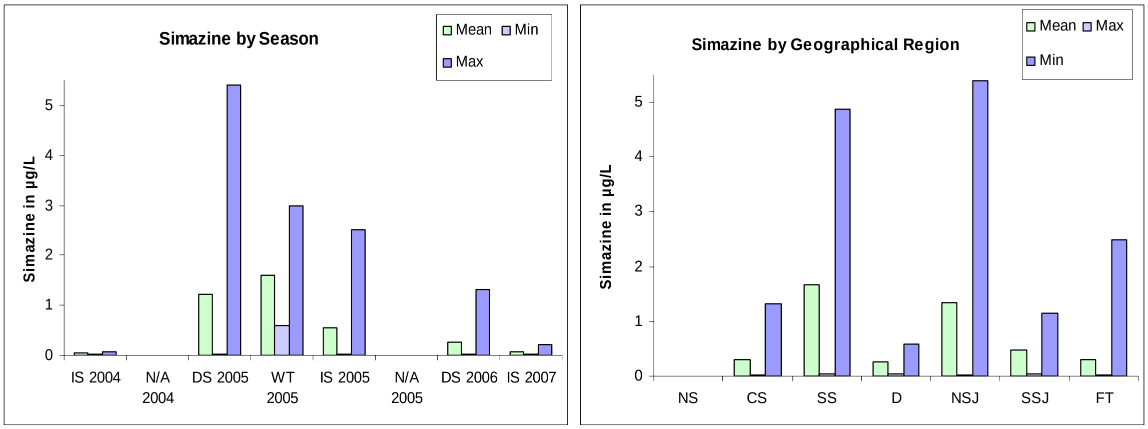
Molinate had a detection frequency of 6%. The analyte was only found during the irrigation seasons with increasing seasonal mean and maximum concentrations over the years. The greatest maximum concentration (1.26 µg/L) occurred during IS 2007 in the CS. The SS had a maximum concentration of 0.76 µg/L during IS 2005. The NSJ, SSJ and FT had few detections. Molinate has a WQTL of “ND” as it is a prohibited discharge pesticide.

Figure 26. Molinate mean, minimum, and maximum concentrations by season and region.



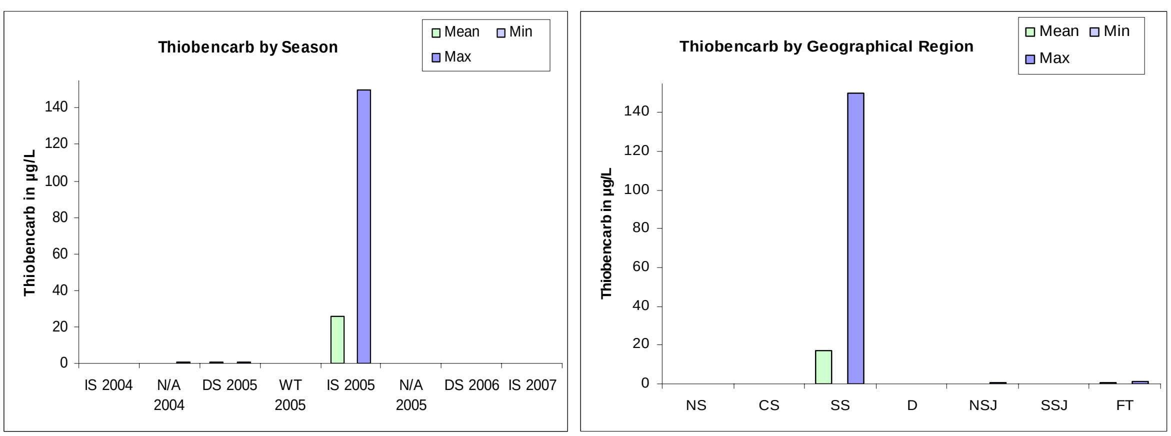
Simazine had a detection frequency of 19%. It was found in all seasons except NA 2004/2005. WT 2005 had the highest seasonal mean concentration of 1.608 µg/L (Figure 27). The SS had the highest regional mean concentration with 1.658 µg/L. The highest concentration (5.4 µg/L) occurred during DS 2005 in NSJ. This concentration as well as the maximum concentration for SS (4.88 µg/L) was above the WQTL of 4.0 µg/L.

Figure 27. Simazine mean, minimum, and maximum concentrations by season and region.



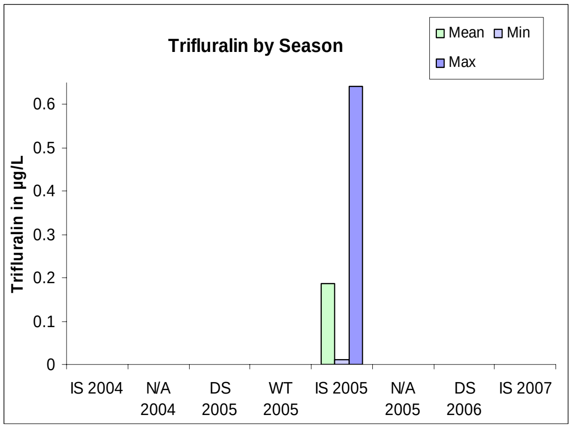
Thiobencarb was found in 6% of all water samples and had the highest concentration during IS 2005 (150 µg/L) in SS (Figure 28). Thiobencarb was also detected during the IS 2004, NA 2004, DS 2005 and IS 2007 and in the CS, NSJ, SSJ and FT, but with very low concentrations. The WQTL for thiobencarb is "ND" because there is a prohibition of discharge for thiobencarb.

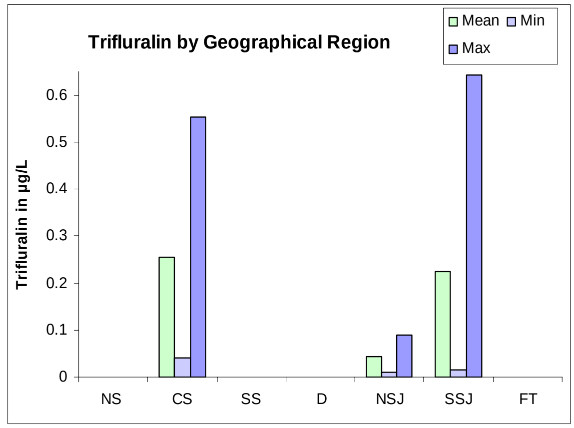
Figure 28. Thiobencarb mean, minimum, and maximum concentrations by season and region.



Eighteen percent of all collected water samples contained trifluralin. It was only detected during the IS 2005 and in three of seven regions (CS, NSJ and SSJ). Mean seasonal and regional concentrations ranged between 0.044 and 0.25 4µg/L (Figure 29). The greatest concentration was found in the SSJ with 0.643 µg/L. The CS had the high maximum concentration of 0.552 µg/L; the NSJ average and maximum concentrations were below 0.09 µg/L. Trifluralin has no current WQTL.

Figure 29. Trifluralin mean, minimum, and maximum concentrations by season and region.

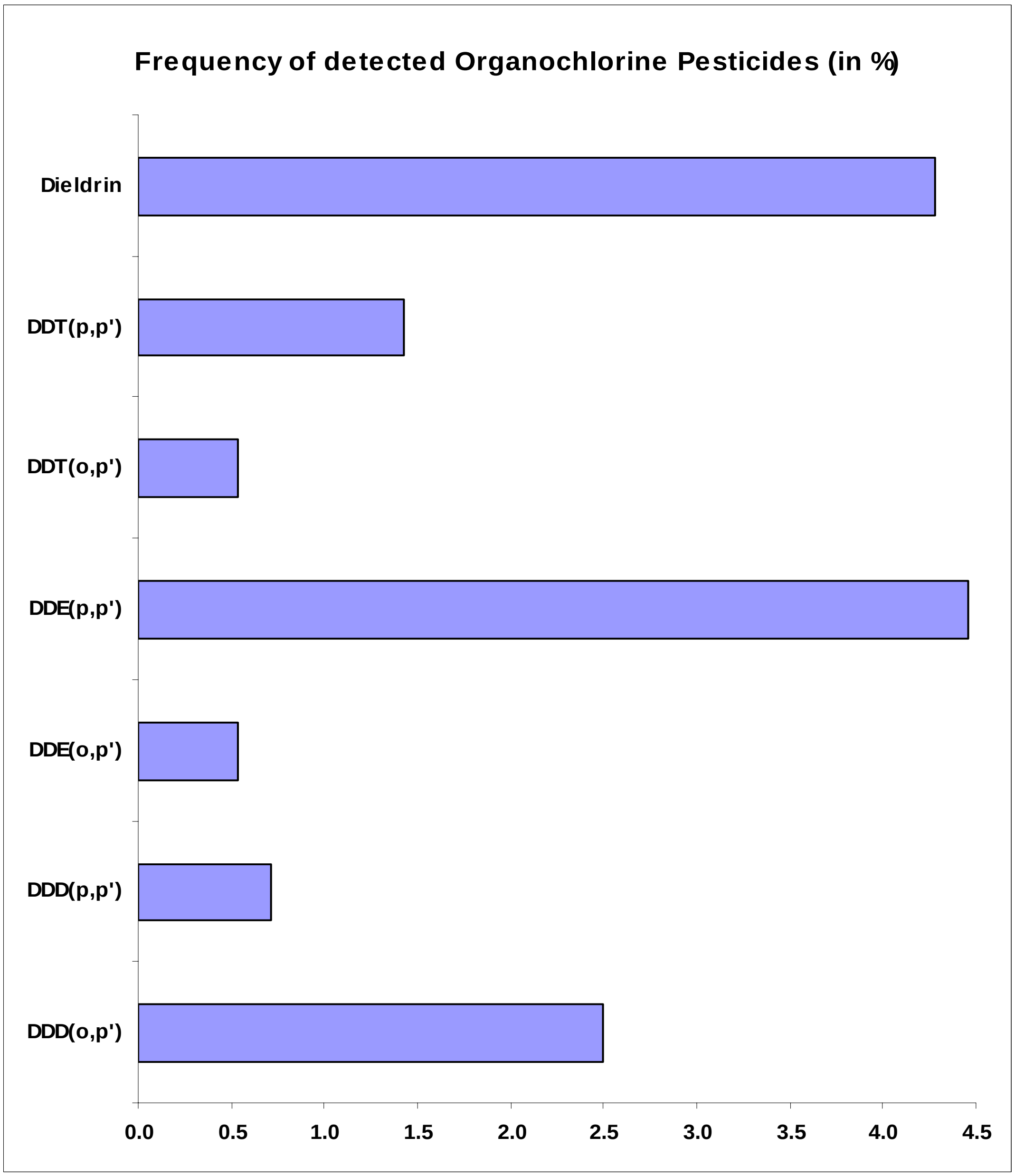




ORGANOCHLORINE PESTICIDES (OCH)

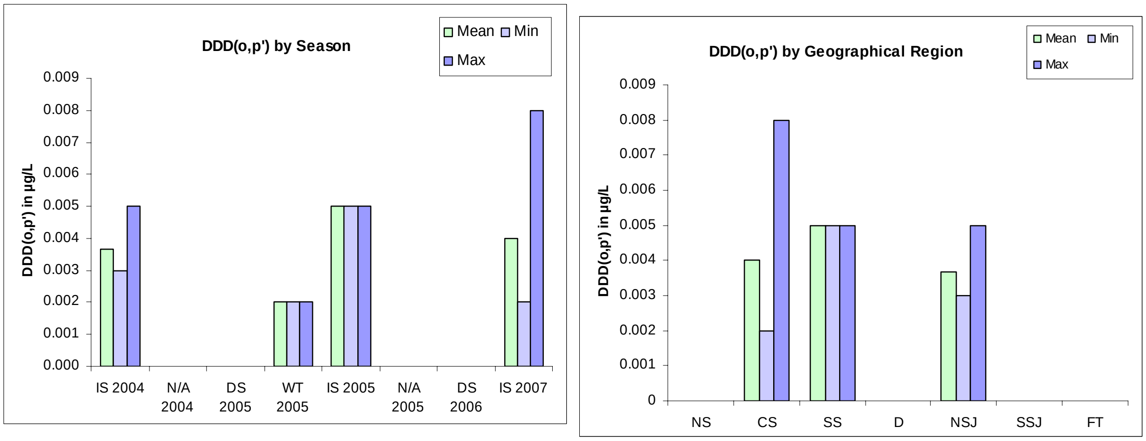
The suite of organochlorines for which analyses were conducted included: DDD, DDE, DDT, dicofol, dieldrin, endrin and methoxychlor. Difocol, endrin and methoxychlor were never detected and are therefore not included in the results below. Detection frequencies ranged between 0.5 and 4.5% (Figure 30).

Figure 30. Frequency of detected organochlorine pesticides (percentage of total samples).



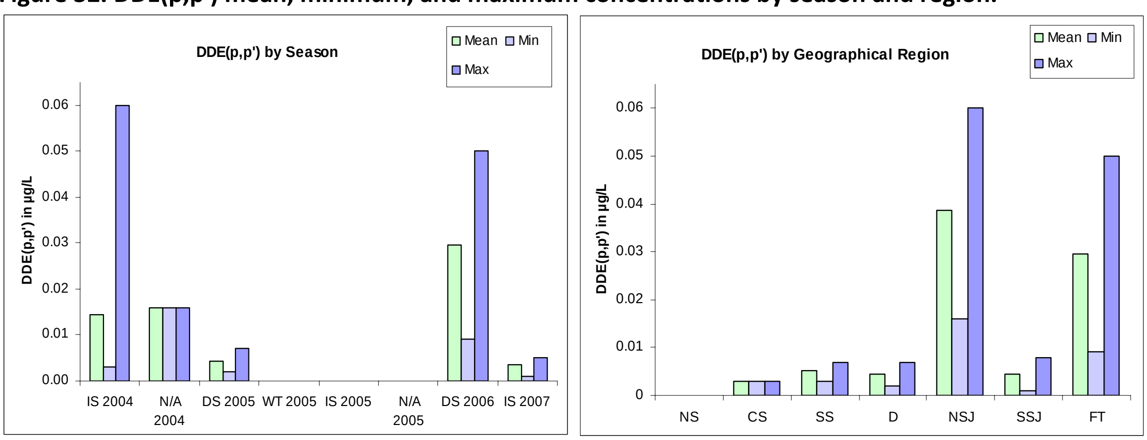
DDD(o,p’) was detected with a frequency of 2.5% during the irrigation seasons and WT 2005. Seasonal and regional mean concentrations were between 0.002 and 0.005 µg/L (Figure 31). The highest concentration was found during the IS 2007 in the CS (0.008 µg/L). The SS and NSJ also had detections of DDD(o,p’). DDD(o,p’) has no current WQTL.

Figure 31. DDD(o,p') mean, minimum, and maximum concentrations by season and region.



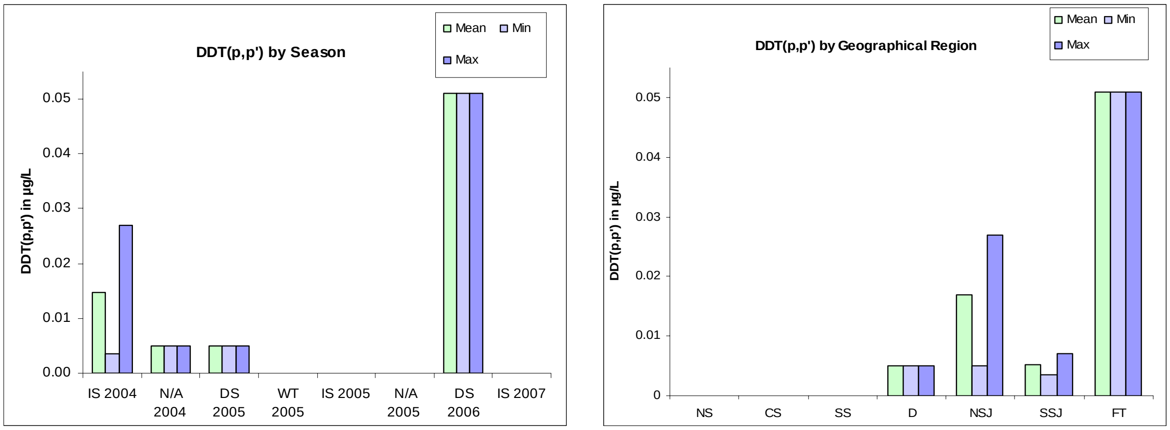
DDE(p,p’) was detected with a frequency of 4.5%. It was found during IS 2004, NA 2004, DS 2005, DS 2006 and IS 2007 and in all regions except NS. All mean, minimum and maximum concentrations were above the WQTL of 0.00059 µg/L (Figure 32). The maximum concentration of 0.06 µg/L occurred during IS 2004 at NSJ. DS 2006 also had an elevated maximum concentration of 0.05 µg/L in the FT area.

Figure 32. DDE(p,p') mean, minimum, and maximum concentrations by season and region.



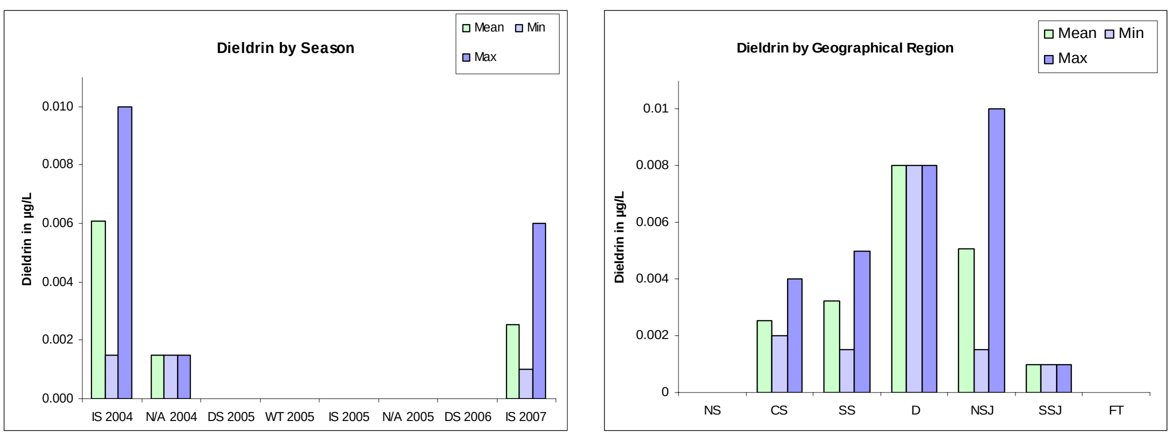
DDT(p,p’) had a detection frequency of 1.4%. It was found during IS 2004, NA 2004, the two dormant seasons and in all regions from the Delta and to the south. All seasonal and regional mean, minimum and maximum concentrations were above the WQTL of 0.00059 µg/L (Figure 33). The highest concentration was found during DS 2006 in the FT area with 0.051 µg/L.

Figure 33. DDT(p,p')mean, minimum, and maximum concentrations by season and region.



Dieldrin was found in 4.3% of all water samples. It was only detected during IS 2004, NA 2004 and IS 2007, but in five of seven regions. The highest dieldrin concentration was found during IS 2004 in NSJ with 0.01 µg/L (Figure 34). The Delta had the second highest concentration of 0.008 µg/L. All seasonal and regional mean, minimum and maximum concentrations were above the WQTL of 0.00014 µg/L.

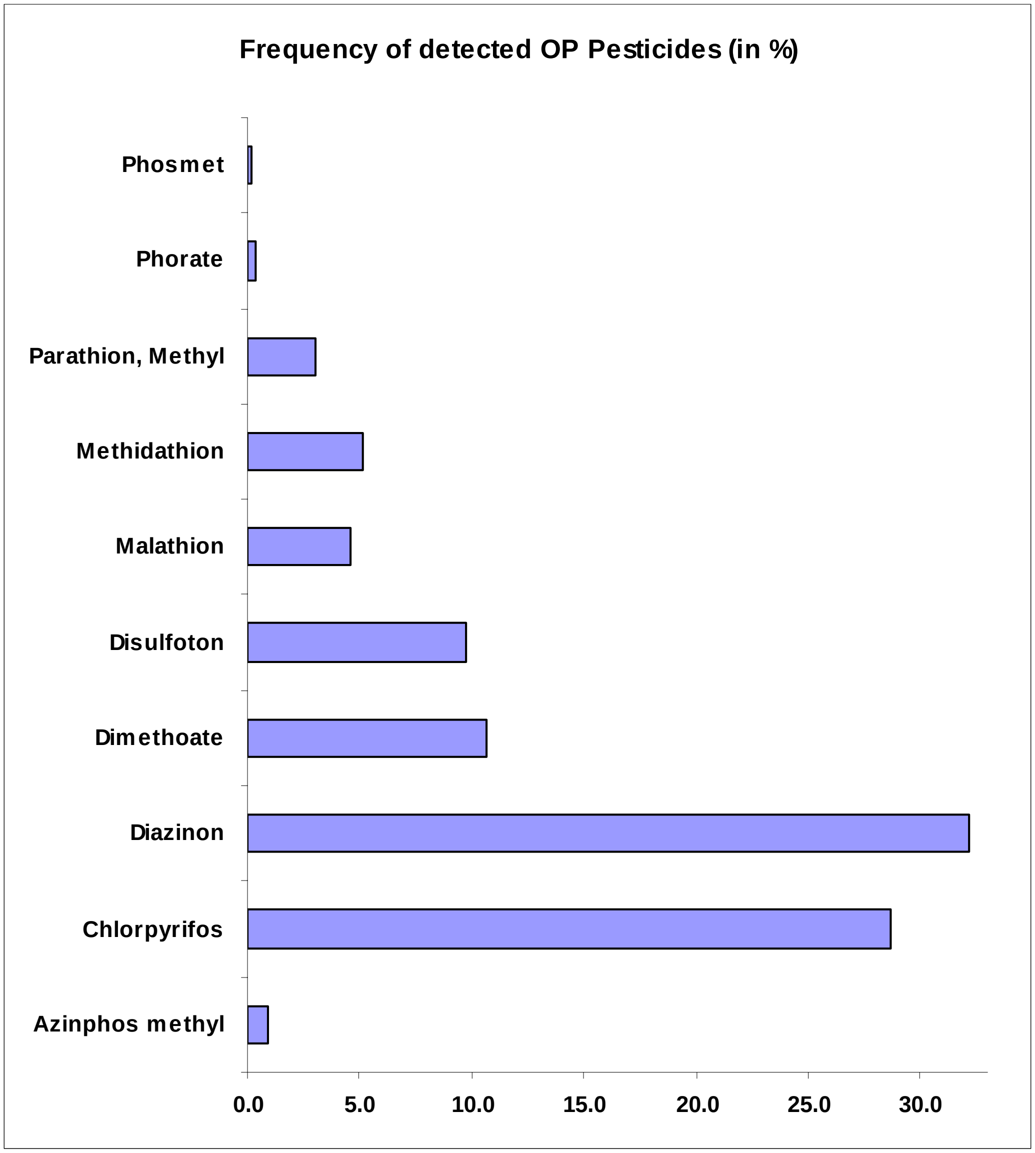
Figure 34. Dieldrin mean, minimum, and maximum concentrations by season and region.



Organophosphate Pesticides (OP)

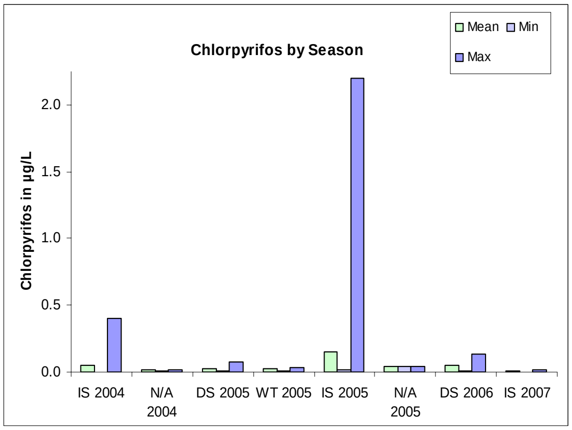
The suite of organophosphates included: azinphos methyl, chlorpyrifos, diazinon, dimethoate, disulfoton, malathion, methidathion, parathion ethyl, parathion methyl, phorate and phosmet. Parathion ethyl was never detected. The results will be presented only for chlorpyrifos, diazinon, dimethoate, disulfoton, malathion, methidathion and parathion methyl. OP detection frequencies ranged between 0.18 and 32.2% (Figure 35).

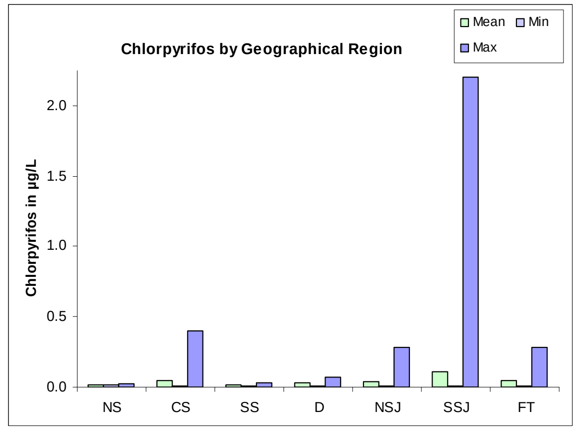
Figure 35. Frequency of detected Organophosphate Pesticides (percentage of total samples).



Chlorpyrifos was detected during all seasons and in all regions with a frequency of 28.7%. Six of eight seasonal means (except NA 2004 and IS 2007) and all regional mean concentrations were above the WQTL of 0.015 µg/L (Figure 36). The highest concentration (2.2 µg/L) was found during IS 2005 in the SSJ. Seasonal and regional minimum concentrations ranged between 0.004 and 0.046 µg/L.

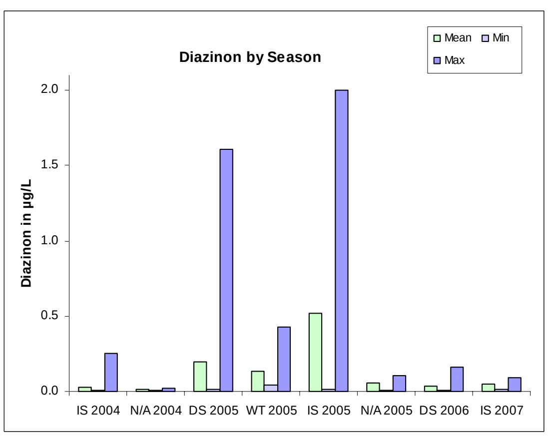
Figure 36. Chlorpyrifos mean, minimum, and maximum concentrations by season and region.

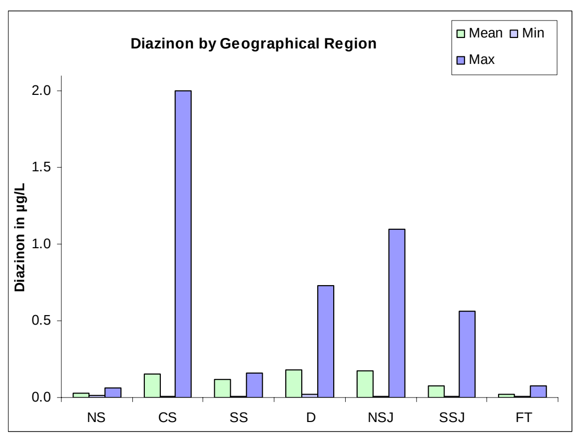




Diazinon was found during all seasons and in all regions with a detection frequency of 32.2%. The seasonal mean concentrations were between 0.013-0.519 µg/L; three of eight mean concentrations (DS 2005, WT 2005 and IS 2005) were above the WQTL of 0.1 µg/L (Figure 37). The regional mean concentrations were between 0.019-0.179 µg/L; four of seven mean concentrations (CS, SS, D and NSJ) were above the WQTL. The highest concentration was 2 µg/L found during IS 2005 in the CS.

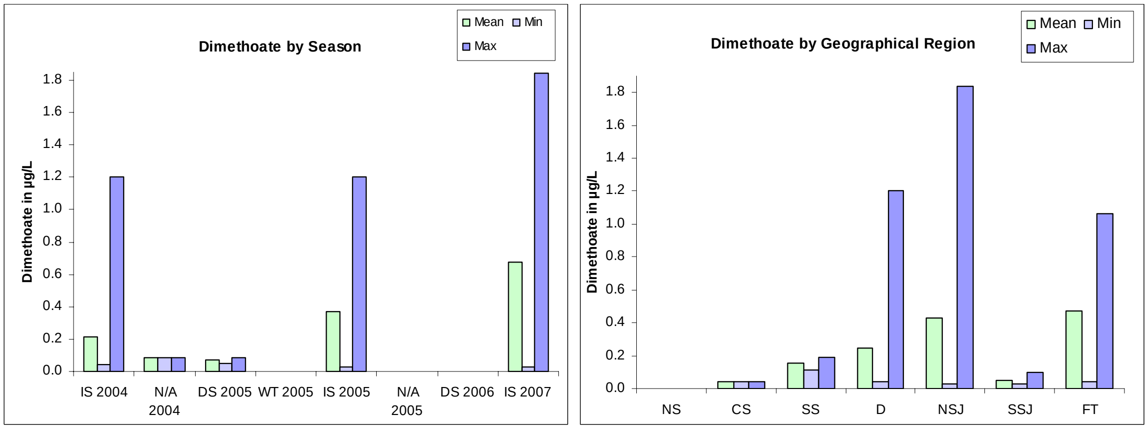
Figure 37. Diazinon mean, minimum, and maximum concentrations by region.





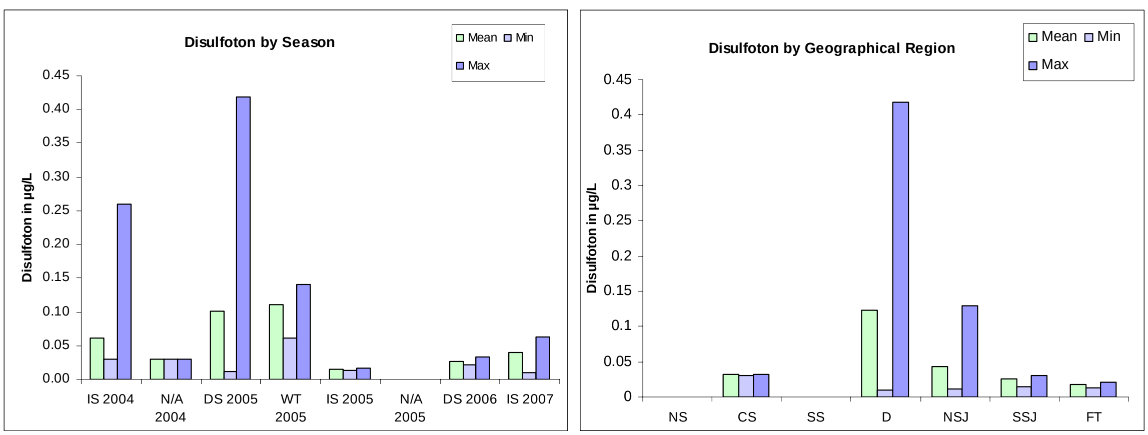
Dimethoate had a detection frequency of 10.6%. It was found during all irrigation seasons, NA 2004, DS 2005 and in all regions except the NS (Figure 38). All seasonal and regional means and minimums were below the WQTL of 1.0 µg/L. Three seasonal maximum values were above the WQTL during IS 2004 (1.2 µg/L), IS 2005 (1.2 µg/L) and IS 2007 (1.84 µg/L). Three regional maximum values were above the WQTL in the Delta (1.2 µg/L), NSJ (1.84 µg/L) and FT (1.06 µg/L).

Figure 38. Dimethoate mean, minimum, and maximum concentrations by season and region.



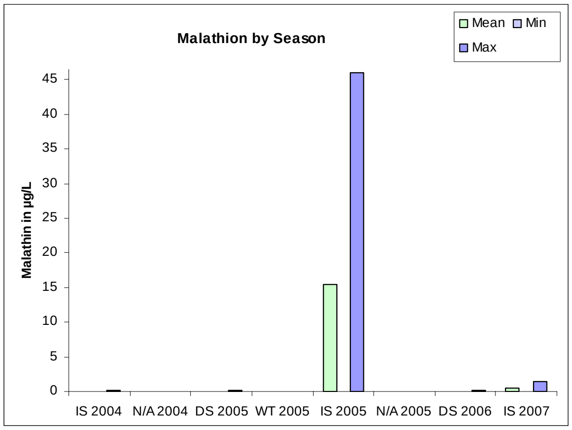
Disulfoton was found in 9.7% of the water samples in all seasons except NA 2005 and in all regions except NS and SS. Seven of the seasonal mean and maximum concentrations were above the WQTL of 0.05 µg/L, in IS 2004, DS 2005, WT 2005 and IS 2007 (Figure 39). Regional mean and maximum concentrations were above the WQTL in the Delta and NSJ. The highest concentration (0.418 µg/L) was found during DS 2005 in the Delta.

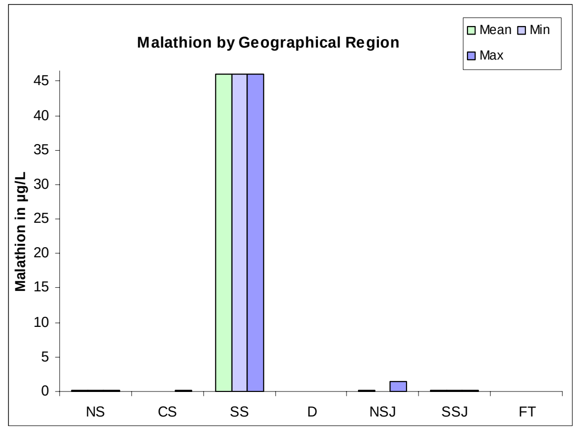
Figure 39. Disulfoton mean, minimum, and maximum concentrations by season and region.



Malathion had a detection frequency of 4.6%. It was found in all irrigation and dormant seasons and in all regions except the Delta (Figure 40). The highest concentration was seen during IS 2005 in SS with 46 µg/L. The WQTL for malathion is “ND” because the discharge of malathion is prohibited.

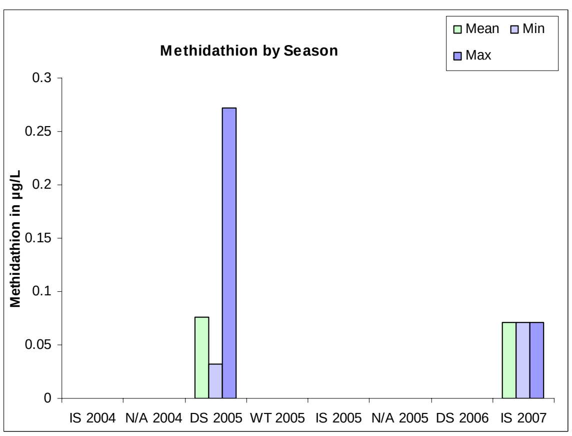
Figure 40. Malathion mean, minimum, and maximum concentrations by season and region.

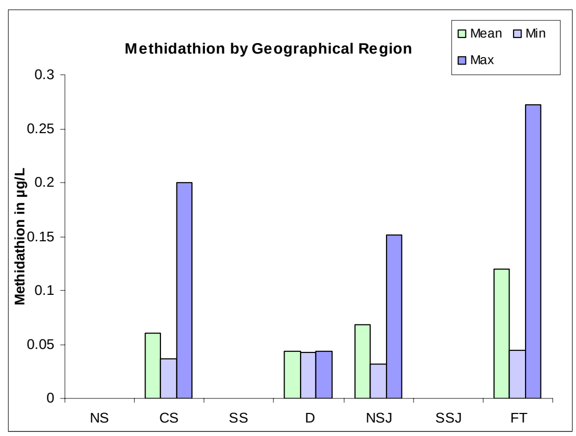




Methidathion was in 5.1% of all water samples. It was found during DS 2005 and IS 2007, and in the CS, D, NSJ and FT regions. All detections were below the WQTL of 0.7 µg/L (Figure 41). The highest concentration was 0.272 µg/L which occurred during DS 2005 in FT.

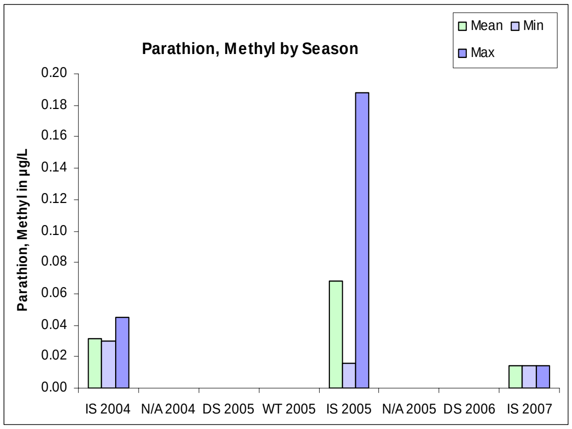
Figure 41. Methidathion mean, minimum, and maximum concentrations by season and region.

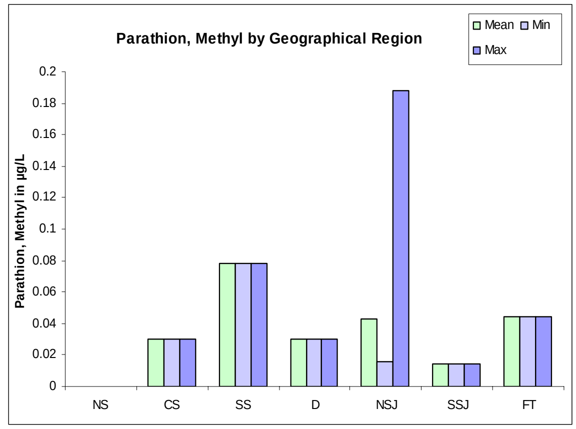




Parathion, Methyl had a detection frequency of 3%; it was only found during the irrigation seasons and in all regions except NS (Figure 42). The current WQTL for Parathion, Methyl is "ND" because the discharge of methyl parathion is prohibited. The highest concentration was found during IS 2005 in NSJ (0.188 µg/L).

Figure 42. Parathion, Methyl mean, minimum, and maximum concentrations by season and region.

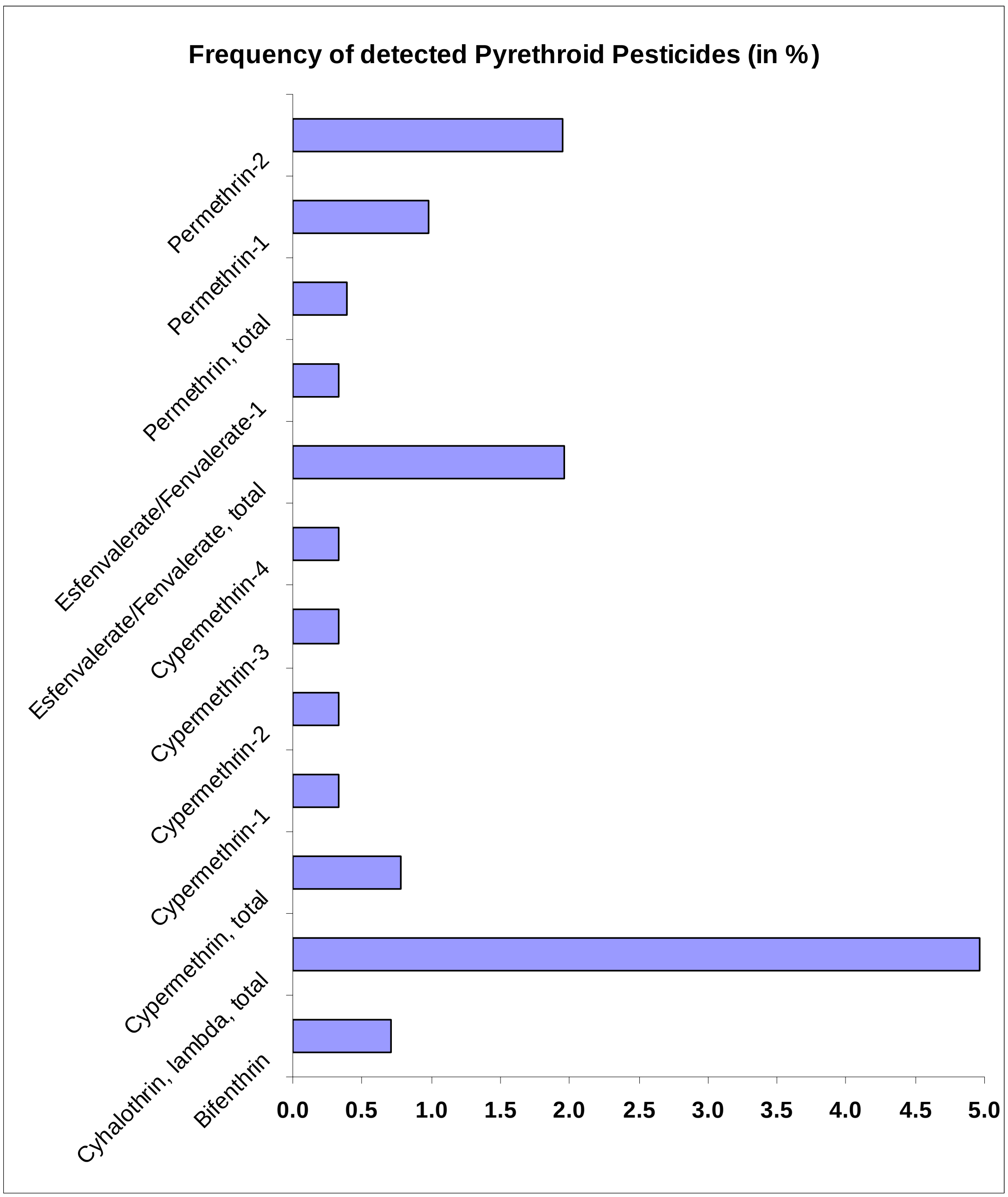




PYRETHROID PESTICIDES (Pyrethroids)

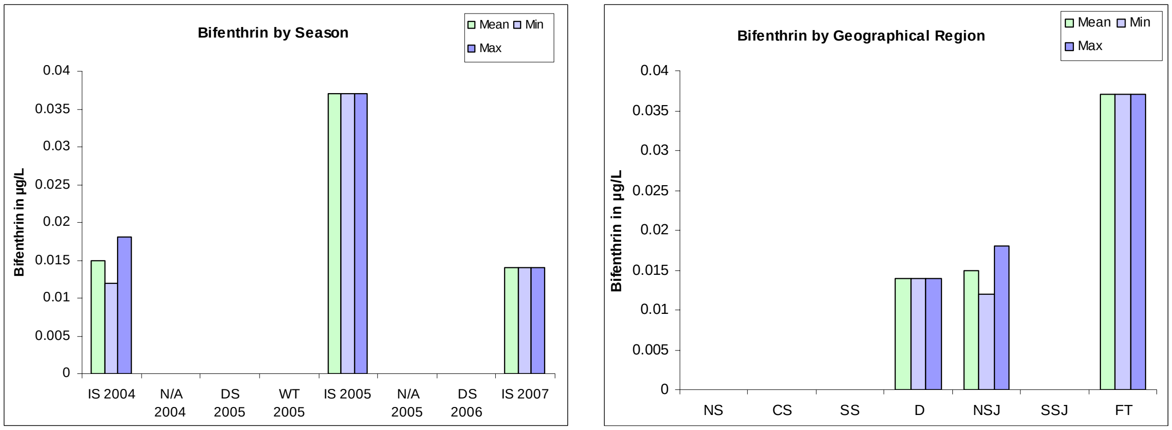
The suite of pyrethroids for which analyses were conducted included bifenthrin, cyfluthrin (cyfluthrin-1, -2, -3 and -4), cyhalothrin, lambda (cyhalothrin, lambda-1 and -2), cypermethrin (cypermethrin-1, -2, -3, and -4), deltamethrin, esfenvalerate/fenvalerate (esfenvalerate/fenvalerate-1 and -2) and permethrin (permethrin-1 and -2). All analytes except cyfluthrin and deltamethrin were detected. Results focus on bifenthrin, cyhalothrin, lambda, total, cypermethrin, total, esfenvalerate/fenvalerate, total and permethrin, total. Pyrethroid detection frequencies ranged between 0.39 and 4.9% (Figure 43).

Figure 43. Frequency of detected pyrethroid pesticides (percentage of total samples).



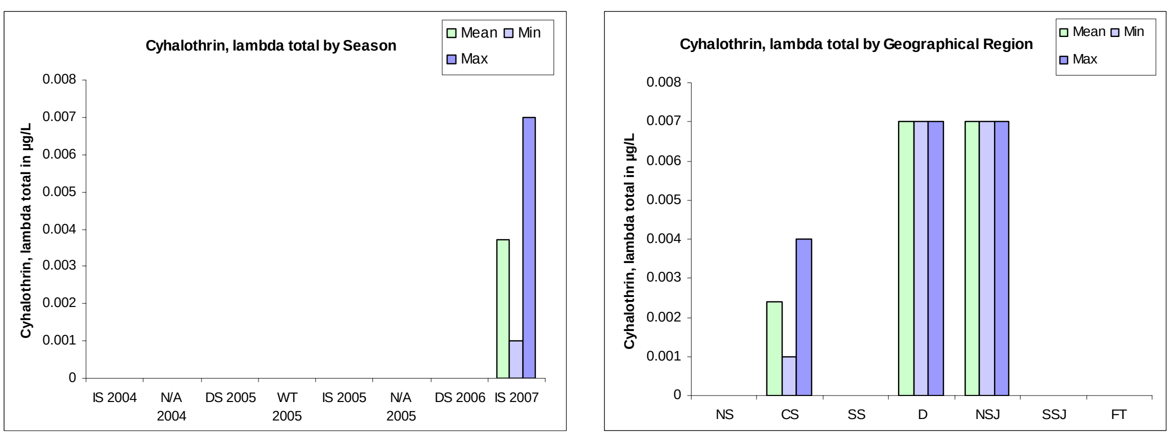
Bifenthrin was detected with a frequency of 0.7% during the irrigation seasons. The highest concentration was found during IS 2005 in FT with 0.037µg/L (Figure 44). Other detections occurred during the IS 2004 in NSJ and during IS 2007 in the Delta region. All the detected values were below the WQTL of 110 µg/L.

Figure 44. Bifenthrin mean, minimum, and maximum concentrations by season and region.



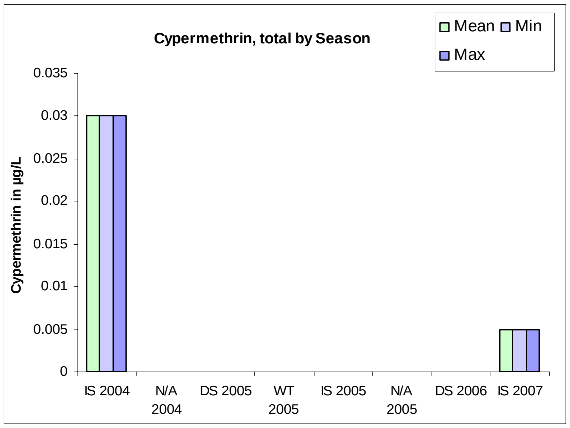
Cyhalothrin, lambda, total was detected only during IS 2007 with a frequency of 4.9%. It was found in three regions, CS, Delta and NSJ. Delta and NSJ had the same maximum concentration of 0.007 µg/L (Figure 45). All concentrations were below the WQTL of 35 µg/L.

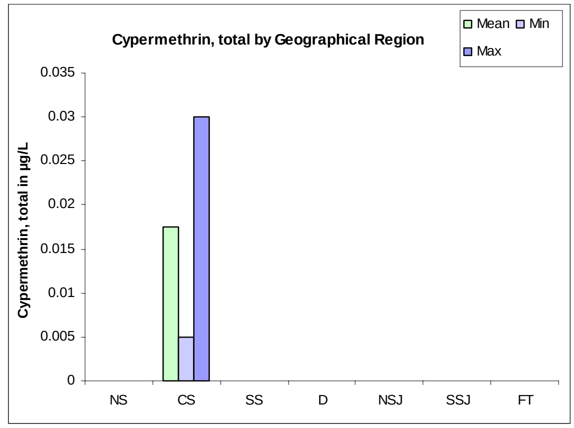
Figure 45. Cyhalothrin, lambda, total mean, minimum, and maximum concentrations by season and region.



Cypermethrin, total had a detection frequency of 0.8% and was only found in the CS during IS 2004 and IS 2007. The highest concentration was 0.03 µg/L (Figure 46). All seasonal and regional mean, minimum and maximum concentrations were above the WQTL of 0.002 µg/L.

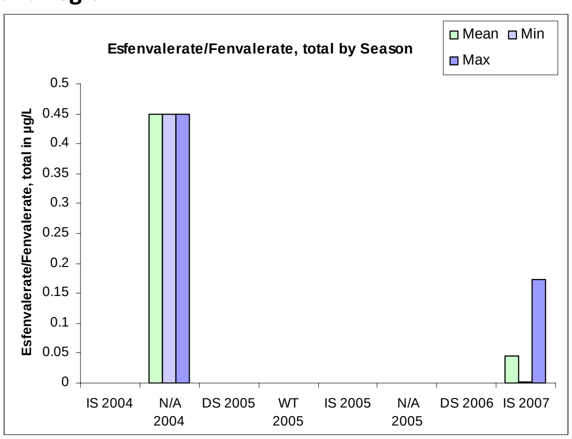
Figure 46. Cypermethrin, total mean, minimum, and maximum concentrations by season and region.

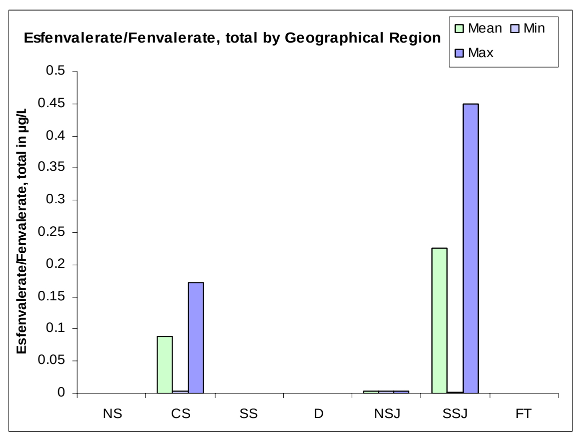




Esfenvalerate/Fenvalerate, total had a detection frequency of 2%. It was found during NA 2004 and IS 2007 in CS, NSJ and SSJ (Figure 47). The highest concentration was 0.45µg/L during NA 2004 in SSJ. Esfenvalerate/Fenvalerate, total has no current WQTL.

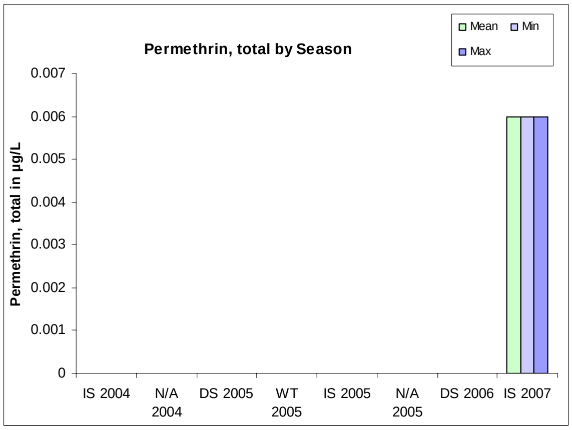
Figure 47. Esfenvalerate/Fenvalerate, total mean, minimum, and maximum concentrations by season and region.

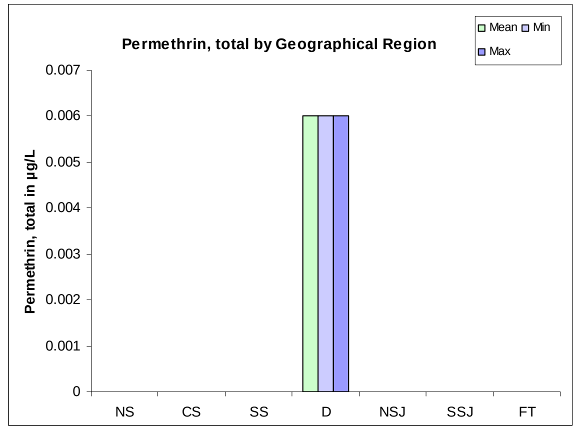




Permethrin, total was only detected during IS 2007 in the Delta region with a frequency of 0.4%. The sample had a concentration of 0.006µg/L (Figure 48), which is below the WQTL of 0.03 µg/L.

Figure 48. Permethrin, total mean, minimum, and maximum concentrations by season and region.





Toxicity

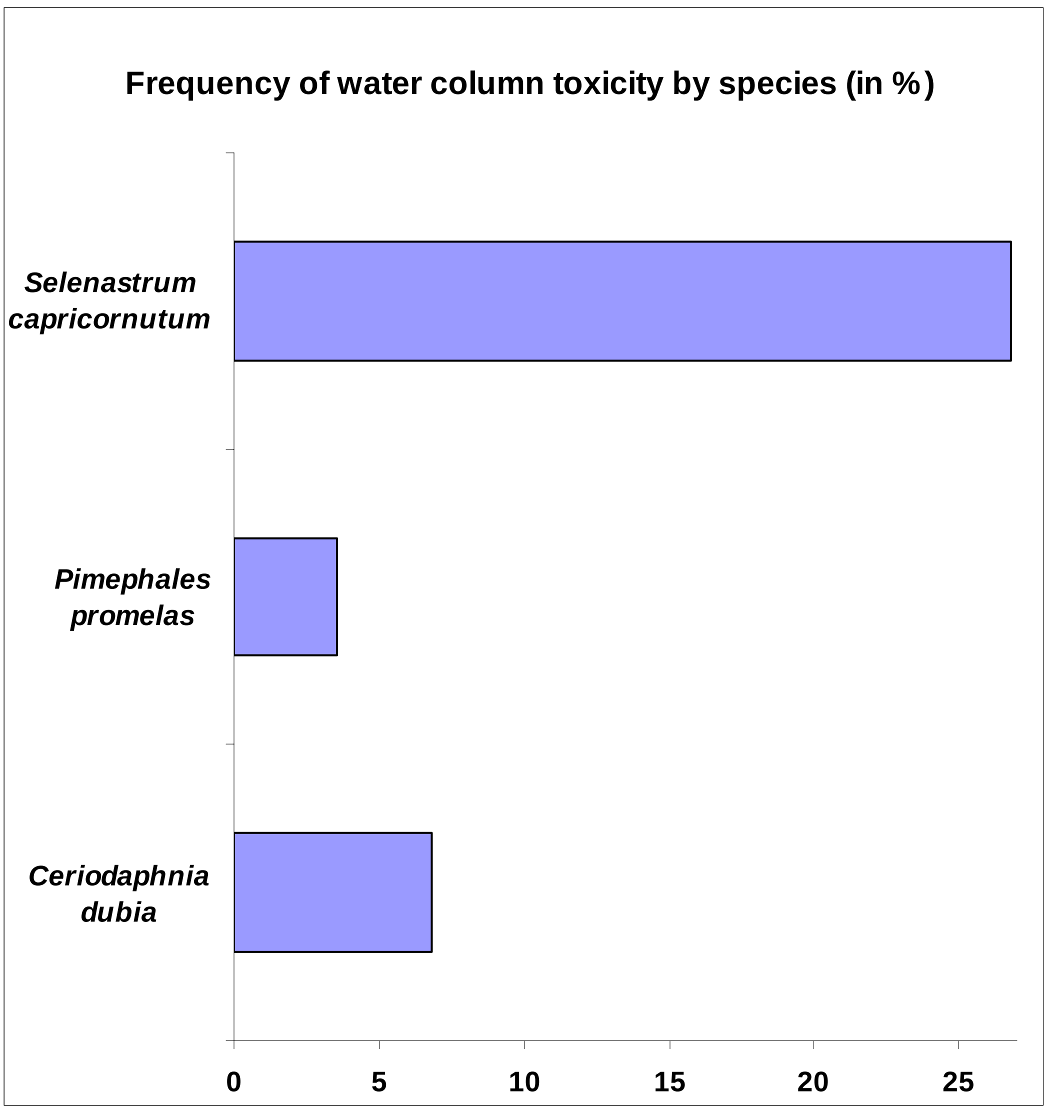
Sediment toxicity

Sediment toxicity tests were conducted by Dr. Don Weston at the University of California Berkeley. Sediment toxicity was conducted with *Hyalella azteca* with mortaligy as the endpoint. Dr. Weston's report can be found in Appendix 7.

Water column toxicity

Toxicity to *Ceriodaphnia dubia* occurred with a frequency of 6.82%, toxicity to *Pimephales promelas* occurred in 3.54% of the samples, and toxicity to *Selenastrum capricornutum* occurred in 26.77% of the samples.

Figure 49. Frequency of water column toxicity by species (percentage of total samples)

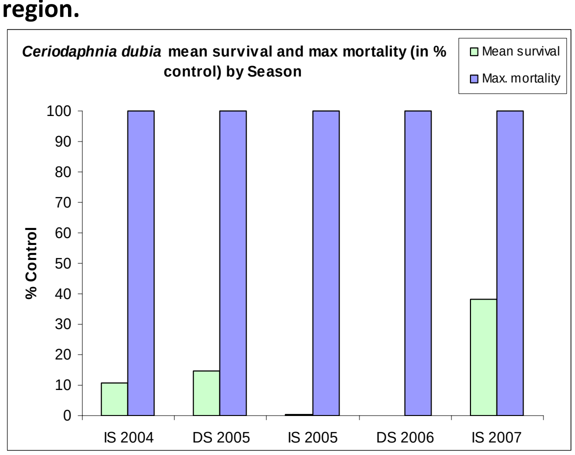


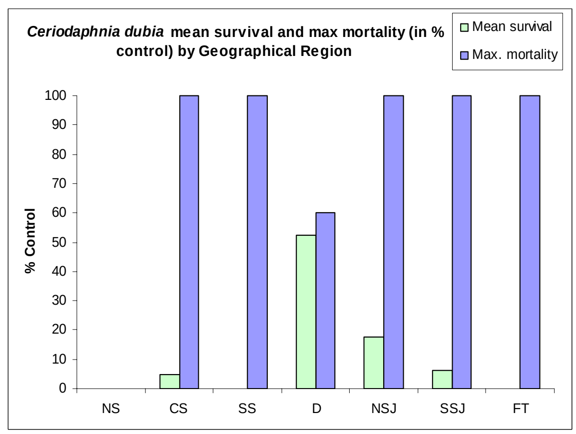
The following mean survival and maximum mortality reflect only the toxic samples for the different species, not the total number of samples.

Ceriodaphnia dubia (Figure 50)

Samples from IS 2007 had the highest survival rate at 38.3% of the control samples. IS 2005 and DS 2006 displayed very low or no survival in their toxic samples, 0.4 and 0.0% survival compared to the control, respectively. All seasons had a maximum mortality of 100% compared to the control. The NS had no *Ceriodaphnia* toxicity. Toxic Delta water samples had the highest mean survival rate with 52.5% survival compared to the control and the lowest maximum mortality rate of 60% compared to the control. All other regions had 100% maximum mortality in their toxic samples.

Figure 50. Ceriodaphnia dubia mean survival and maximum mortality (percent of control) by season and region.

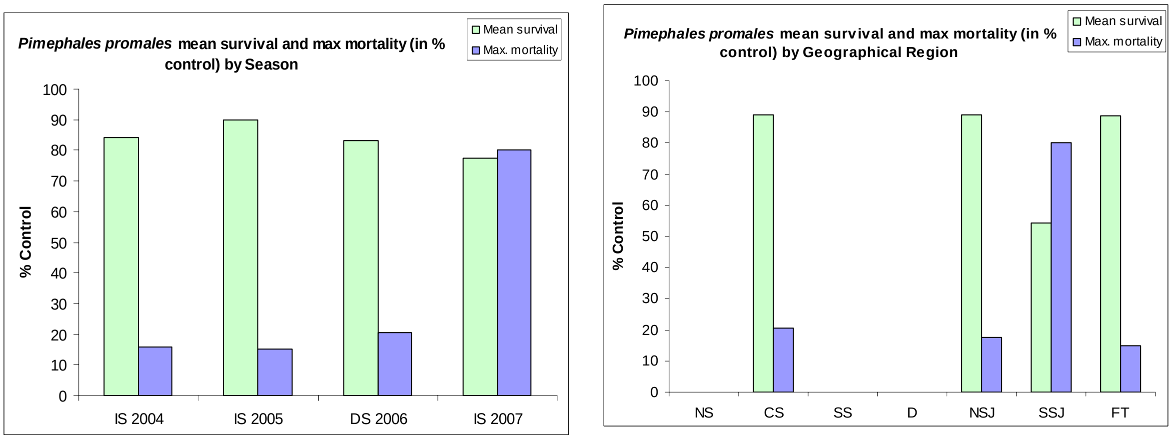




Pimephales promelas (Figure 51)

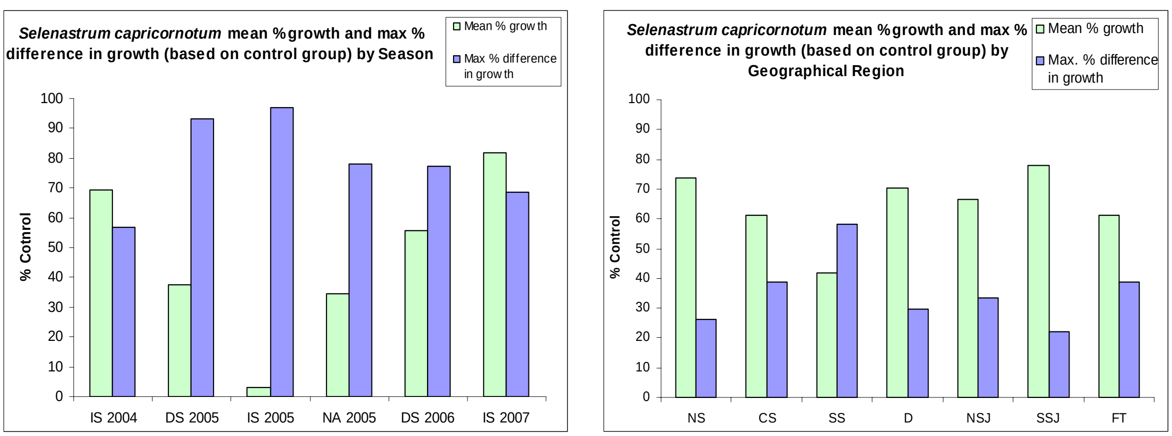
Seasonal mean survival rates for all toxic samples ranged between 77.5 and 90% compared to the control samples. IS 2007 had the highest maximum mortality of 80% compared to the control in its toxic samples. NS, SS and Delta had no *Pimephales* toxicity. CS, NSJ and FT had similar mean survival rates (88 – 89% compared to the control). SSJ had the highest maximum mortality of 80% compared to the control in its toxic samples.

Figure 51. *Pimephales promelas* mean survival and maximum mortality (in % control) by season and region.



Selenastrum capricornutum (Figure 52)

Figure 52. *Selenastrum capricornutum* mean growth and maximum difference in growth (percentage compared to the control group) by season and region.



The IS 2007 had the highest mean percentage of growth, compared to control samples, of all seasonal toxic water samples (81.8%), while IS 2005 displayed the lowest relative growth at 3%. DS 2005 and IS 2005 had the highest maximum percentage of difference in growth, compared to control samples, with 93.2 and 97%, respectively. All regions had samples toxic to algae. SS had the lowest mean percent growth, compared to control samples, with 41.6% and the highest maximum percent difference in growth with 58.4%.

Water samples are tested for toxicity using standard EPA tests in which algal (*Selenastrum capricornutum*) growth in the sample water over four days is compared to the growth of algae in control water. Generally, 50 percent less growth compared to growth in control water 'triggers' a Toxicity Identification Evaluation (TIE). Toxicity is also tested on the daphnid (*Ceriodaphnia dubia*) and fathead minnow (*Pimephales promelas*). Acute tests are run for 4 days and a survival rate of less than 50 percent in sample water 'triggers' a TIE for that species.

TIEs can be performed in three phases. Phase I TIEs attempt to identify the general class of toxicant causing the toxicity by removing potential chemical sources and retesting for toxicity. A Phase II TIE specifically identifies the compound or material that is responsible for the toxicity by adding the suspected toxicant back to the water to recover toxicity. A Phase III TIE examines the relationship between the concentration of the toxic compound and the toxicity found in the sample water. TIEs are performed following standard EPA methods. Some TIEs can vary slightly from standard protocols depending on additional information that may be available such as the level of ammonia in the sample.

The Department of Fish and Game Aquatic Toxicology Laboratory (Elk Grove, CA) (DFG-ATL) performed toxicity testing in 2004. All lab reports and electronic data were provided directly to the CVRWQCB and the AEAL has only a few photocopies of partial toxicity test results and TIE reports. Five 2004 TIE's were performed by DFG-ATL. All samples had caused toxicity to *Ceriodaphnia.* All samples had more than one potential cause of toxicity. While the SS04 results were not provided to the AEAL, all other TIEs identified organophosphates as the cause of toxicity, two samples identified carbamates, one sample identified organochlorines and herbicides, and another identified metals. All samples were collected during the Irrigation Season.

The 2005 samples were analyzed by AQUA Science (Davis, CA). These samples included both storm and irrigation sampling. Their results indicated that herbicides were the cause of toxicity to *Selenastrum*, and organophosphates were the cause of toxicity to *Ceriodaphnia*. The AQUA Science TIE report is provided as Appendix 6 and results are summarized in Table 3.

The 2006 and 2007 samples were again analyzed by DFG-ATL. The one TIE performed with *Ceriodaphnia* indicates toxicity caused by a pyrethroid. TIEs performed on samples toxic to *Selenastrum* identified cationic metals as the suspected toxicant. The different suspected toxicants in the *Selenastrum* TIEs may be due to seasonal or geographical differences in what is applied to fields or slight differences in methods between the two laboratories. DFG-ATL reports that experimental manipulations done with a *Selenastrum* TIE affect nutrient availability, which may confound growth of *Selenastrum*.

Of the 24 TIEs, 17 were for *Ceriodaphnia* toxicity and seven for *Selenastrum* toxicity. Sixteen of 17 TIEs for *Ceriodaphnia* identified organophosphates as the primary toxicant or one of a suite of toxicants. Two of the seven *Selenastrum* TIEs identified herbicides as the cause and four TIEs identified cationic metals as the cause of toxicity. The results of one TIE were inconclusive.

Table 3. Tie results for samples with >50% mortality (Ceriodaphnia) or >50% reduction in growth (Selenastrum) from 2004 through 2007.

Site ID	Sample Date	Season	Species Tested	Compound Class	Analytical Laboratory
CS12	07/12/04	Irrigation	*C. dubia*	OP, Carbamates, Metals	DFG-ATL
FT05	07/22/04	Irrigation	*C. dubia*	OP	DFG-ATL
CS15	07/26/04	Irrigation	*C. dubia*	OP, Carbamates	DFG-ATL
SS04	07/27/04	Irrigation	*C. dubia*	N/A	DFG-ATL
NSJ18	08/12/04	Irrigation	*C. dubia*	OP, OCH, Herbicides	DFG-ATL
CS15	1/26/05	Dormant	*C. dubia*	OP	AQUA Science
SSJ03	1/27/05	Dormant	*C. dubia*	OP	AQUA Science
CS15	2/16/05	Dormant	*C. dubia*	OP	AQUA Science
CS15	2/16/05	Dormant	*S. capricornutum*	Herbicides	AQUA Science
SS06	2/16/05	Dormant	*S. capricornutum*	Herbicides	AQUA Science
CS12	6/13/05	Irrigation	*C. dubia*	OP, Carbamates	AQUA Science
CS23	6/13/05	Irrigation	*C. dubia*	OP	AQUA Science
SS05	6/14/05	Irrigation	*C. dubia*	OP	AQUA Science
SSJ03	7/7/05	Irrigation	*C. dubia*	OP	AQUA Science
SSJ04	7/705	Irrigation	*C. dubia*	OP	AQUA Science
SSJ07	7/7/05	Irrigation	*C. dubia*	OP	AQUA Science
CS01	7/11/05	Irrigation	*S. capricornutum*	N/A	AQUA Science
NSJ31	7/13/05	Irrigation	*C. dubia*	OP	AQUA Science
SSJ04	7/20/05	Irrigation	*C. dubia*	OP, Carbamates	AQUA Science
FT32	1/15/06	Dormant	*C. dubia*	Pyrethroid	DFG-ATL

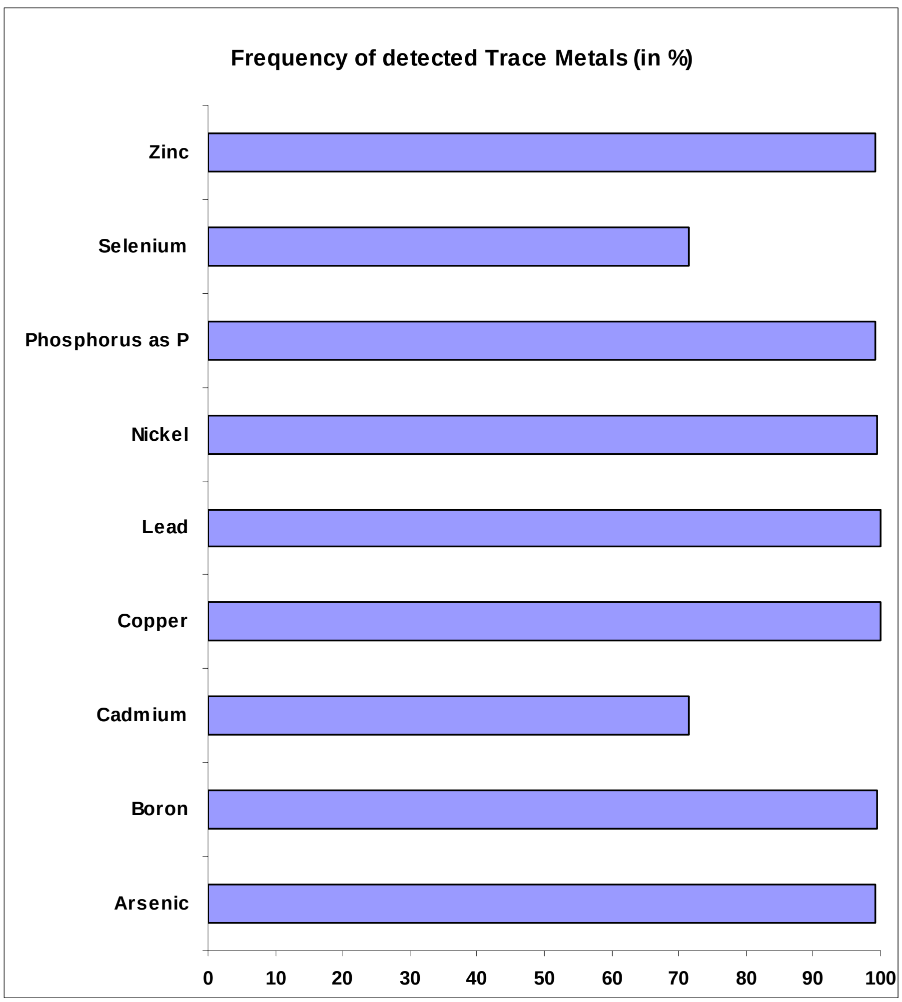
CS32	2/27/06	Dormant	*S. capricornutum*	Cationic metals	DFG-ATL
FT32	2/28/06	Dormant	*S. capricornutum*	Cationic metals	DFG-ATL
FT32	3/1/06	Dormant	*S. capricornutum*	Cationic metals	DFG-ATL
D04	8/8/07	Irrigation	*S. capricornutum*	Cationic metals	DFG-ATL

METALS

Metal samples were not collected during the split sampling events (NA 2004 and NA 2005). Therefore the following results only reflect the six main sampling seasons.
The results of five samples collected on November 28, 2007 are not included since the data were not available at the time of completion of the report. The five sites are CS34, LSAC29, CS31, D04 and NSJ31. A complete list of results is on a separate CD delivered with this report.

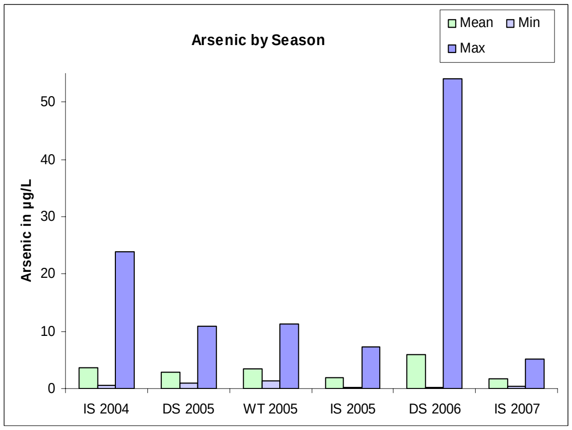
The suite of metals for which analyses were performed included arsenic, boron, cadmium, copper, lead, nickel, phosphorus as P, selenium and zinc. The detection frequencies of those metals ranged between 71 and 100% (Table 53). Copper and lead were the most frequently detected metals (100%).

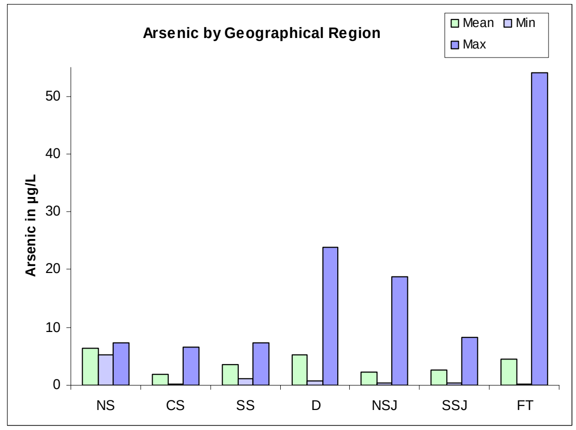
Figure 53. Frequency of detected trace metals (percentage of total samples).



Arsenic was detected in 99.3% of all samples, and during all seasons and in all regions (Table 54). Seasonal mean concentrations ranged between 1.66 and 5.99 µg/L, regional mean concentrations were between 1.81 and 6.36 µg/L. The highest arsenic concentrations were found during the DS 2006 in FT and during IS 2004 in the Delta region with 54 µg/L and 23.8 µg/L, respectively. The WQTL for arsenic is 10 µg/L. All seasonal and regional mean concentrations were below the WQTL, although four of six seasonal maximum concentrations and three of seven regional maximum concentrations were above the WQTL.

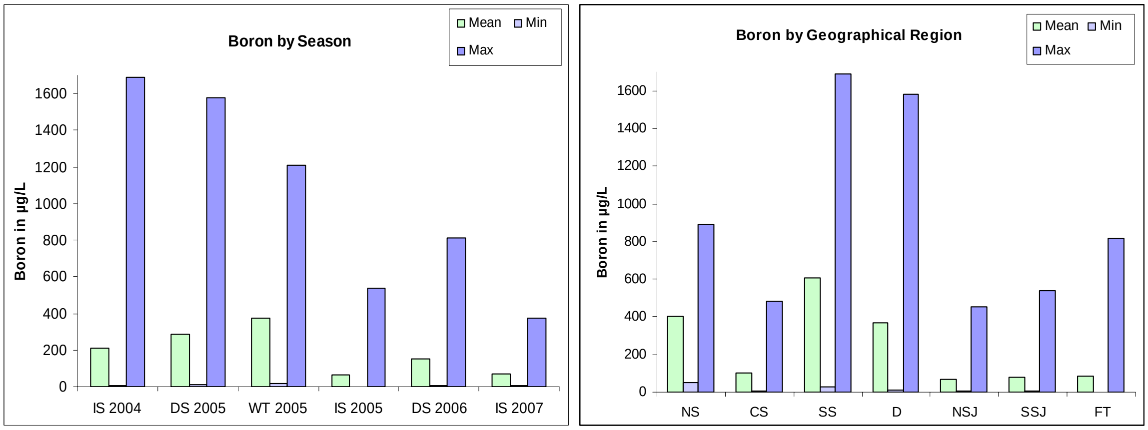
Figure 54. Arsenic mean, minimum, and maximum concentrations by season and region.





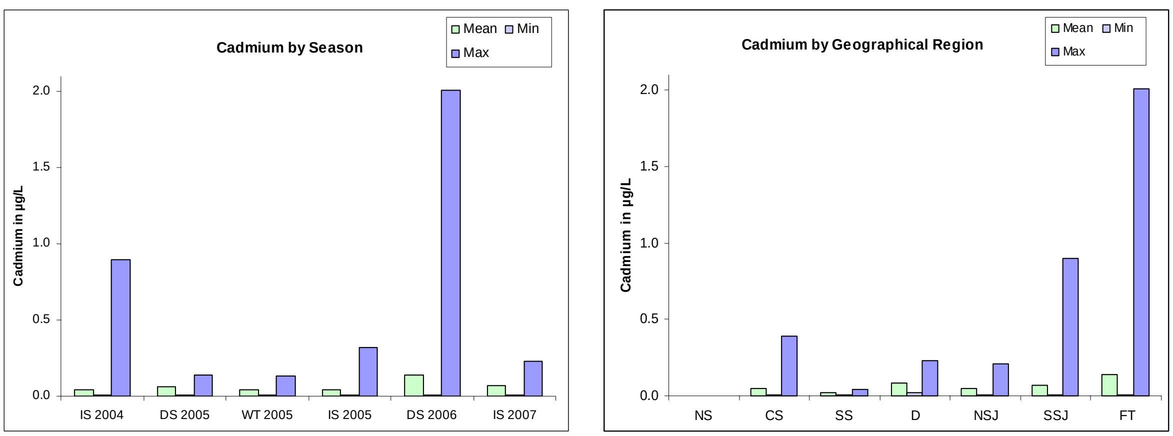
Boron was detected with a frequency of 99.5%. It was detected during all seasons and in every region. The seasonal mean concentrations were between 67.15 and 372.27 µg/L, the regional mean concentrations between 66.45 and 605.63 µg/L (Table 55). The maximum boron concentrations were found during IS 2004 in SS and DS 2005 in the Delta region (1690 and 1580 µg/L, respectively). The WQTL for boron is 700 µg/L. Four of six seasonal maximum and four of seven regional maximum concentrations were above the WQTL.

Figure 55. Boron mean, minimum, and maximum concentrations by season and region.



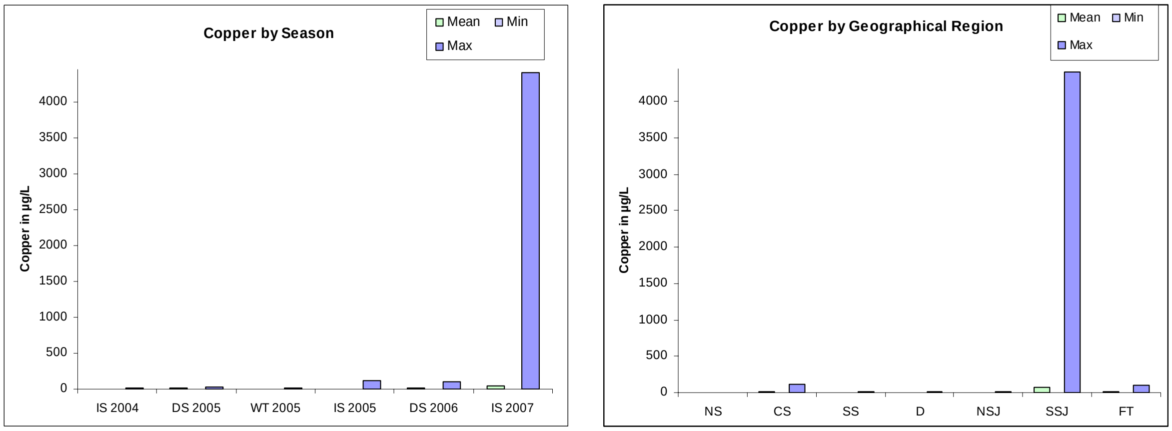
Cadmium was found in 71.4% of all water samples from all seasons and all regions except the NS (Figure 56). Mean seasonal and regional cadmium concentrations ranged between 0.02 and 0.14 µg/L. The highest cadmium concentration, 2.01 µg/L, occurred during DS 2006 in the FT. The WQTL for cadmium is variable and based on the hardness of the water.

Figure 56. Cadmium mean, minimum, and maximum concentrations by season and region.



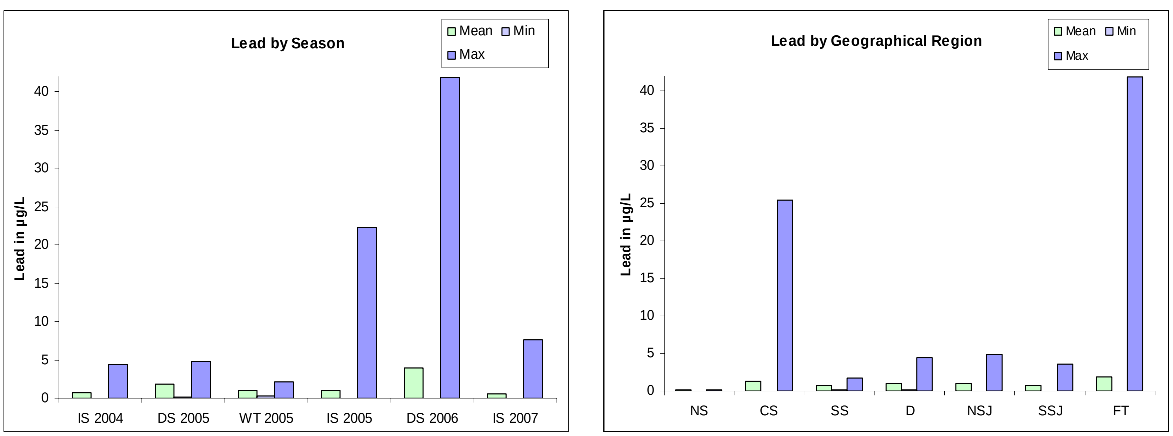
Copper was detected in every sample, in every season and region. Seasonal mean concentrations for 2004-2006 varied between 4.12 and 13.76 µg/L, regional mean concentrations for the same time period ranged between 1.4 and 8.18 µg/L (Figure 57). Maximum concentrations (2004-2006) for each season and region ranged between 1.85 and 115 µg/L. The IS 2007 in SSJ is not included in these statistical summaries since it was clearly an outlier value with a mean concentration of 4403 µg/L. The WQTL for copper is variable and based on the hardness of the water.

Figure 57. Copper mean, minimum, and maximum concentrations by season and region.



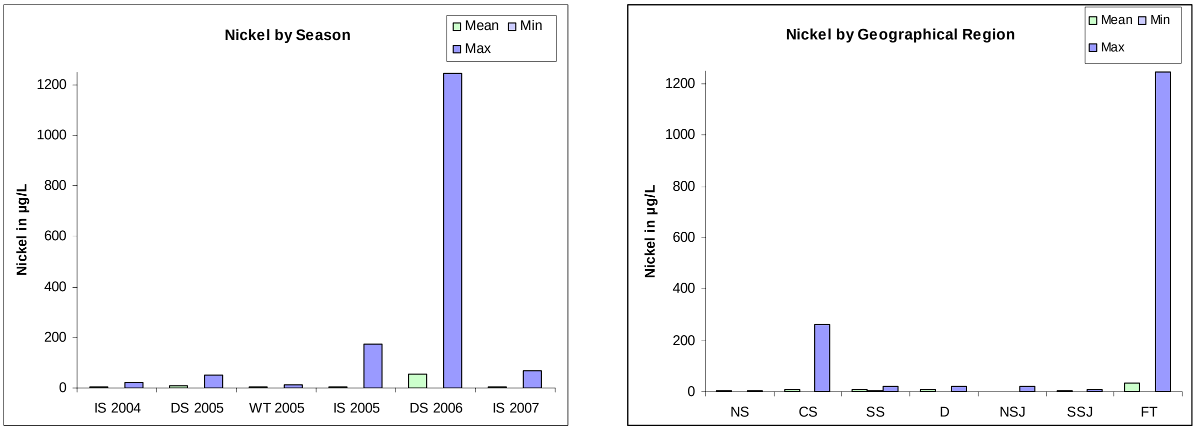
Lead was detected with a frequency of 100%, and found in every season and region. Seasonal and regional mean concentrations were between 0.11 and 3.93 µg/L (Figure 58). The highest lead concentration occurred during DS 2006 in FT (41.8 µg/L). The WQTL for lead is variable for hardness values between 1-70 and 2 µg/L for hardness of 71 and greater.

Figure 58. Lead mean, minimum, and maximum concentrations by season and region.



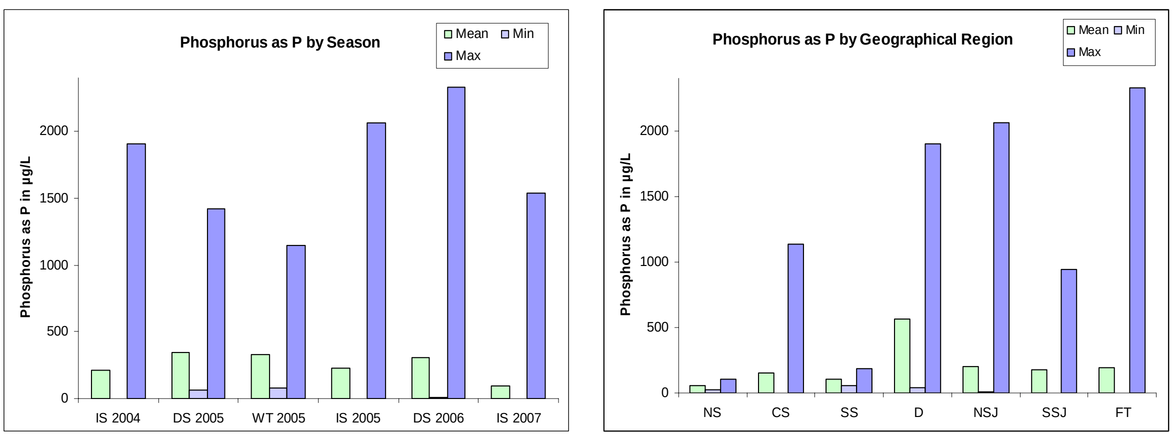
Nickel was detected with a frequency of 99.5% and found during all seasons and in all regions. The seasonal and regional mean concentrations, excluding DS 2006 (54.03 µg/L) and FT (35.45 µg/L), were between 1.94 and 10.14 µg/L (Figure 59). The mean values for DS 2006 and FT are influenced by the highest nickel concentration of 1245 µg/L detected during DS 2006 in FT. The WQTL for nickel is variable with hardness between 1-18 and 12 µg/L with a hardness value greater than 18.

Figure 59. Nickel mean, minimum, and maximum concentrations by season and region.



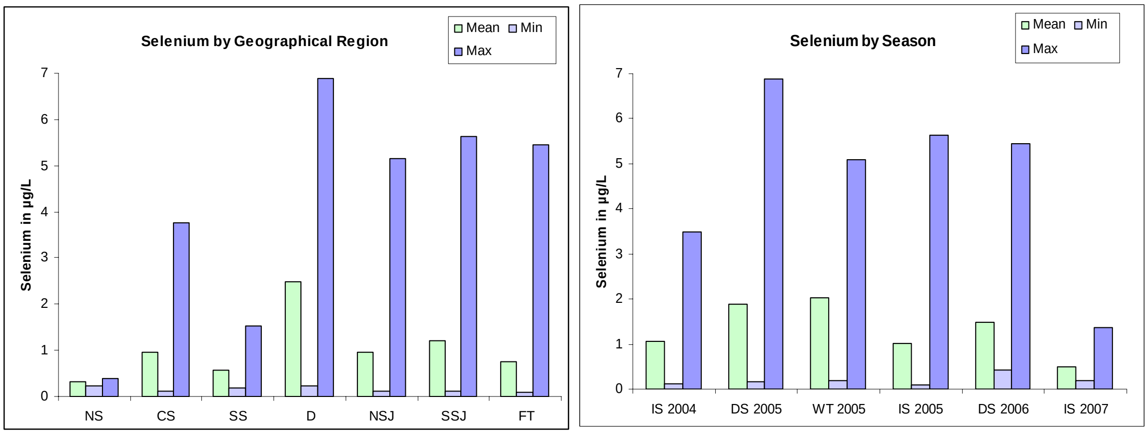
Phosphorus as P was found in 99.3% of all water samples, during all seasons and in all regions. The seasonal and regional mean concentrations ranged between 56.02 and 561.53 µg/L (Figure 60). The highest phosphorus concentration, 2326 µg/L, occurred during the DS 2006 in FT. Phosphorus as P has no current WQTL.

Figure 60. Phosphorus as P mean, minimum, and maximum concentrations by season and region.



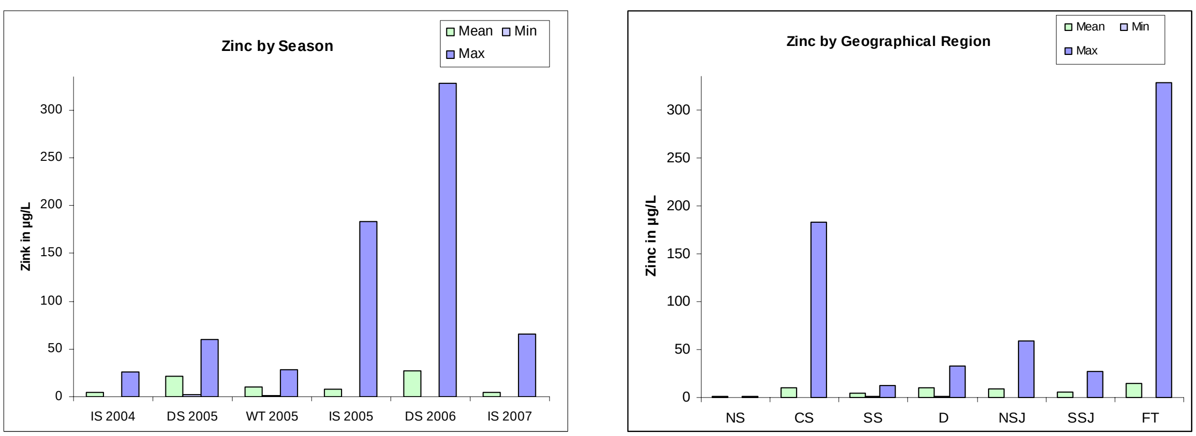
Selenium was detected with a frequency of 71.5% and found during all seasons and in all regions. Seasonal and regional mean concentrations ranged between 0.32 and 2.49 µg/L (Figure 61). The maximum selenium concentration occurred during DS 2005 in the Delta region (6.88 µg/L). The current WQTL for selenium is 5 µg/L (based on a 4-day average).

Figure 61. Selenium mean, minimum, and maximum concentrations by season and region.



Zinc was found in 99.3% of all collected water samples. It was found during all seasons and in all regions. The seasonal and regional mean concentrations varied between 0.61 and 27.66 µg/L (Figure 62). The highest zinc concentrations were seen during DS 2006 in FT and during IS 2005 in CS (328 µg/L and 183 µg/L, respectively). The WQTL for zinc is variable and based on the hardness of the water.

Figure 62. Zinc mean, minimum, and maximum concentrations by season and region.



Loads

Loads were only calculated for the Dormant Season 2005/06. The following discussion focuses on the discharge and load calculations of NSJ28, CS07, CS15 and FT16. Discharge for the locations CS07 and FT16 were obtained from discharge gauges, for all other locations discharge measurements were taken by the sampling teams. Equipment problems and unsafe stream conditions led to incomplete data sets.

NSJ28

Figure 63. Discharge and diazinon loads at NSJ28 - DS 2005

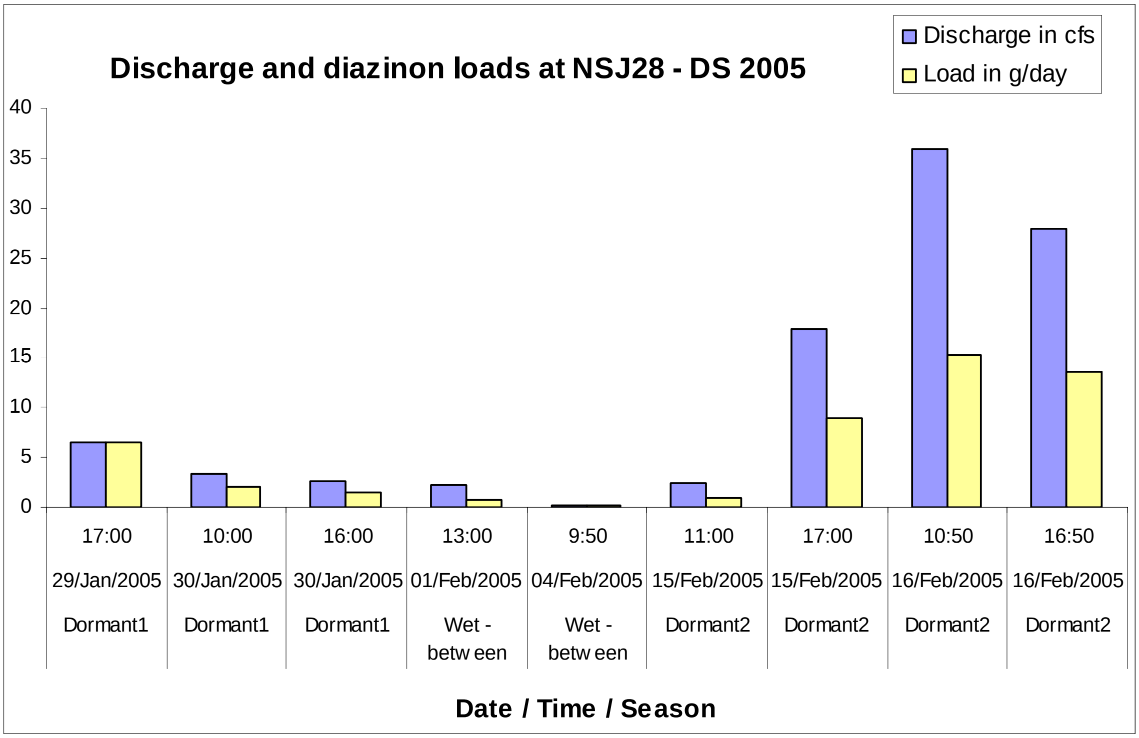
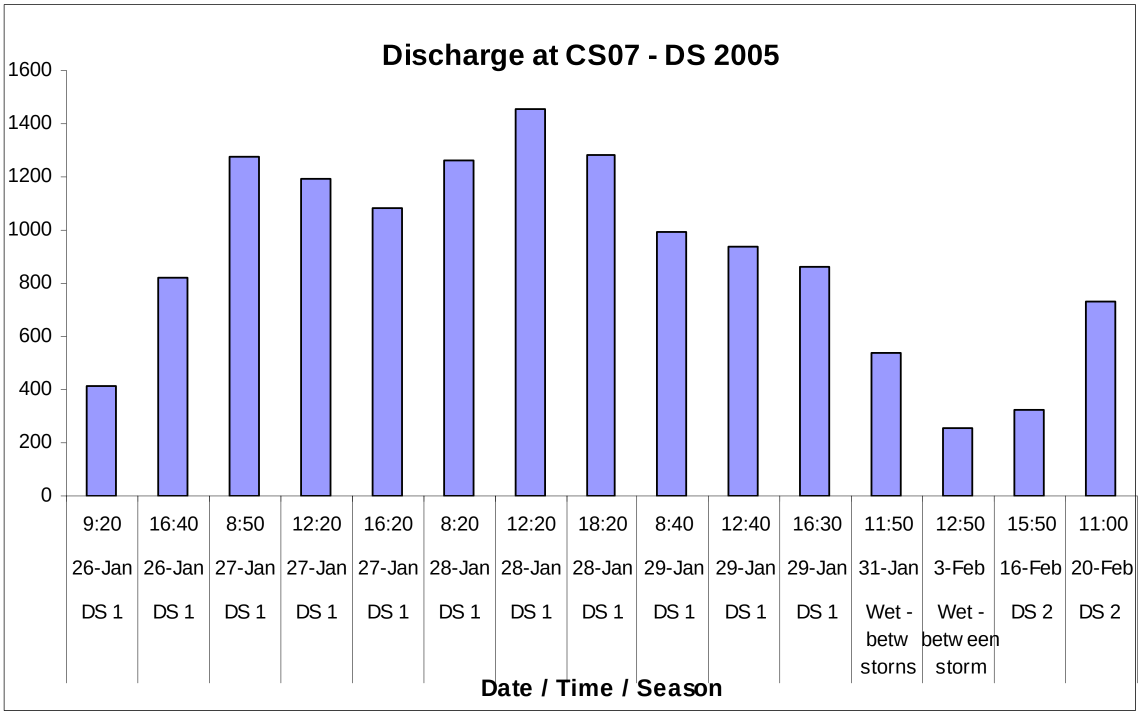


Figure 63 provides the discharge and diazinon loads during the Dormant Season 2005/06 for NSJ28. This site was scheduled to be sampled twice daily during the storm events. The graph shows the end of the first storm, samples taken between storms and the second storm. The stream is small (width about 3 m). The greatest load corresponds with the peak of the hydrograph. The diazinon concentration for the last three samples (0.204, 0.210 and 0.198 µg/L, respectively) are almost identical. The increased load is a result of the increased discharge and not on a higher pesticide concentration.

CS07

CS07 was sampled three times daily (Figure 64). No pesticides were detected at CS07 so loads were not calculated.

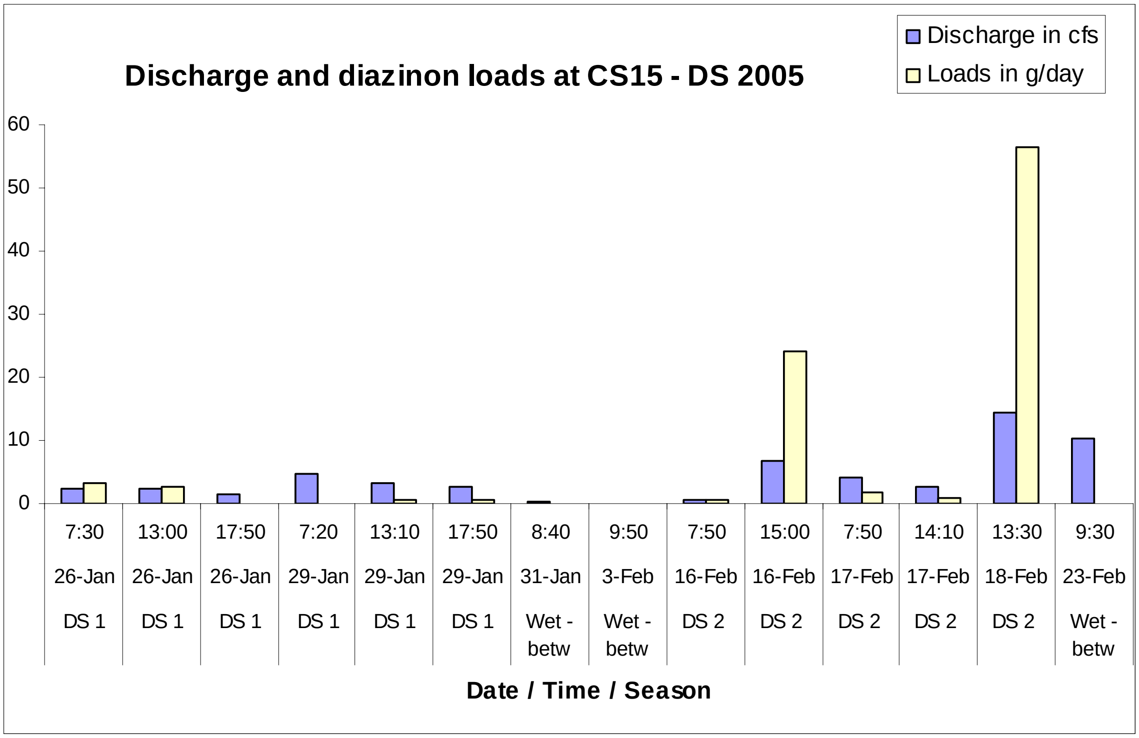
Figure 64. Discharge at CS07 - DS 2005



CS15

CS15 (width 1.5-2m) shows a less structured hydrograph pattern. Discharge could not be measured during the peak flow on January 27th and 28th due to unsafe creek conditions. The diazinon concentrations during the first storm were the highest on the 26th of January and were ten times greater than on the following days. It seems that even with higher discharge (too high to be safely measured) on the two following days, the diazinon concentrations went down. During the second storm, CS15 was sampled twice a day. There are two peaks in the storm hydrograph, and the greatest loads are found during the two peaks. Concentrations of diazinon for the greatest loads are ten times greater than any of the other sample concentrations.

Figure 65. Discharge and diazinon loads at CS15 - DS 2005

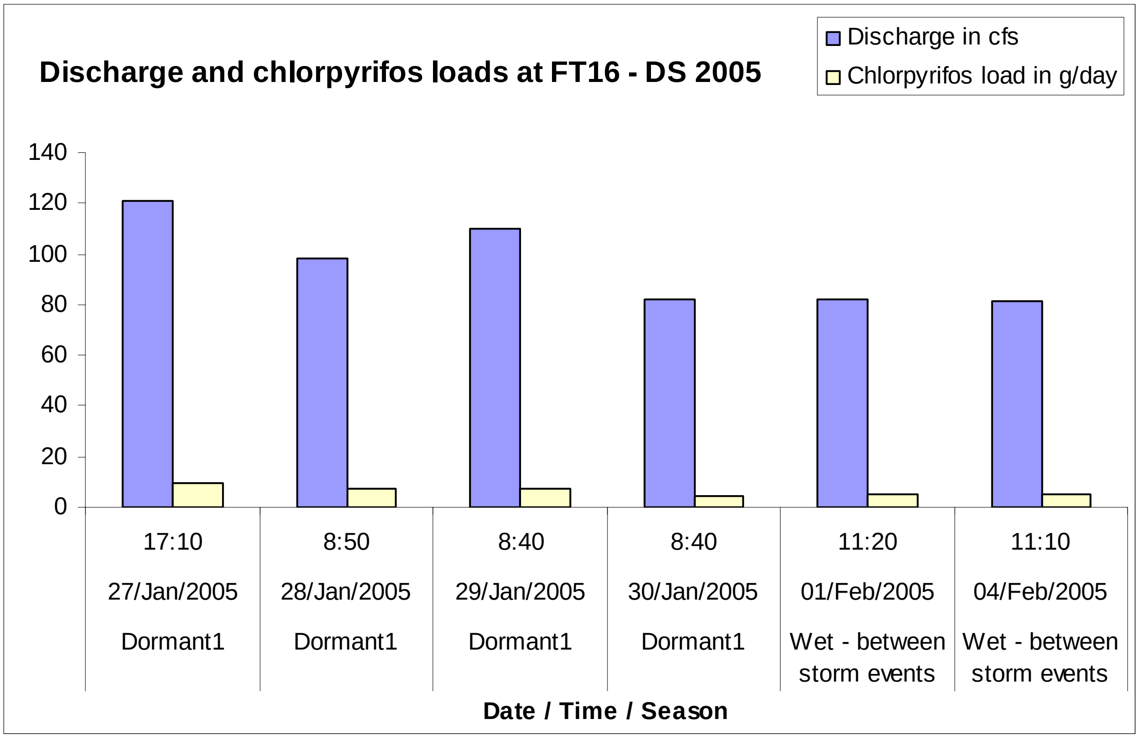


FT16

Discharge values for Kings River at Reed Ave were obtained through the Kings River Water Association. Samples were collected once a day and only during the first storm and between storm sampling.

The loads correspond well with the hydrograph during the storm event (Figure 66). The chlorpyrifos concentrations are similar throughout the storm so variations in the loads result mainly from differences in discharge.

Figure 66. Discharge and chlorpyrifos loads at FT16 - DS 2005



DISCUSSION

Exceedances of water quality objectives for field parameters were commonplace throughout the Central Valley and across the entire period of sampling. The Sacramento Valley experienced fewer exceedances than the San Joaquin Valley, Delta, or the Fresno-Tulare regions but the Central Sacramento region experienced a greater number of exceedances than either the North Sacramento or South Sacramento regions.

Statistical analyses were performed to determine which regions of the Valley (see below) were experiencing significantly greater or lower concentrations of various constituents. Due to extreme outliers, the data were not normally distributed however, the ANOVA was performed on untransformed data. ANOVAs are typically robust to deviations from normality, and performing the tests on untransformed data facilitated interpretation of results.

Field Parameters

As expected, DO tended to be lower during the irrigation season sampling periods due to the elevated temperature. The correlation between DO and temperature for all sites within the Valley is -0.32 which indicates that as water temperature increases, the DO level decreases as expected. The Valley was divided into four geographic regions; Sacramento Valley, Delta, San Joaquin Valley, and the Fresno-Tulare region. The grouping was performed to increase the sample sizes from the original geographic subregions and facilitate statistical analyses. The mean DO for all regions except the San Joaquin Valley was above 7.0 mg/L. The mean DO for the San Joaquin Valley was only 4.9 mg/L which was significantly different from the other three regions (one way ANOVA, $F = 23.04$, $p = 0.000$). None of the other three regions had significantly different DO from each other.

pH exceedances of the Basin Plan standards both above and below the acceptable range (6.5 – 8.5) were common. pH exceedances above the Basin Plan standard were more common than pH exceedances below the standard of 6.5 most probably reflecting the daytime sampling schedule. Daytime photosynthetic/nighttime respiration often drives pH dynamics in surface waters, particularly when flow is minimal. As with DO, pH was significantly lower in the San Joaquin Valley region from all other regions although the mean pH was not below the 6.5 lower standard (one way ANOVA, $F = 19.15$, $p = 0.0000$). The Delta had the next lowest mean pH which was significantly different from the San Joaquin Valley and the Fresno-Tulare regions. Once again, due to outliers in the data particularly in the San Joaquin Valley, the data were not normally distributed and the ANOVA was performed on untransformed data.

Specific conductivity varied considerably across the Valley with smallest mean value in the Fresno-Tulare region and the largest mean value in the Delta. The EC in the Delta was significantly greater than the EC in other regions (one way ANOVA, F = 65.61, p = 0.000). None of the other three regions was significantly different from each other. The data again were not normally distributed.

Mean water temperature was very similar across the Valley and no significant differences were detected (one way ANOVA, F = 0.70, p = 0.549).

As expected, DO was greater, pH was lower, and water temperature was lower during the winter dormant season. Interestingly, EC was elevated in the winter relative to the summer in all regions except the San Joaquin Valley in which EC was nearly constant across the seasons (two way ANOVA, regions main effect F = 64.68, p = 0.000; seasons main effect F = 57.98, p = 0.000; interaction F = 15.74, p = 0.000). The greatest difference between the dormant season and the irrigation season occurred in the San Joaquin Valley where the mean EC in the winter was nearly twice the mean EC in the irrigation season. Typically, EC might be expected to be elevated during the summer as irrigation would tend to concentrate the salts through evaporation and transpiration. However, this is clearly not the case. The explanation for this is not clear although the elevated EC may be the result of upstream releases of salts from the west side of the San Joaquin Valley. The lack of a difference between seasons in the Delta was a result of the sampling locations being within Delta island interior drainage channels. During the winter, these channels collect water from seepage or storm water runoff and although they contain a mixture of Delta water and storm water, the water in the drain channels is primarily from the Delta which is a mixture of both Sacramento River water and San Joaquin River water.

Physical Parameters, Nutrients, and Metals

As expected, the Delta had significantly greater mean total dissolved solids concentration than the other three regions (F = 115.47, p = 0.0000). TDS is a measure of salt and the water in the Delta islands is typically salty. Mean total organic carbon concentration was also significantly greater in the Delta compared to the other three regions (F = 14.72, p = 0.0000).

Several nutrients were measured during the course of the study. Ammonia as N was found in all regions of the Valley, with the greatest mean concentration found in the Delta. The San Joaquin Valley had the next highest mean concentration, and the Sacramento Valley and the Fresno-Tulare regions had the lowest mean concentrations. The means were significantly different (F = 5.37, p = 0.0013) and the Delta was the location that was significantly different. Mean Nitrate + Nitrite as N was significantly greater in the Delta and San Joaquin Valley compared to the Sacramento Valley and the Fresno-Tulare regions (F = 13.19, p = 0.0000) and mean concentration of Nitrite as N was also greater in the Delta region compared to the other three regions (F = 8.37, p = 0.0000). Mean concentration of orthophosphate as P was significantly greater in the

Delta compared to the Sacramento Valley or the Fresno-Tulare regions (F = 6.62, p = 0.0002).

Detections of metals were common during the entire period of monitoring. Selenium and cadmium were the least detected elements but were detected in approximately 70% of the samples analyzed. Other metals were detected in nearly 100% of the samples including zinc and copper. Exceedances of Basin Plan standards are based in some cases on the hardness of the water. Although hardness was measured in this study, no calculations were made to determine if concentrations of metals exceeded the WQTLs. It was not a focus of this study to determine if the metals were in exceedance of Basin Plan standards and the calculations were not made. Consequently it is not possible to determine which samples were in exceedance of the water quality standards.

TIE'S AND CHEMISTRY

The most common detections of chemicals were for organophosphate pesticides, primarily diazinon and chlorpyrifos. While other classes of pesticides, e.g. carbamates, experienced detections at less than 5% of the samples, diazinon and chlorpyrifos pesticides were detected in as many as 30% of the samples. Other organophosphate pesticides, e.g. dimethoate were detected in over 10% of the samples collected. Not unexpectedly, the results of the TIEs indicated that organophosphate pesticides were the cause of toxicity in a majority of the cases. Carbamates were found as a contributing factor in three of the TIEs and pyrethroids and metals were each found as the cause in a single TIE.

Chlorpyrifos detections varied across the Valley with the largest number of detections in the San Joaquin Valley (69 of 220 samples, 31%) and the fewest in the Delta (16 of 51 samples, 31%). Interestingly, the percentages of detections were identical. The Sacramento Valley (34 of 216 samples, 16%) and the Fresno-Tulare region (42 of 71 samples, 59%) were intermediate but the percentages of detections were very different. There was a single outlier sample in the Sacramento Valley (2.2 µg/L) which was removed before statistical analyses. When compared across all subregions, there were no statistically significant differences in chlorpyrifos concentrations (F = 0.49, p = 0.82). When the subregions were grouped into the four major geographic regions, there were also no differences among regions in mean chlorpyrifos concentration of the detections (F = 0.55, p = 0.65). The results were similar for diazinon at the subregion (F = 1.04, p = 0.40) and the region levels (F = 1.14, p = 0.33). These results indicate that these two pesticides are a problem across the entire Central Valley and become a more frequent problem as one moves south through the Valley. However, there is no portion of the valley that experiences greater concentrations in the water than others. This is an interesting result considering the extreme variability in climate, crops, irrigation practices, soils, and hydrography across the valley. The remaining organophosphate pesticides had few detections and could not be analyzed statistically. Carbamate and organochlorine pesticides also had relatively few detections and no statistical analyses were performed.

The herbicides had too few detections on which to perform statistical analyses on a subregional basis. Consequently, data were combined at the regional level for analysis. Atrazine was detected most frequently across the Valley. Even though the mean concentration in the San Joaquin Valley was almost four times greater than the mean concentration in the other regions, small sample sizes precluded detecting statistically significant differences among regions ($F = 2.26$, $p = 0.09$). By far, the largest number of detections also occurred in the San Joaquin Valley. Diuron mean concentration for detections were significantly different across regions ($F = 5.31$, $p = 0.0024$). Mean concentration in the San Joaquin Valley was an order of magnitude lower than the mean concentration in the Sacramento Valley. Those two locations were significantly different from each other by a Bonferroni multiple comparisons test. Mean concentrations in the Delta and Fresno-Tulare region were very similar. None of the mean concentrations from any region were above the WQTL of 2 µg/L. Metolachlor was detected only in two regions, the Sacramento Valley and the San Joaquin Valley although no samples were analyzed from the Delta. Mean concentrations in the two regions were not significantly different ($F = 0.25$, $p = 0.62$). Simazine mean concentrations in the four regions differed significantly ($F = 2.90$, $p = 0.039$), with the greatest mean concentration occurring in the San Joaquin Valley. The mean concentrations in the other regions were two to four times lower than in the San Joaquin Valley. No samples were analyzed for trifluralin in the Delta. No detections occurred in the Fresno-Tulare region, and only five detections occurred in the Sacramento Valley. Small sample sizes led to low power in the statistical analysis, and no differences in mean concentration were found between the Sacramento Valley and the San Joaquin Valley samples ($F = 0.74$, $p = 0.40$).

Overall, the results of the herbicide analysis suggest differential use of herbicides between the Sacramento Valley and the San Joaquin Valley. The Sacramento Valley experienced greater mean concentrations of diuron and lower mean concentrations of atrazine compared to the San Joaquin Valley. Diuron and atrazine are both soluble herbicides, and it would be expected that if both were applied in both regions, both herbicides would be expected to appear in surface water. Because of the similarities in chemical properties between herbicides, the differences in soils between regions would not be expected to cause differential runoff. Confirmation of differential use could be obtained through and examination of Pesticide Use Reports, however, the examination may need to be stratified by proximity to surface waters. Use of other herbicides and detections in surface waters appears to be similar across the Valley.

The primary pesticides that are the most problematic in the Valley with respect to the frequency of detection, and the concentrations of the constituents in the samples, are chlorpyrifos, diazinon, atrazine, simazine, and diuron. They share a low K_{oc} value (1800-6000 depending on the source, 1000, 100, 130, 480 respectively) indicating that they are highly soluble and readily mobilized by storm water or irrigation return flows. All are used during the dormant season; the herbicides are used almost exclusively in the dormant season and both chlorpyrifos and diazinon are used all year around. The three herbicides account for 58% of all detections of herbicides during the entire period of sampling, and the two organophosphate pesticides account for 59% of all organophosphate, carbamate, and fungicide detections. Eliminating these five chemicals from runoff would eliminate nearly 60% of the pesticides from surface waters of the Valley. Based on the results of the TIEs, eliminating these five constituents could also potentially eliminate over 75% of the toxicity observed.

The results suggest that the Delta and the San Joaquin Valley have the greatest relative percentage of exceedances of field, physical parameters, nutrients, and metals compared to the Sacramento and Fresno-Tulare regions. The relatively high concentrations of constituents in the San Joaquin Valley are generated within the Valley and eventually transported to the San Joaquin River and eventually to the delta. The sample locations for the Delta were all located in drain channels within the interior of Delta islands and would not reflect to any major extent, the water delivered to the Delta from the San Joaquin or Sacramento Rivers. However, it is also not well understood how much water moves from the Delta island interior channels to the Delta water ways. Much of the water needs to be pumped from the islands to the Delta and the amount and rate of pumping depends on several factors including the rate of seepage and the relative subsidence of the islands, the amount of rainfall or irrigation water, and the size of the interior channels. Often, the pumps are attached to float mechanisms that activate the pumps when the water level in the drain channels reaches a certain depth. Pumping continues until the water level in the channel drops back to a preset level. Organic carbon and dissolved solids are conserved constituents and are not expected to change concentration prior to pumping into the Delta. Nitrogen can go through changes due to nitrification and denitrification processes and can also be utilized by benthic and pelagic algae, submerged and emergent aquatic vegetation, and vegetation found along the banks of the interior drain channels. Consequently, it is not clear that the nitrate, nitrite, and ammonia found in the interior drain channels will be moved to the Delta channels. Likewise, nitrogen in the tributaries to the San Joaquin and Sacramento rivers is likely to undergo transformation and it is unclear how much reaches the Delta in the forms measured upstream. Phosphates tend to be particle bound, and unless significant settling occurs, phosphates are likely to be moved in similar concentration from the interior drain channels to the Delta channels when the pumps are activated. Because storm water and irrigation return flows tend to mobilize sediment from fields and move to the channels, pumps activated due to storm water or irrigation would most likely move phosphates to the Delta. Water temperature and DO are not conserved and are expected to change dramatically when pumps move drain water to the Delta. The act of pumping would aerate the water, and mixing drain water with pumped water would result in the drain water reaching the reduced temperatures of the Delta almost immediately. Overall, until a better understanding of amount and rate of pumping is obtained, it will not be possible to determine to what extent constituents are moved to the Delta channels where they could come into contact with biological receptors.