distribución original en el sistema del río Sevier y ha sido extirpada del sistema del río Beaver. Se están llevando a cabo trabajos para estimar su estado y determinar los niveles de poblaciones actuales en otros drenajes en Utah. Examinamos el uso del hábitat de la carpita cueruda en dos escalas espaciales. Para evaluar las características del macrohábitat censamos 59 lugares en la parte sur central de Utah. En cada localidad medimos nueve variables del hábitat y anotamos todas las especies de peces encontradas. Se compararon las características de los hábitats sin carpitas cuerudas, densidades bajas, y densidades altas usando análisis logístico de regresión. La carpita cueruda presenta un rango amplio de tolerancia para las variables físicas. Estas no ocurren en zonas mas altas de los 2,195 m en elevación, y fueron menos abundantes en lugares con muchas truchas morenas. Se cuantificaron las características de microhábitat en tres lugares. Dentro de cada lugar muestreamos 100 puntos al azar. En cada punto cuantificamos la profundidad, temperatura, oxígeno disuelto, velocidad, substrato, cobertura, especies encontradas, su abundancia y tamaño. La carpita cueruda evita corrientes de alta velocidad y substratos arenosos/limosos. Ocupan áreas en el agua con velocidad reducida creadas por piedras grandes, troncos y otras obstrucciones con substratos gruesos/finos.

Wong, D.M.; Barrett, P.; Keeney, S.; Sada, D. and Threloff, D.

(DMW- California Department of Fish and Game (CDFG), Bishop office, CA; PB - U.S. Fish and Wildlife Service, Carlsbad field offce, CA; SK- CDFG, Indio, CA; DS- Bishop, CA; DT- Death Valley National Park, Furnace Creek, CA)

Ecoregion report for Southern California and Eastern Sierra

ABSTRACT

This report summarizes conservation efforts undertaken by governmental agencies and others in the Southern California and Eastern Sierra, and describes the status of native populations. The geographic area generally includes the area of California south of the Tehachapi Mountains and the east side of the Sierra Nevada to Lake Tahoe.

The U.S. Fish and Wildlife Service (FWS) published a Petition to List the Santa Ana sucker *Catostomus santaanae* as Endangered. Although the sucker was described as common in the Los Angeles, San Gabriel, and Santa Ana River drainages in the 1970's, it has dramatically declined throughout significant portions of its range. The FWS published a Petition to List the Southern California population of the Mountain yellow-legged frog *Rana muscosa* as Endangered with Critical Habitat.

An ad hoc group of individuals working with southern California native fish issues has been meeting regularly since January 1996 to exchange information. The Southern California Native Fishes Workgroup is chaired by Dr. Tom Haglund and consists of representatives from federal and state governments, universities, and others with an interest in the issues.

The Santa Ana speckled dace, *Rhinichthys osculus* ssp., has experienced a drastic decline due to urbanization, diversions, and introduced species. Because it is yet to be described as a subspecies, the FWS rejected a petition to list it. A petition to list the Shay Creek stickleback, a distinct population of unarmored threespine stickleback, *Gasterosteus aculeatus williamsoni*, was also rejected by the FWS because it is considered an undescribed subspecies. Although technically a listed species, this population may be extirpated in its native meadow on private land due to habitat degradation.

Trapping surveys for desert pupfish, *Cyprinodon macularius*, in the Salton Sea area conducted by the Department of Fish and Game (DFG) continue to reveal that large populations of tilapia, *Tilapia* spp., are threatening desert pupfish populations in irrigation drains. Pupfish in southern Salton Sea drains are also jeopardized by irrigation district project proposals. The San Felipe Creek population is doing well, but tilapia are present in the section of creek designated as critical habitat. Salt Creek continues to support a small, but stable, desert pupfish population despite the presence of numerous mosquitofish, Gambusia affinis.

DFG trapping surveys revealed that Mohave tui chub, *Gila bicolor mohavensis*, are thriving in one of the ponds at the DFG's Camp Cady Wildlife Area. China Lake Naval Air Weapons Station received funding to compare the genetic variability among several subspecies of *Gila* including Mohave tui chub . Depending upon the results of this genetics study, the Mohave Tui Chub Advisory Committee may revise the Mohave tui chub Recovery Plan.

Native fish populations in Death Valley National Park (DVNP) and the Amargosa River are stable. However, the Longstreet Inn and golf course and proposed development of a 30,000 person resort community could affect

(* indicates author who presented paper at symposium) flows in Death Valley, Devils Hole, and the Amargosa River. DVNP has initiated studies to quantify the water movement into Death Valley from the upgradient aquifer. A DVNP-contracted study was recently completed for the Devils Hole pupfish, *Cyprinodon diabolis*, to investigate larval fish distribution. Monitoring wells will be installed by DVNP at Darwin Falls, Furnace Creek, and Amargosa River. Within two years DVNP anticipates funding to develop a mitigation plan/management facility at Badwater to protect the Badwater snail, *Assiminea infima*.

Owens pupfish, *Cyprinodon radiosus*, populations in the Owens Valley are stable, but not secure. Largemouth bass, *Micropterus salmoides*, are present in the Bureau of Land Management (BLM) pupfish refuge in Fish Slough; and no native fishes are present in the Owens Valley Native Fishes Sanctuary for the same reason. Owens tui chub, *Gila bicolor snyderi*, populations are stable with the exception of the upper Owens River gorge, where chubs have not been documented for five years. However, a reach of lower Owens River gorge, rewatered as the result of litigation, now contains a population of pure Owens tui chub confirmed by Dr. R.R. Miller in July 1997 which is subject to imminent threats. Attempts to move a number of chubs from the new population have been thwarted by the Los Angeles Department of Water and Power (LADWP). Owens dace, *Rhinichthys osculus* ssp., populations are stable with the exception of a population near Little Alkali Lake in Long Valley which has been invaded by mosquitofish. Hydrobiid snail, *Pyrgulopsis* and *Tryonia*, and Owens sucker, *Catostomus fumieventris*, populations remain stable in the Owens River Basin.

The FWS draft Owens Basin Wetland and Aquatic Species Recovery Plan (Plan) has not been finalized. However, the DFG has obtained Section 6 monies totaling $112,000 over three years to help implement the Plan. Given recent negative actions from LADWP and their livestock operator lessees, it appears that the recovery effort to restore native species, including Owens pupfish and Owens tui chub, to large areas of LADWP lands will be difficult.

Lahontan cutthroat trout, Oncorhynchus clarki henshawi, populations in the Walker River watershed are still in the process of being restored by the DFG. Small populations of Lahontan cutthroat trout are currently present in five streams. The Slinkard Creek population contains individuals which exhibit an unexplained spinal deformity which precludes their use for restocking purposes. The other native fishes of the Walker River watershed appear stable. The DFG is comparing the current distribution of native fish species with similar information obtained in the 1970's.

Reporte de la ecoregión del Sur de California y la parte este de la Sierra

RESUMEN

Este reporte resume los esfuerzos de conservación realizados por agencias gubernamentales y otras agencias al sur de California y este de Sierra, y describe el estado de las poblaciones nativas. El área geográfica generalmente incluye el área de California al sur de las montañas Tehachapi y al lado este desde la Sierra Nevada al lago Tahoe.

The U.S. Fish and Wildlife Service (FWS) publicó una solicitud para enlistar al matalote de Santa Ana *Catostomus santaanae* como en peligro. Aunque el matalote de Santa Ana fue descrito como muy común en los drenajes de Los Angeles, San Gabriel, y el río Santa Ana en los 70, este ha decaído dramáticamente a lo largo de las porciones significativas de su rango. The FWS publicó una solicitud para enlistar la población de la rana patas amarillas de montaña *Rana muscosa* del sur de California como en peligro y con hábitat crítico.

Desde enero de 1996 un grupo de individuos *ad hoc* que trabajan con los peces nativos del sur de California se ha estado reuniendo regularmente para intercambiar información. El Grupo de Trabajo para los Peces Nativos del Sur de California esta presidido por el Dr. Tom Haglund y consiste de representantes del gobierno federal y estatal, universidades, y otros con intereses en el tema.

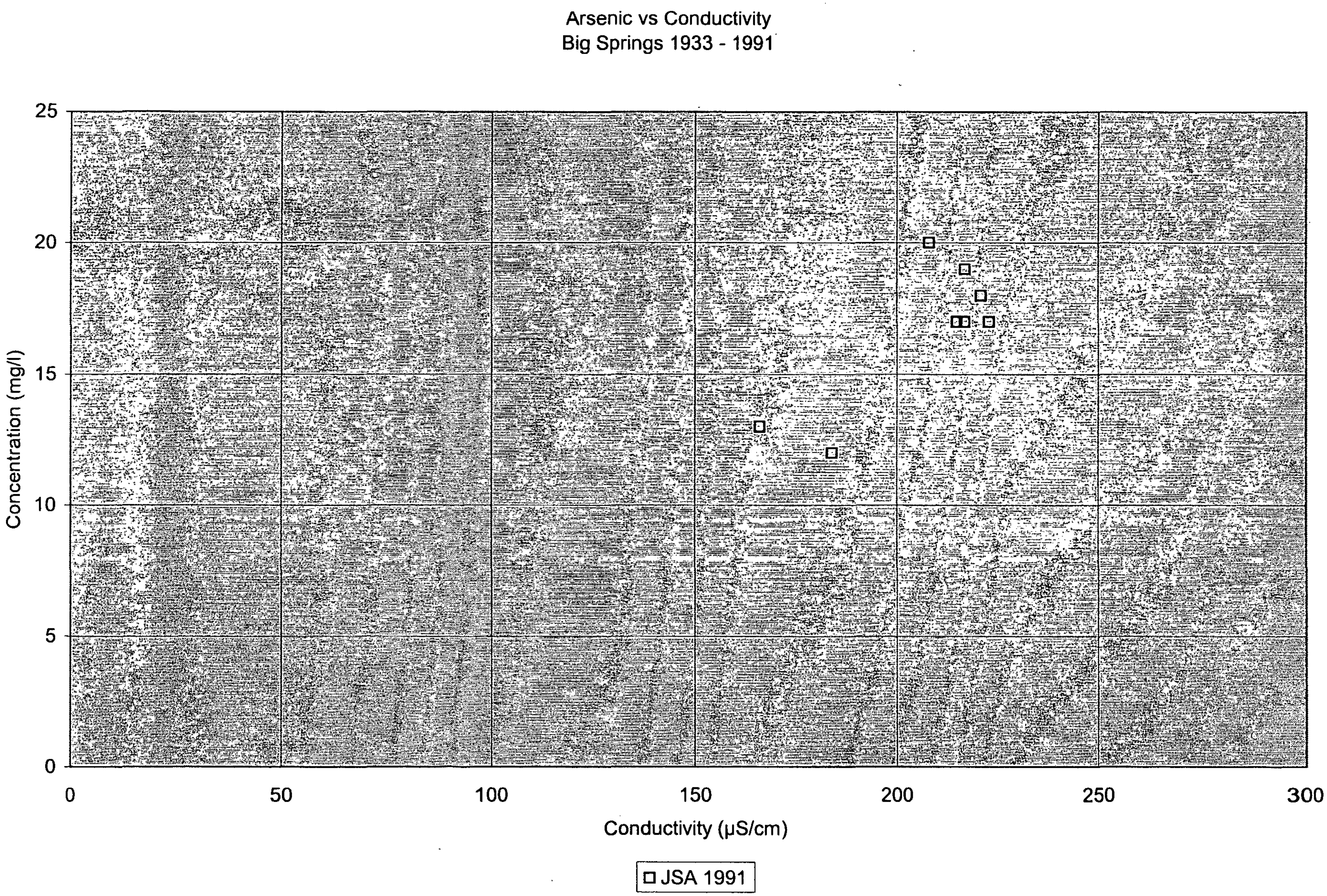
La carpa pinta de Santa Ana, *Rhinichthys osculus* ssp., ha experimentado un decrecimiento drástico debido a la urbanización, desviaciones y a las especies introducidas. Debido a que esta aún no ha sido descrita como una subespecie, la FWS rechazó la solicitud para enlistarla. Una solicitud para enlistar el espinocho de la quebrada Shay, una población distinta del espinocho, *Gasterosteus aculeatus williamsoni*, también fue rechazada por el FWS ya que es considerada una subespecie no descrita. Aunque técnicamente es una especie enlistada, esta población puede ser extirpada de su llanura nativa en tierras privadas debido a la degradación del hábitat.

Se continúan los censos por trampeo del cachorrito del desierto, *Cyprinodon macularius*, dirigidos por el Department of Fish and Game (DFG) en el área de Salton Sea. Estos trabajos revelan que las poblaciones de tilapia, *Tilapia* spp., están amenazando las poblaciones de cachorrito del desierto en los desaguaderos de

(* indicates author who presented paper at symposium)

Data from

Los Angeles Department of
Water and Power



Arsenic vs Conductivity
Big Springs 1933 - 1991
Concentration (mg/l)
25
20
15
10
5
0
0
50
100
150
200
250
300
Conductivity (µS/cm)
JSA 1991

OWENS RIVER at Benton Crossing

Comments: Flow Data from 1940 was not merged since no Chemical data was collected

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The following data was collected by Los Angeles Department of Water and Power

FIELD DATA ---->

Sampling Date	Flow cfs	As µg/l
Feb-73	104.1	100
Nov-82	153.3	60
Dec-82	145.2	
Jan-83	138.1	70
Feb-83	127.0	
Mar-83	137.5	
Apr-83	135.2	70
May-83	226.5	100
Jun-83	455.7	30
Jul-83	402.9	40
Aug-83	266.9	30
Sep-83	196.3	90
Oct-83	184.3	60
Nov-83	174.2	40
Dec-83	169.7	
Jan-84	169.3	
Feb-84	150.7	
Mar-84	160.6	
Apr-84	255.6	40
May-84	485.3	30
Jun-84	495.2	30
Jul-84	347.3	20
Aug-84	169.1	80
Sep-84	169.1	100
Oct-84	311.4	40
Nov-84	300.5	40
Dec-84	259.4	
Jan-85	152.4	70
Feb-85	277.9	
Mar-85	324.2	30
Apr-85	329.8	20
May-85	315.6	40
Jun-85	337.8	20
Jul-85	289.0	20
Aug-85	276.2	30
Sep-85	329.5	30
Oct-85	302.7	
Nov-85	289.3	20
Dec-85	195.5	50
Jan-86	191.7	90
Feb-86	165.3	60
Mar-86	159.0	100
Apr-86	175.6	40
May-86	274.9	50
Jun-86	376.4	30
Jul-86	228.8	40
Aug-86	211.3	70
Sep-86	320.0	70
Oct-86	322.2	40
Nov-86	217.8	70
Dec-86	221.6	170
Jan-87	332.6	60
Feb-87	284.6	50
Mar-87	233.0	40
Apr-87	178.0	80
May-87	319.1	40
Jun-87	224.2	40
Jul-87	131.4	70
Aug-87	117.1	60
Sep-87	111.3	90
Oct-87	114.2	100
Nov-87	144.2	100
Dec-87	235.6	50
Jan-88	238.6	50
Feb-88	209.4	60
Mar-88	185.6	70
Apr-88	179.1	30
May-88	198.0	70
Jun-88	228.7	10
Jul-88	178.3	30
Aug-88	168.5	70

Sep-88	173.5	50
Oct-88	173.1	80
Nov-88	158.4	70
Dec-88	154.6	50
Jan-89	150.0	50
Feb-89	155.6	40
Mar-89	185.8	60
Apr-89	173.9	60
May-89	267.6	40
Jun-89	218.0	30
Jul-89	102.9	70
Aug-89	99.4	100
Sep-89	95.7	90
Oct-89	101.4	80
Nov-89	99.1	90
Dec-89	100.4	90
Jan-90	100.3	90
Feb-90	93.1	100
Mar-90	99.3	80
Apr-90	100.7	50
May-90	107.4	100
Jun-90	121.7	90
02-May-91		
17-May-91		
05-Jun-91		
21-Jun-91		
12-Jul-91		
25-Jul-91		
15-Aug-91		
29-Aug-91		

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STATISTICS:	Lab As µg/l
Samples (n)	83
Mean	60
Minimum (0% IQR)	10
25% IQR	40
Median (50% IQR)	60
75% IQR	80
Maximum (100% IQF	170
Detection Limit	
% > Detection Limit	

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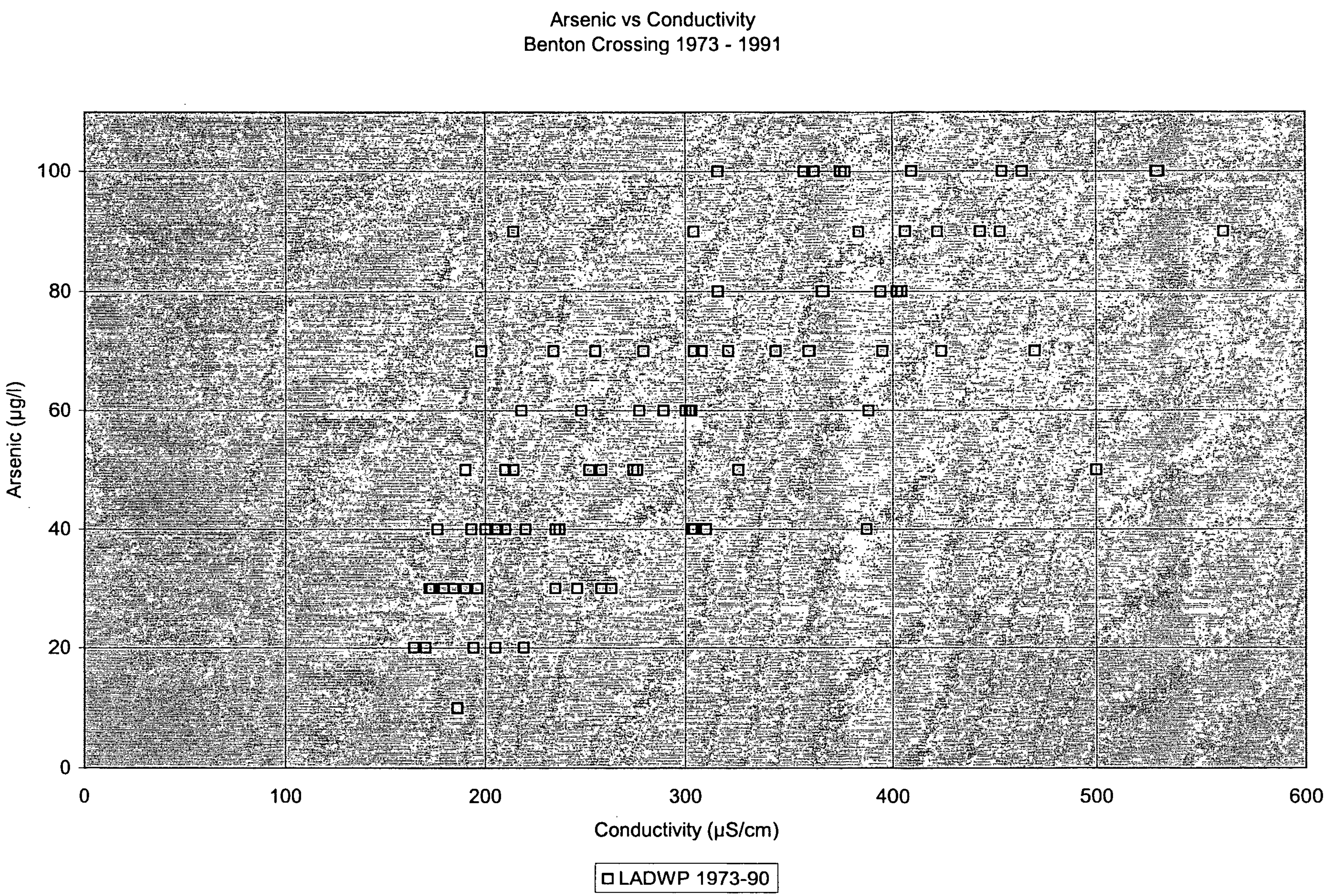


Arsenic vs Conductivity
Benton Crossing 1973 - 1991
Arsenic (µg/l)
0
20
40
60
80
100
0
100
200
300
400
500
600
Conductivity (µS/cm)
LADWP 1973-90

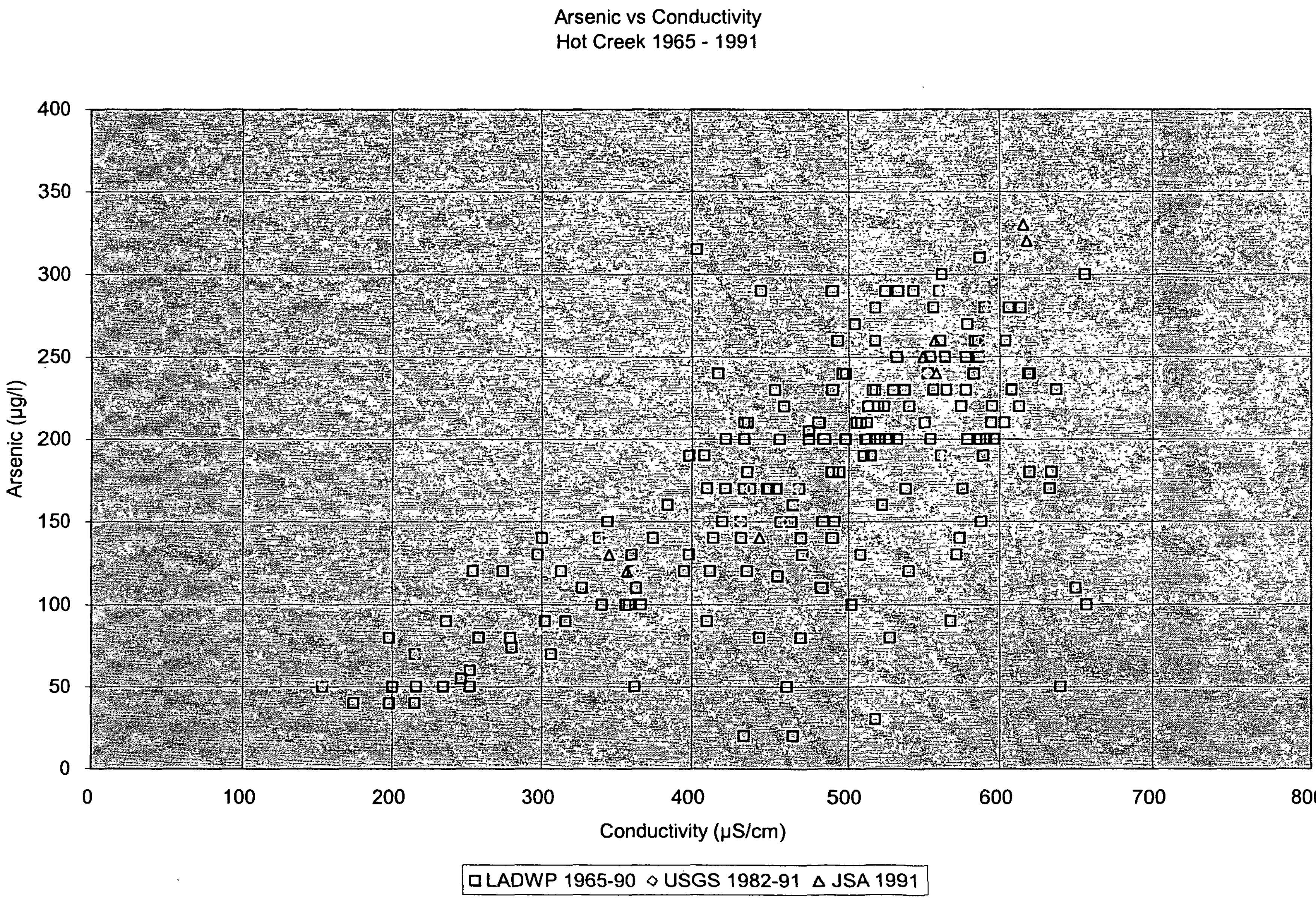
DWP files not used

— BELOW-ETP.WK1 (older than 1989)

~~[illegible].WK1~~ —

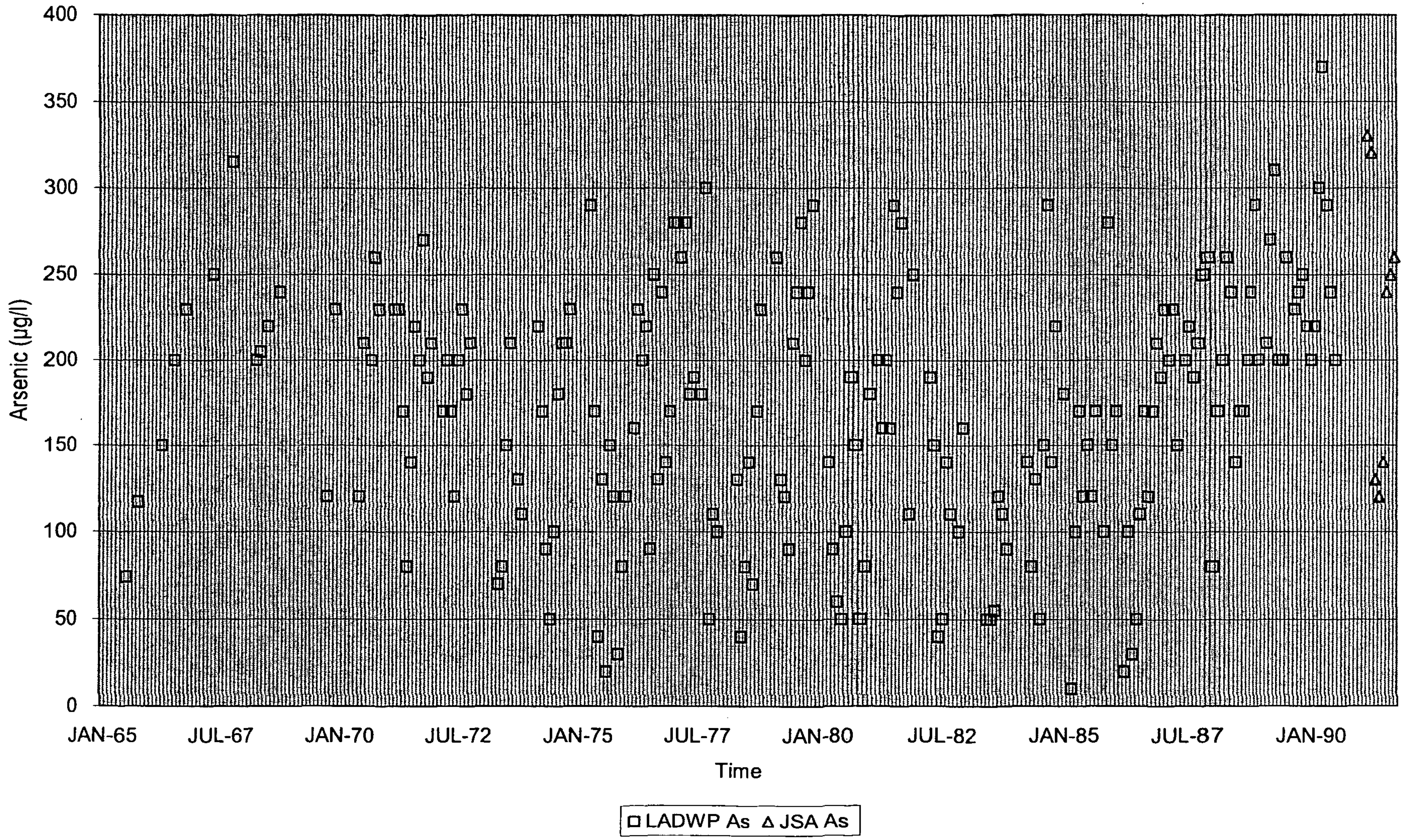
CONVICT.WK1

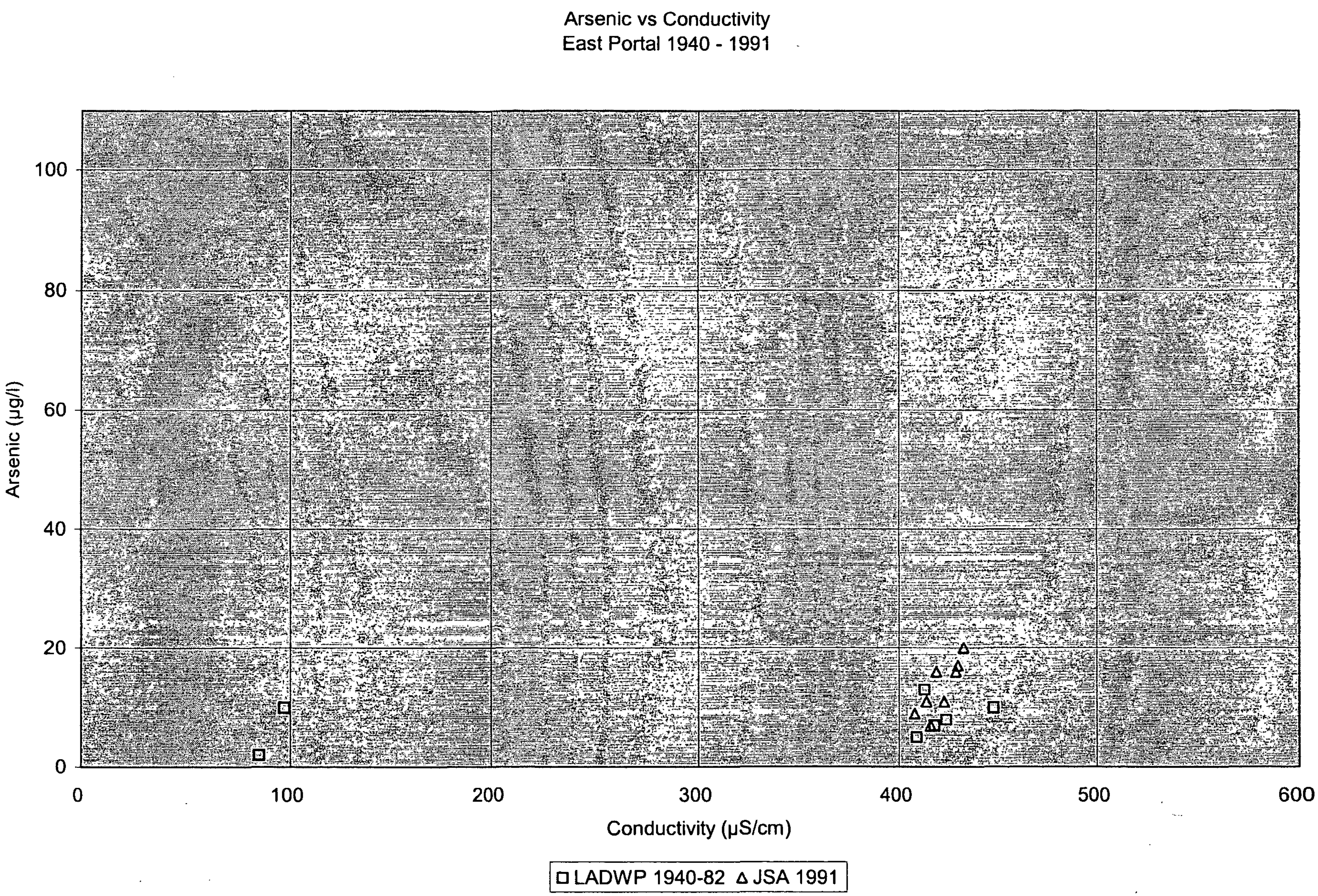
CROOKED

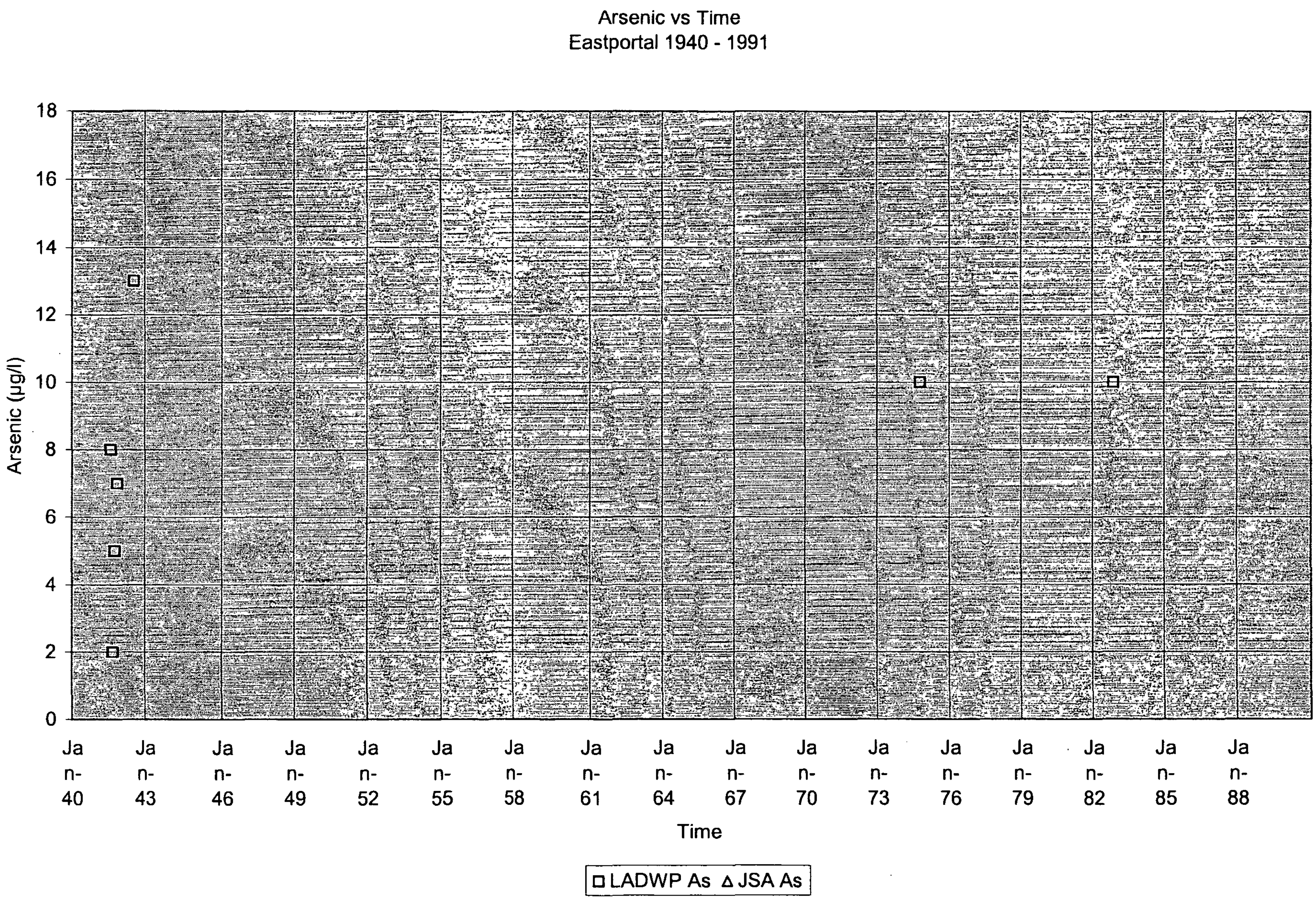


Arsenic vs Conductivity
Hot Creek 1965 - 1991
Arsenic (µg/l)
0
50
100
150
200
250
300
350
400
0
100
200
300
400
500
600
700
800
Conductivity (µS/cm)
LADWP 1965-90
USGS 1982-91
JSA 1991

Arsenic vs Time
Hot Creek 1965 - 1991




Arsenic vs Conductivity
East Portal 1940 - 1991
Arsenic (µg/l)
0
20
40
60
80
100
0
100
200
300
400
500
600
Conductivity (µS/cm)
LADWP 1940-82
JSA 1991


Arsenic vs Time
Eastportal 1940 - 1991
Arsenic (µg/l)
18
16
14
12
10
8
6
4
2
0
Jan-40
Jan-43
Jan-46
Jan-49
Jan-52
Jan-55
Jan-58
Jan-61
Jan-64
Jan-67
Jan-70
Jan-73
Jan-76
Jan-79
Jan-82
Jan-85
Jan-88
Time
LADWP As
JSA As

Mar-56	241.6	0.60	0.7	60
Apr-56	325.2	0.47	0.6	42
May-56	505.8	0.57	0.6	46
Jun-56	421.0	0.48	0.6	52
Jul-56	388.4	0.45	0.5	34
Aug-56	431.4	0.38	0.4	40
Sep-56	122.1	0.44	0.6	32
Oct-56	385.3	0.65	0.5	28
Nov-56	271.3	0.49	0.5	47
Dec-56	263.7	0.67	0.6	39
Jan-57	252.9	0.73	0.9	51
Feb-57	199.9	0.94	0.8	63
Mar-57	289.1	0.71	0.7	41
Apr-57	233.5	0.70	0.6	51
May-57	502.8	0.56	0.7	38
Jun-57	304.9	0.72	0.7	22
Jul-57	374.8	0.73	0.7	33
Aug-57	364.6	0.72	0.6	35
Sep-57	224.4			
Oct-57	127.7			
Nov-57	161.7	0.61	0.6	29
Dec-57	316.2	0.78	0.8	40
Jan-58	347.3	0.88	0.9	24
Feb-58	358.5	0.88	0.8	19
Mar-58	373.8	0.98	0.8	18
Apr-58	380.0	0.55	0.6	22
May-58	259.7	0.70	0.9	36
Jun-58	119.2	0.78	0.6	12
Jul-58	233.0	0.70	0.8	46
Aug-58	349.8	0.72	0.7	36
Sep-58	190.1			
Oct-58	321.9	0.68	0.7	39
Nov-58	406.9	0.81	0.8	33
Dec-58	348.7	0.59	0.6	24
Jan-59	214.8			
Feb-59	74.7			
Mar-59	418.5	1.16	0.8	46
Apr-59	441.1	0.77	0.6	22
May-59	374.3	0.66	0.6	19
Jun-59	375.5	0.68	0.6	32
Jul-59	476.1	0.76	0.67	4
Aug-59	603.8	0.58	0.63	27
Sep-59	583.5	0.58	0.54	28
Oct-59	18.8			
Nov-59	329.3	1.16	0.61	33
Dec-59	331.3	0.46	0.63	22
Jan-60	313.5	0.78	0.62	25
Feb-60	307.3	0.91	0.97	38
Mar-60	328.4	0.80	0.96	55
Apr-60	314.8	0.80	0.70	30
May-60	309.6	0.85	0.66	25
Jun-60	276.7			

Jul-60	357.2	0.55	0.64	32
Aug-60	314.6	0.52	0.54	28
Sep-60	288.1	0.71	0.54	28
Oct-60	122.4			
Nov-60	261.1	0.81	0.64	35
Dec-60	225.7	0.76	0.66	35
Jan-61	196.3	0.76	0.70	41
Feb-61	144.4	0.74	0.64	38
Mar-61	182.8	0.72	0.60	34
Apr-61	172.6	0.88	0.74	48
May-61	258.5	0.92	0.72	47
Jun-61	209.8	0.72	0.73	45
Jul-61	276.6	0.87	0.76	28
Aug-61	382.0	0.84	0.71	
Sep-61	398.7	0.69	0.67	22
Oct-61	380.8	0.76	0.73	38
Nov-61	44.7			
Dec-61	198.4			
Jan-62	247.7	0.82	0.79	
Feb-62	111.1	0.58	0.60	
Mar-62	55.1			
Apr-62	154.2			
May-62	416.9	0.96	0.78	
Jun-62	258.5	0.81	0.79	
Jul-62	290.4	0.59	0.77	
Aug-62	600.6	0.64	0.62	
Sep-62	606.4	0.63	0.57	
Oct-62	385.6	0.66	0.65	
Nov-62	312.5	0.60	0.62	
Dec-62	310.5	0.59	0.62	
Jan-63	279.9	0.64	0.45	
Feb-63	68.9			
Mar-63	108.3			
Apr-63	244.4		0.62	
May-63	441.7	0.73	0.73	
Jun-63	178.3			
Jul-63	269.9	0.60	0.74	
Aug-63	528.1		0.67	
Sep-63	224.6			
Oct-63	544.2	0.56	0.63	
Nov-63	464.8		0.60	
Dec-63	403.5	0.57	0.68	
Jan-64	341.7			
Feb-64	280.4	0.57	0.76	
Mar-64	58.6	0.46	0.54	
Apr-64	340.4	0.65	0.62	13
May-64	335.8	0.62	0.71	
Jun-64	256.5	0.58	0.61	
Jul-64	234.7	0.66	0.63	
Aug-64	324.9	0.63	0.60	
Sep-64	536.5	0.72	0.70	
Oct-64	405.1	0.73	0.61	

Nov-64	214.7	0.57	0.87	
Dec-64	146.8	0.66	0.62	
Jan-65	245.6	0.69	0.86	
Feb-65	433.0	0.74	0.75	
Mar-65	216.4			
Apr-65	479.6	0.64	0.73	
May-65	359.6	0.61	0.70	
Jun-65	257.4		0.64	
Jul-65	186.7	0.45	0.51	
Aug-65	221.1	0.47	0.66	
Sep-65	460.8	0.45	0.53	
Oct-65	244.9	0.74	0.55	
Nov-65	186.1	0.57	0.54	
Dec-65	197.5	0.65	0.66	
Jan-66	193.5	0.75	0.63	
Feb-66	178.0	0.97	0.68	
Mar-66	212.9	1.3	1.00	
Apr-66	460.6	0.66	0.65	
May-66	460.0	0.61	0.62	
Jun-66	493.9	0.65	0.67	
Jul-66	531.2	0.51	0.52	
Aug-66	571.2	0.57	0.53	
Sep-66	515.2	0.54	0.67	
Oct-66	116.9			
Nov-66	274.7	0.62	0.57	
Dec-66	82.6			
Jan-67	316.3	0.59	0.73	
Feb-67	336.3	0.97	0.73	
Mar-67	131.3			
Apr-67	486.3	0.79	0.79	
May-67	505.8	0.70	0.80	
Jun-67	106.2	0.65	0.67	
Jul-67	244.5	0.65	0.61	
Aug-67	498.6	0.65	0.60	
Sep-67	371.4	0.67	0.44	
Oct-67	244.6	0.60	0.52	
Nov-67	306.3	0.54	0.57	
Dec-67	347.1	0.55	0.70	
Jan-68	268.2			
Feb-68	253.3	0.82	0.84	
Mar-68	245.2	0.59	0.60	
Apr-68	388.8	0.69	0.72	
May-68	365.8	0.68	0.57	
Jun-68	253.7	0.63	0.31	
Jul-68	414.4	0.60	0.67	
Aug-68	414.1	0.68	0.62	
Sep-68	324.4	0.43	0.62	
Oct-68	76.1			
Nov-68	204.6			
Dec-68	320.3	0.53	0.64	
Jan-69	225.7	1.14	0.47	100
Feb-69	244.3	1.10	0.92	70

Mar-69	566.9	1.20	1.10	70
Apr-69	704.2	1.23	1.07	70
May-69	634.8	0.62	0.62	
Jun-69	677.3	0.58	0.53	
Jul-69	395.6	0.36	0.49	
Aug-69	326.2	0.40	0.47	
Sep-69	266.7	0.45	0.43	
Oct-69	328.2	0.64	0.65	
Nov-69	451.6	0.57	0.56	
Dec-69	283.8	0.61	0.55	50
Jan-70	275.7	0.70	0.78	50
Feb-70	261.4	0.82	0.75	20
Mar-70	283.5			
Apr-70	373.6	0.55	0.68	
May-70	319.3	0.63	0.69	
Jun-70	521.3	0.56	0.72	70
Jul-70	501.9	0.40	0.65	
Aug-70	622.3	0.57	0.72	
Sep-70	595.1	0.35	0.59	70
Oct-70	131.0			
Nov-70	463.5	0.63	0.60	40
Dec-70	506.5	0.59	0.61	40
Jan-71	218.6	0.71	0.67	50
Feb-71	121.0			
Mar-71	162.3			
Apr-71	401.1	0.61	0.72	40
May-71	512.1	0.71	0.69	40
Jun-71	493.8	0.60	0.73	40
Jul-71	448.8	0.70	0.70	60
Aug-71	606.2	0.53	0.64	60
Sep-71	321.3	0.57	0.57	50
Oct-71	403.9		0.61	60
Nov-71	481.6	0.50	0.49	30
Dec-71	152.3			
Jan-72	92.6	0.46	0.63	30
Feb-72	100.4			
Mar-72	396.8	0.80	0.76	40
Apr-72	539.9	0.73	0.70	40
May-72	607.9	0.52	0.80	40
Jun-72	495.4	0.65	0.65	50
Jul-72	548.9	0.64	0.63	30
Aug-72	616.9	0.56	0.54	40
Sep-72	582.4	0.56	0.60	30
Oct-72	351.9	0.59	0.66	40
Nov-72	207.2	0.58	0.59	40
Dec-72	209.0	0.72	0.72	40
Jan-73	93.7	0.66	0.69	30
Feb-73	167.8	0.66	0.67	40
Mar-73	126.8	1.1	0.98	80
Apr-73	318.7	0.82	0.61	50
May-73	226.5	0.50	0.48	30
Jun-73	86.8	0.57	0.64	40

Jul-73	331.2	0.64	0.49	50
Aug-73	612.0	0.52	0.50	30
Sep-73	676.9	0.52	0.58	40
Oct-73	595.0	0.50	0.56	40
Nov-73	378.7	0.55	0.57	40
Dec-73	167.6	0.58	0.60	30
Jan-74	144.4	0.52	0.58	10
Feb-74	222.8	0.70	0.73	50
Mar-74	219.7	0.55	0.64	30
Apr-74	505.0	0.60	0.63	10
May-74	547.1	0.51	0.65	30
Jun-74	430.8	0.46	0.56	20
Jul-74	457.1	0.47	0.53	60
Aug-74	554.0	0.42	0.54	40
Sep-74	628.6	0.41	0.47	40
Oct-74	446.6	0.43	0.50	30
Nov-74	262.3	0.38	0.55	40
Dec-74	274.1	0.41	0.50	30
Jan-75	177.5	0.50	0.58	40
Feb-75	120.7	0.53	0.65	50
Mar-75	156.5	0.47	0.72	40
Apr-75	427.2	0.48	0.70	20
May-75	534.1	0.46	0.77	50
Jun-75	488.5	0.43	0.65	30
Jul-75	503.9	0.42	0.65	30
Aug-75	564.3	0.40	0.54	30
Sep-75	453.4	0.37	0.48	30
Oct-75	397.6	0.55	0.55	30
Nov-75	365.1	0.41	0.57	20
Dec-75	423.7	0.35	0.56	10
Jan-76	330.6	0.51	0.61	20
Feb-76	391.3	0.48	0.55	30
Mar-76	305.1	0.49	0.54	30
Apr-76	414.2	0.50	0.62	30
May-76	283.5	0.50	0.62	40
Jun-76	447.8	0.59	0.65	40
Jul-76	585.0	0.48	0.68	30
Aug-76	664.8	0.53	0.65	50
Sep-76	422.5	0.52	0.65	30
Oct-76	233.5	0.55	0.68	30
Nov-76	377.5	0.58	0.53	10
Dec-76	375.2	0.66	0.76	30
Jan-77	98.8			
Feb-77	99.4	0.44	0.63	20,
Mar-77	187.4			
Apr-77	121.2	0.69	0.88	60
May-77	110.2	0.70	0.80	20
Jun-77	153.2	0.68	0.88	40
Jul-77	172.9	0.71	0.91	50
Aug-77	200.5	0.70	0.87	30
Sep-77	156.7	0.72	0.93	80
Oct-77	117.6	0.92	0.88	70

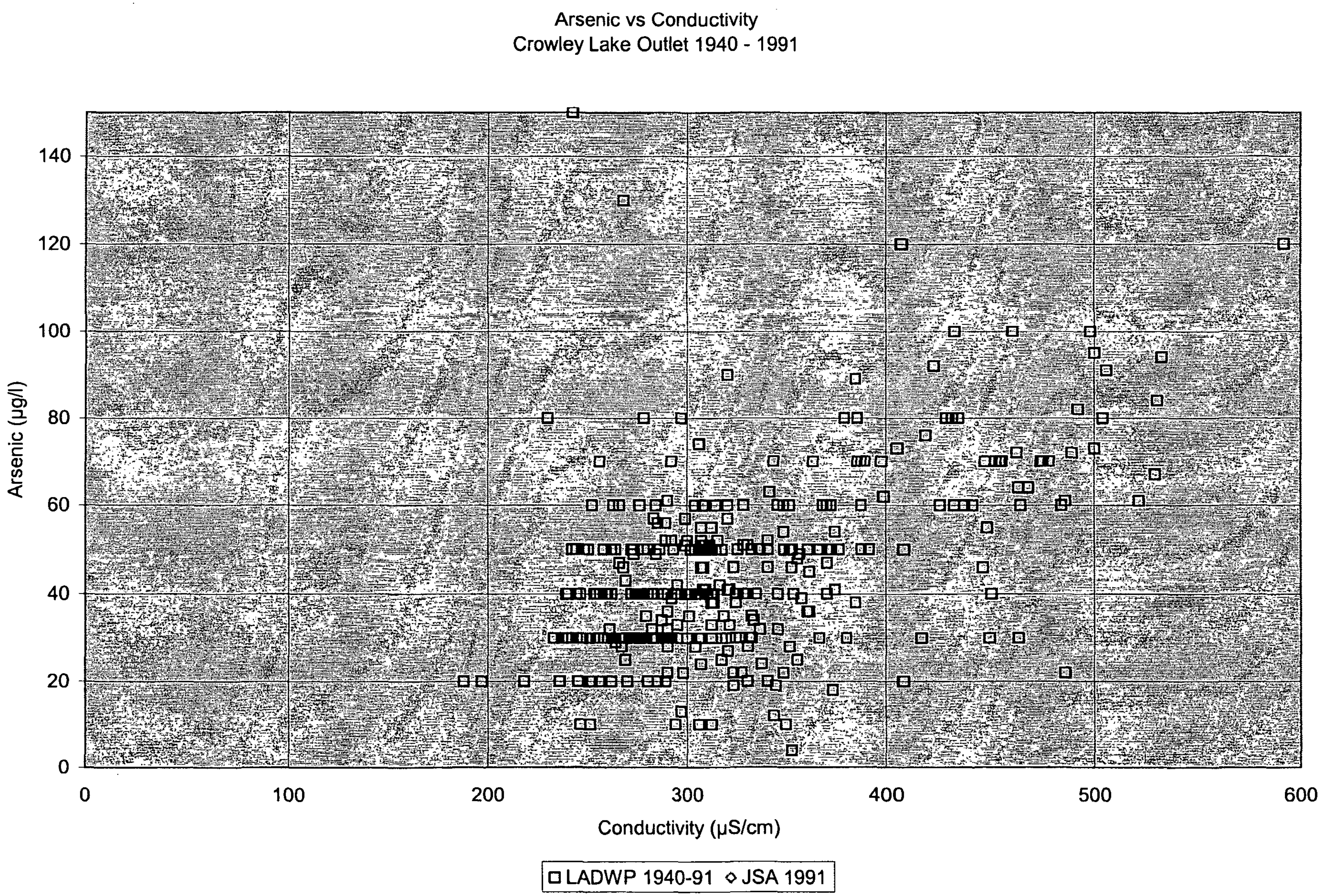
Nov-77	147.6	1.0	0.89	20
Dec-77	324.0	0.96	0.95	30
Jan-78	220.4	1.1	1.10	30
Feb-78	109.1			
Mar-78	166.6	1.6	1.40	120
Apr-78	473.5	1.2	0.89	60
May-78	539.2	0.79	0.74	40
Jun-78	127.7	0.37	0.44	30
Jul-78	81.0			
Aug-78	256.0	0.50	0.45	80
Sep-78	484.5	0.52	0.51	30
Oct-78	561.3	0.53	0.45	30
Nov-78	504.4	0.48	0.49	50
Dec-78	499.9	0.54	0.44	40
Jan-79	577.4	0.68	0.54	40
Feb-79	451.7	0.67	0.54	80
Mar-79	437.2	0.92	0.68	90
Apr-79	98.1			
May-79	561.5	0.55	0.55	60
Jun-79	467.9	0.52	0.50	40
Jul-79	536.4	0.41	0.45	50
Aug-79	542.2	0.48	0.48	40
Sep-79	563.7	0.56	0.53	150
Oct-79	517.4	0.48	0.48	40
Nov-79	446.5	0.48	0.51	50
Dec-79	343.6	0.60	0.58	50
Jan-80	248.8	1.1	0.90	70
Feb-80	126.8	1.0	0.89	30
Mar-80	546.3	0.94	0.83	10
Apr-80	447.8	0.96	0.66	30
May-80	529.5	0.70	0.62	40
Jun-80	277.2	0.69	0.57	30
Jul-80	251.8		0.54	30
Aug-80	478.5		0.49	40
Sep-80	632.0		0.58	50
Oct-80	539.6		0.63	40
Nov-80	616.3		0.64	40
Dec-80	437.6		0.79	30
Jan-81	527.7		0.69	50
Feb-81	309.9		0.74	50
Mar-81	87.6			
Apr-81	249.2		0.65	30
May-81	496.7		0.61	50
Jun-81	376.4		0.69	40
Jul-81	508.0		0.69	40
Aug-81	570.5		0.67	50
Sep-81	636.2	0.63	0.71	50
Oct-81	259.0		0.57	40
Nov-81	530.9	0.68	0.78	30
Dec-81	534.4			
Jan-82	407.3		0.75	40
Feb-82	453.3		0.93	120

Mar-82	236.9			
Apr-82	482.2		0.79	80
May-82	316.5	0.72	0.71	60
Jun-82	243.1		0.38	20
Jul-82	369.8		0.48	30
Aug-82	455.7	0.56	0.50	30
Sep-82	528.5		0.41	30
Oct-82	467.6	0.45	0.48	30
Nov-82	498.2	0.54	0.54	
Dec-82	489.1			30
Jan-83	445.8			50
Feb-83	475.6			
Mar-83	626.3			
Apr-83	667.5			50
May-83	612.8			
Jun-83	317.0			
Jul-83	339.2			20
Aug-83	449.0			20
Sep-83	509.3			20
Oct-83	317.1			30
Nov-83	547.2		0.61	30
Dec-83	377.8			
Jan-84	547.6			
Feb-84	375.2			
Mar-84	325.5			
Apr-84	631.4			30
May-84	320.7			40
Jun-84	304.8			60
Jul-84	378.8			30
Aug-84	392.0			50
Sep-84	596.2			40
Oct-84	308.4			
Nov-84	210.5			
Dec-84	494.8			
Jan-85	361.9		0.83	40
Feb-85	399.0			
Mar-85	327.2	0.80	1.0	30
Apr-85	392.0		0.68	20
May-85	239.9		0.64	50
Jun-85	255.3		0.64	20
Jul-85	360.3		0.69	20
Aug-85	596.0		0.61	30
Sep-85	617.1	0.54	0.62	10
Oct-85	345.8		0.63	40
Nov-85	414.0		0.55	20
Dec-85	235.0		0.65	20
Jan-86	337.1		0.85	60
Feb-86	279.6		0.91	60
Mar-86	459.4	1.6	1.3	70
Apr-86	602.3		0.76	40
May-86	404.5		0.72	30
Jun-86	237.9		0.74	30

Jul-86	288.4		0.68	30
Aug-86	358.4		0.64	50
Sep-86	594.8	0.49	0.55	60
Oct-86	462.8		0.58	40
Nov-86	343.7		0.64	50
Dec-86	380.1		0.58	130
Jan-87	259.1		0.56	50
Feb-87	412.3		0.67	50
Mar-87	351.5	0.68	0.62	40
Apr-87	214.1		0.51	40
May-87	133.8		0.67	40
Jun-87	373.8		0.70	40
Jul-87	533.6		0.70	50
Aug-87	553.6		0.66	50
Sep-87	274.0	0.55	0.70	50
Oct-87	109.3		0.86	60
Nov-87	92.9		0.85	60
Dec-87	268.0		1.00	60
Jan-88	246.4		0.77	50
Feb-88	311.9		0.78	70
Mar-88	435.4	0.82	0.80	60
Apr-88	258.9		0.70	30
May-88	161.2		0.75	60
Jun-88	197.8		0.80	40
Jul-88	364.1		0.90	50
Aug-88	470.5		0.90	50
Sep-88	164.4	0.56	0.83	50
Oct-88	128.3		0.81	50
Nov-88	170.6		0.89	70
Dec-88	207.4		1.00	50
Jan-89	441.9		0.84	50
Feb-89	198.8		1.10	60
Mar-89	227.2	0.95	0.85	60
Apr-89	156.7		0.82	70
May-89	154.6		0.97	50
Jun-89	195.7		0.79	50
Jul-89	520.6		1.0	60
Aug-89	352.8		0.89	80
Sep-89	202.9	1.1	1.1	70
Oct-89	80.3		0.84	60
Nov-89	107.2		0.80	60
Dec-89	96.0		0.90	40
Jan-90	106.8		1.0	60
Feb-90	96.9		1.0	22
Mar-90	105.0	1.4	1.1	70
Apr-90	75.1		1.2	100
May-90	189.8		1.2	70
Jun-90	104.7		1.1	70
Jul-90	127.5		1.1	60
Aug-90	135.5		1	100
Sep-90	92.1	1.4	0.98	30
Oct-90			1	72

Nov-90			1	64	
Dec-90			1	64	
Jan-91			1	95	
Feb-91			1.2	84	
Mar-91		1.32	1.21	61	
Apr-91	308	1.32	1.24	72	
May-91	362	1.42	1.3	82	
Jun-91	333	1.49	0.44	91	
Jul-91		1.49	1.02	67	
Aug-91	343	1.44	0.98	61	
Sep-91	325	1.45	1.04	80	
Oct-91	301	1.35	1.07	70	
Nov-91	297	0.86	0.95	73	
Dec-91	289	0.83	0.92	94	
May-91					110
May-91					110
Jun-91					77
Jun-91					94
Jul-91					92
Jul-91					98
Aug-91					70
Aug-91					90
Sep-91					110
Sep-91					90

STATISTICS:	Lab TDS mg/l	Lab B mg/l	Lab F mg/l	Lab As µg/l	Lab As µg/l
Samples (n)	8	445	542	343	10
Mean		0.73	0.71	44	94
Minimum (0% IQR)		0.31	0.31	4	70
25% IQR		0.57	0.60	30	90
Median (50% IQR)		0.69	0.70	40	94
75% IQR		0.85	0.80	51	110
Maximum (100% IQR)		1.6	1.4	150	110
Detection Limit					4
% > Detection Limit					100



Arsenic vs Conductivity
Crowley Lake Outlet 1940 - 1991
Arsenic (µg/l)
Conductivity (µS/cm)
0
20
40
60
80
100
120
140
0
100
200
300
400
500
600
LADWP 1940-91
JSA 1991

HOT CREEK at County Road at bridge

Comments: All flows were measured at County Road

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The following data was collected by Los Angeles Department of Water and Power

FIELD DATA ---->

Sampling Date	Flow cfs	EC µS/cm	Temp. °C	SO4 mg/l	B mg/l	F mg/l	As µg/l	Fe µg/l
JAN-65	47.6							
FEB-65	39.0							
MAR-65	44.2							
APR-65	48.3							
MAY-65	59.5	466	27.5	26		1.60		200
JUN-65	119.5	269	20.5	11		0.87		150
JUL-65	120.7	280	21.0	12	0.90	0.84	74	50
AUG-65	97.9	213	18.0	8.6		0.67		100
SEP-65	69.3	404	23.5	18		1.40		30
OCT-65	60.2	456	24.0	20	1.6	1.70	117	10
NOV-65	56.3							
DEC-65	52.2							
JAN-66	50.8							
FEB-66	42.0							
MAR-66	50.1							
APR-66	51.8	485	22.0	24	1.9	1.90	150	20
MAY-66	77.8	343	22.0	16		1.30		40
JUN-66	70.9	380	23.5	17		1.50		40
JUL-66	50.1	518	30.5	23		2.10	200	20
AUG-66	43.8	562	33.0	23	2.1	2.40		10
SEP-66	42.1	560	25.5	24		2.30		40
OCT-66	43.5	537	25.0	26	2.0	2.00	230	100
NOV-66	40.4	584	28.0	26	2.3	2.30		40
DEC-66	53.1							
JAN-67	43.7							
FEB-67	41.0							
MAR-67	53.7							
APR-67	54.7							
MAY-67	86.0	564	28.5	18		1.60	250	60
JUN-67	166.0	250	14.0	8.6	1.9	1.20		60
JUL-67	210.9	238	17.5	8.2	0.81	1.20		60
AUG-67	111.9	304	20.5	12	0.55	0.81		100
SEP-67	88.7	340	21.5	16		1.10		50
OCT-67	72.1	403	21.0	20		1.20	315	30
NOV-67	61.5	454	24.0	19	1.5	1.50		50
DEC-67	57.9							
JAN-68	54.9							

FEB-68	51.2							
MAR-68	50.1							
APR-68	47.7	532	24.0	29		2.10	200	30
MAY-68	56.4	476	23.5	21	2.1	1.60	205	150
JUN-68	62.8	503		28		1.82		70
JUL-68	47.0	524	30.0	27	1.7	2.02	220	200
AUG-68	43.2	524	26.0	21		2.10		10
SEP-68	40.1	517	29.0	27		2.10		10
OCT-68	41.4	498	25.5	32	2.0	2.00	240	60
NOV-68	42.5	456	22.0	26		2.10		60
DEC-68	42.1							
JAN-69	42.1							
FEB-69	38.7							
MAR-69	48.7							
APR-69	71.0							
MAY-69	193.9	207	13.0	12	0.53	0.52		60
JUN-69	272.0	188	14.0	9.5	0.53	0.49		60
JUL-69	213.6	198	19.5	10	0.56	0.55		100
AUG-69	124.0	279	21.0	19		0.86		40
SEP-69	84.5	362	22.5	19		1.20		100
OCT-69	80.7	274	18.5	23	1.0	1.50	120	60
NOV-69	65.1	460	20.5	30		1.70		10
DEC-69	61.7	490	22.5	26		2.10	230	10
JAN-70	62.6							
FEB-70	54.9							
MAR-70	60.2	482	21.0	23		1.40		40
APR-70	59.4	474	21.5	30	1.7	1.90		10
MAY-70	78.9	404	23.5	21	1.7	1.50		30
JUN-70	113.8	313	21.5	15	1.0	1.20	120	10
JUL-70	87.4	434	28.5	23	1.2	1.70	210	10
AUG-70	58.2	502	26.0	27	1.7	2.00		10
SEP-70	53.3	485	26.0	33	1.8	1.80	200	40
OCT-70	53.0	493	24.5	27	1.9	2.00	260	100
NOV-70	53.8	518	25.0	30	2.3	2.00	230	20
DEC-70	54.5							
JAN-71	51.6							
FEB-71	45.8							
MAR-71	49.2	530	23.5	28	1.0	2.00	230	30
APR-71	45.2	556	26.0	30	2.5	2.60	230	10
MAY-71	70.5	434	23.5	23	1.8	1.50	170	20
JUN-71	102.0	279	20.5	17	0.91	0.90	80	40
JUL-71	72.4	374	26.5	24	1.3	1.40	140	30
AUG-71	52.0	520	30.5	28	2.0	2.10	220	10
SEP-71	45.6	521	26.0	28		2.10	200	100
OCT-71	49.5	504	22.0	26	1.9	2.00	270	40
NOV-71	49.2	515	21.5	26	1.7	1.90	190	20
DEC-71	45.2	550	21.0	29	2.2	2.10	210	30
JAN-72	45.4							
FEB-72	41.6							
MAR-72	46.9	538	24.5	27	2.0	2.20	170	30
APR-72	42.2	532	23.0	27		2.10	200	10
MAY-72	52.5	450	26.5	28		2.10	170	40

JUN-72	76.9	395	26.5	21	1.6	1.50	120	20
JUL-72	44.7	527	32.5	26	2.1	2.30	200	20
AUG-72	38.4	578	32.0	30	2.2	2.50	230	60
SEP-72	47.1	490	26.0	26	1.7	1.80	180	200
OCT-72	47.2	508	24.5	25	1.6	1.70	210	10
NOV-72	44.1							
DEC-72	45.4							
JAN-73	45.6							
FEB-73	42.3							
MAR-73	44.7							
APR-73	60.0							
MAY-73	120.8	215	13.5	11	0.62	0.38	70	150
JUN-73	146.6	258	18.0	17	0.69	0.85	80	60
JUL-73	92.4	420	26.0	21	1.4	1.40	150	40
AUG-73	61.8	482	27.0	26	1.6	1.80	210	40
SEP-73	52.8	496	26.0	25	1.5	2.00		20
OCT-73	51.5	508	24.5	27	1.6	2.00	130	100
NOV-73	59.6	327	12.0	18	0.96	1.00	110	200
DEC-73	51.7							
JAN-74	52.1							
FEB-74	44.1							
MAR-74	50.4	513	23.0	24	1.7	2.00	220	60
APR-74	49.6	470	21.5	26	1.5	1.80	170	20
MAY-74	101.0	302	16.0	16	0.83	1.10	90	40
JUN-74	147.9	200	14.5	11	0.54	0.64	50	100
JUL-74	90.8	366	23.0	17	1.1	1.40	100	40
AUG-74	63.1	436	24.5	22	1.3	1.60	180	60
SEP-74	51.7	505	28.5	22	1.6	1.80	210	100
OCT-74	52.3	512	27.5	28	1.6	2.10	210	40
NOV-74	46.2	516	21.5	28	1.6	2.00	230	40
DEC-74	45.6							
JAN-75	45.3							
FEB-75	38.2							
MAR-75	44.8							
APR-75	43.0	490	26.0	25	1.4	2.20	290	40
MAY-75	78.0	438	22.0	20	1.1	2.00	170	100
JUN-75	153.8	174	14.0	9.4	0.35	0.55	40	200
JUL-75	94.0	398	25.0	22	1.2	1.30	130	30
AUG-75	59.4	434	23.0	22	1.0	1.40	20	100
SEP-75	53.9	465	24.5	24	1.1	1.50	150	30
OCT-75	59.7	436	20.0	19	0.71	1.80	120	
NOV-75	49.5	518	19.5	28	1.4	2.00	30	100
DEC-75	48.1	528	21.0	24	1.4	1.10	80	100
JAN-76	46.1	540	20.5	28	1.4	1.90	120	100
FEB-76	43.0							
MAR-76	48.4	523	25.5	26	1.2	2.20	160	600
APR-76	39.8	516	23.5	25	1.6	2.30	230	40
MAY-76	57.4	457	23.0	21	1.3	1.80	200	10
JUN-76	43.9	540	25.0	25	1.6	2.20	220	100
JUL-76	40.9	568	28.5	26	1.7	2.40	90	400
AUG-76	40.0	586	29.0	27	1.8	2.50	250	200
SEP-76	38.6	572	26.0	26	1.8	2.30	130	200

OCT-76	39.9	583	29.0	26	1.5	2.30	240	40
NOV-76	36.4	574	25.0	31	1.6	1.70	140	150
DEC-76	35.7	633	19.5	37	2.0	2.60	170	100
JAN-77	35.0	606	24.5	33	1.7	2.70	280	150
FEB-77	33.9	614	25.0	30	1.8	2.70	280	80
MAR-77	37.4	584	25.0	29	1.7	2.60	260	30
APR-77	34.8	590	24.5	30	1.9	2.50	280	300
MAY-77	30.2	634	22.0	28	2.0	2.30	180	100
JUN-77	41.5	561	29.0	29	1.5	2.30	190	200
JUL-77	36.9	672	27.0	33	1.9	2.70		40
AUG-77	34.0	620	31.5	33	1.8	2.50	180	20
SEP-77	34.3	656	25.0	33	1.9	2.70	300	80
OCT-77	34.2	640	31.0	33	2.2	2.60	50	20
NOV-77	32.1	650	24.5	35	2.9	2.40	110	80
DEC-77	32.2	657	27.0	35	2.9	2.70	100	100
JAN-78	31.5							
FEB-78	28.8							
MAR-78	34.1							
APR-78	53.2							
MAY-78	88.9	360	14.5	21	0.64	1.20	130	100
JUN-78	189.6	198	15.0	11	0.50	0.44	40	60
JUL-78	154.4	198	18.0	9.8	0.60	0.56	80	100
AUG-78	95.2	300	20.5	16	1.0	1.00	140	100
SEP-78	95.1	306	16.5	16	1.0	1.10	70	200
OCT-78	68.9	422	19.0	21	1.4	1.50	170	80
NOV-78	59.6	454	19.5	23	1.6	1.80	230	10
DEC-78	54.9							
JAN-79	58.2							
FEB-79	51.5							
MAR-79	57.6	518	24.5	28	1.2	1.80	260	100
APR-79	55.8	472	19.0	24	1.9	1.70	130	10
MAY-79	99.9	254	18.0	12	0.82	0.78	120	200
JUN-79	106.5	316	20.5	16	1.1	1.10	90	100
JUL-79	73.0	436	30.0	22	1.7	1.70	210	100
AUG-79	56.2	496	29.5	25	2.0	2.00	240	150
SEP-79	51.6	518	28.8	25	1.9	2.00	280	40
OCT-79	48.3	511	26.0	26	1.9	1.90	200	200
NOV-79	44.6	552	19.5	30	2.0	2.00	240	20
DEC-79	44.4	560	21.2	28	2.5	2.20	290	30
JAN-80	51.3							
FEB-80	43.9							
MAR-80	47.0							
APR-80	60.3	414	18.0	20	1.6	1.40	140	20
MAY-80	99.8	236	16.0	12	0.64	0.70	90	30
JUN-80	175.6	252	18.0	12	1.1	0.74	60	30
JUL-80	179.1	234	22.2	9.2		0.78	50	20
AUG-80	95.4	356		16		1.11	100	10
SEP-80	69.0	398	25.5	20		1.40	190	10
OCT-80	61.1	432	20.5	21		0.56	150	30
NOV-80	52.4	462	19.8	23		1.98	50	10
DEC-80	51.3	471	21.0	24		2.10	80	10
JAN-81	50.2	494	18.0	23		2.00	180	10

FEB-81	47.1							
MAR-81	51.2	512	24.0	25	2.0	2.10	200	10
APR-81	49.1	466	24.5	22		1.80	160	10
MAY-81	67.6	422	22.0	20		1.60	200	10
JUN-81	78.0	384	22.0	18		1.40	160	10
JUL-81	52.8	533	27.5	26		2.10	290	10
AUG-81	45.3	552	28.5	24		2.30	240	10
SEP-81	45.1	556	27.0	28	2.3	3.80	280	10
OCT-81	47.8							
NOV-81	46.7	484	18.5	25	2.0	2.00	110	10
DEC-81	46.1	532	19.2	26	1.96	2.10	250	10
JAN-82	40.7							
FEB-82	41.0							
MAR-82	44.2							
APR-82	77.3	408	17.5	21		1.50	190	40
MAY-82	126.0	344	19.5	17	1.1	1.20	150	60
JUN-82	178.6	215	17.5	15		0.57	40	50
JUL-82	170.6	252	19.0	10		0.77	50	70
AUG-82	111.9	338	22.5	32		1.10	140	50
SEP-82	107.1				1.1	1.30	110	
OCT-82	98.2							
NOV-82	85.4				1.2	1.40	100	
DEC-82	74.6		16.5		1.6	0.52	160	
JAN-83	65.4							
FEB-83	59.8							
MAR-83	65.7							
APR-83	68.5							
MAY-83	122.6		19.0		1.3	0.57		
JUN-83	273.0					0.52	50	
JUL-83	245.9		18.0		0.4	0.51	50	
AUG-83	153.9		19.0		0.64	0.72	55	
SEP-83	104.2		22.2		1.60	1.10	120	
OCT-83	92.3		19.0		0.85	1.20	110	
NOV-83	82.7		17.5		1.0	1.35	90	
DEC-83	78.2							
JAN-84	77.6							
FEB-84	63.4							
MAR-84	71.6							
APR-84	65.8				1.2	1.50	140	
MAY-84	120.4				0.78	0.87	80	
JUN-84	128.1				1.1	1.10	130	
JUL-84	108.7				0.98	1.30	50	
AUG-84	77.6				1.4	1.60	150	
SEP-84	64.1				1.9	2.10	290	
OCT-84	71.5				1.6	1.40	140	
NOV-84	60.4				2.7	2.00	220	
DEC-84	59.0							
JAN-85	54.8		21.5		2.3	1.90	180	
FEB-85	50.1							
MAR-85	54.5		22.0		2.2	2.10	10	
APR-85	61.4		28.0		1.4	2.10	100	
MAY-85	82.6				1.4	1.60	170	

JUN-85	86.5		25.5		1.3	1.50	120	
JUL-85	63.5		30.0		1.4	2.00	150	
AUG-85	54.0		30.8		1.5	1.60	120	
SEP-85	54.2		28.0		1.3	2.10	170	
OCT-85	54.0							
NOV-85	50.8	502	27.0	28	1.6	2.20	100	10
DEC-85	52.6		26.0		1.5	2.10	280	
JAN-86	50.6	588	26.0		1.8	2.20	150	
FEB-86	47.7		25.0		2.0	2.20	170	
MAR-86	62.0							
APR-86	81.8	466	25.0	26	1.5	1.70	20	20
MAY-86	138.3	358	17.5		1.0	1.10	100	
JUN-86	225.9		22.8		0.39	0.61	30	
JUL-86	138.0		23.0		0.84	0.88	50	
AUG-86	90.2		27.0		1.2	1.10	110	
SEP-86	76.3	410	29.0	18	1.2	1.40	170	20
OCT-86	78.9		23.2		1.3	1.40	120	
NOV-86	63.7		24.5		1.4	1.50	170	
DEC-86	63.3		25.5		1.6	1.80	210	
JAN-87	61.0		24.0		1.4	1.80	190	
FEB-87	55.2		25.2		1.6	1.70	230	
MAR-87	61.7	498	28.0	26	1.8	1.80	200	
APR-87	45.5		31.2		1.7	2.10	230	
MAY-87	63.4		33.0		2.0	0.44	150	
JUN-87	55.5		27.0		1.5	1.60		
JUL-87	49.6		34.0		1.7	1.90	200	
AUG-87	44.8		33.0		1.8	1.50	220	
SEP-87	44.2	589	31.0	30	1.4	1.80	190	10
OCT-87	45.0		31.5		1.8	1.50	210	
NOV-87	44.6		29.0		1.6	1.10	250	
DEC-87	43.9		25.5		1.8	0.96	260	
JAN-88	45.3		23.0		1.6	1.70	80	
FEB-88	40.3		27.0		1.6	1.80	170	
MAR-88	44.5	554	27.0	29	1.6	1.60	200	20
APR-88	39.6		29.5			2.10	260	
MAY-88	43.8		30.2		1.8	2.10	240	
JUN-88	49.6		24.5		1.4	1.60	140	
JUL-88	47.2		29.5		1.8	2.00	170	
AUG-88	38.7		31.2		1.9	2.30	170	
SEP-88	37.4	596	30.5	29	1.2	2.50	200	10
OCT-88	37.6		32.0		2.1	2.20	240	
NOV-88	35.2		25.0		2.8	2.40	290	
DEC-88	36.0		28.0		2.0	2.80	200	
JAN-89	36.4							
FEB-89	32.8		27.0		2.3	2.40	210	
MAR-89	39.2	579	29.0	76	2.1	2.20	270	40
APR-89	42.0		31.0		2.0	2.10	310	
MAY-89	49.6		30.0		2.2	2.40	200	
JUN-89	51.5		30.0		1.9	1.90	200	
JUL-89	42.1		32.0		2.1	2.60	260	
AUG-89	38.7							
SEP-89	38.5	608	33.5	29	2.6	2.60	230	180

OCT-89	39.5		30.0		2.1	2.30	240	
NOV-89	38.2		27.5		2.4	2.10	250	
DEC-89	36.5		26.5		2.2	2.00	220	
JAN-90	36.3		28.5		2.2	2.30	200	
FEB-90	33.3		25.2		2.3	2.00	220	
MAR-90	37.0	562	28.0	33	2.0	1.80	300	50
APR-90	40.8		30.5		2.4	2.40	370	
MAY-90	47.9		30.0		1.9	2.40	290	
JUN-90	67.3		31.0		1.6	1.90	240	
JUL-90			34.5		1.9	2.50	200	
AUG-90	37.0							
SEP-90	33.0							
OCT-90	33.0							
NOV-90	34.0							
DEC-91	37.0							
JAN-91	31.0							
FEB-91	35.0							
01-May-91	38.0							
17-May-91	37.0							
05-Jun-91	73.0							
21-Jun-91	71.0							
12-Jul-91	54.0							
25-Jul-91	42.0							
15-Aug-91	43.0							
29-Aug-91	44.0							

STATISTICS:	Field EC µS/cm	Field Temp. °C	Lab SO4 mg/l	Lab B mg/l	Lab F mg/l	Lab As µg/l	Lab Fe µg/l
Samples	224	219	163	191	233	201	161
Mean	464	24.2	23	1.6	1.71	172	67
Minimum (0% IQR)	174	12.0	8.2	0.35	0.38	10	10
25% IQR	384	21.0	19	1.2	1.35	120	20
Median (50% IQR)	485	24.5	24	1.6	1.80	180	40
75% IQR	533	27.5	28	1.9	2.10	230	100
Maximum (100% IQF	672	34.5	76	2.9	3.80	370	600
Detection Limit							
% > Detection Limit							

HOT CREEK at County Road at bridge

Comments: All flows were measured at County Road

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The following data was collected by Los Angeles Department of Water and Power

FIELD DATA ---->

Sampling Date	Flow cfs	EC µS/cm	Temp. °C	SO4 mg/l	B mg/l	F mg/l	As µg/l	Fe µg/l
JAN-65	47.6							
FEB-65	39.0							
MAR-65	44.2							
APR-65	48.3							
MAY-65	59.5	466	27.5	26		1.60		200
JUN-65	119.5	269	20.5	11		0.87		150
JUL-65	120.7	280	21.0	12	0.90	0.84	74	50
AUG-65	97.9	213	18.0	8.6		0.67		100
SEP-65	69.3	404	23.5	18		1.40		30
OCT-65	60.2	456	24.0	20	1.6	1.70	117	10
NOV-65	56.3							
DEC-65	52.2							
JAN-66	50.8							
FEB-66	42.0							
MAR-66	50.1							
APR-66	51.8	485	22.0	24	1.9	1.90	150	20
MAY-66	77.8	343	22.0	16		1.30		40
JUN-66	70.9	380	23.5	17		1.50		40
JUL-66	50.1	518	30.5	23		2.10	200	20
AUG-66	43.8	562	33.0	23	2.1	2.40		10
SEP-66	42.1	560	25.5	24		2.30		40
OCT-66	43.5	537	25.0	26	2.0	2.00	230	100
NOV-66	40.4	584	28.0	26	2.3	2.30		40
DEC-66	53.1							
JAN-67	43.7							
FEB-67	41.0							
MAR-67	53.7							
APR-67	54.7							
MAY-67	86.0	564	28.5	18		1.60	250	60
JUN-67	166.0	250	14.0	8.6	1.9	1.20		60
JUL-67	210.9	238	17.5	8.2	0.81	1.20		60
AUG-67	111.9	304	20.5	12	0.55	0.81		100
SEP-67	88.7	340	21.5	16		1.10		50
OCT-67	72.1	403	21.0	20		1.20	315	30
NOV-67	61.5	454	24.0	19	1.5	1.50		50
DEC-67	57.9							
JAN-68	54.9							

FEB-68	51.2							
MAR-68	50.1							
APR-68	47.7	532	24.0	29		2.10	200	30
MAY-68	56.4	476	23.5	21	2.1	1.60	205	150
JUN-68	62.8	503		28		1.82		70
JUL-68	47.0	524	30.0	27	1.7	2.02	220	200
AUG-68	43.2	524	26.0	21		2.10		10
SEP-68	40.1	517	29.0	27		2.10		10
OCT-68	41.4	498	25.5	32	2.0	2.00	240	60
NOV-68	42.5	456	22.0	26		2.10		60
DEC-68	42.1							
JAN-69	42.1							
FEB-69	38.7							
MAR-69	48.7							
APR-69	71.0							
MAY-69	193.9	207	13.0	12	0.53	0.52		60
JUN-69	272.0	188	14.0	9.5	0.53	0.49		60
JUL-69	213.6	198	19.5	10	0.56	0.55		100
AUG-69	124.0	279	21.0	19		0.86		40
SEP-69	84.5	362	22.5	19		1.20		100
OCT-69	80.7	274	18.5	23	1.0	1.50	120	60
NOV-69	65.1	460	20.5	30		1.70		10
DEC-69	61.7	490	22.5	26		2.10	230	10
JAN-70	62.6							
FEB-70	54.9							
MAR-70	60.2	482	21.0	23		1.40		40
APR-70	59.4	474	21.5	30	1.7	1.90		10
MAY-70	78.9	404	23.5	21	1.7	1.50		30
JUN-70	113.8	313	21.5	15	1.0	1.20	120	10
JUL-70	87.4	434	28.5	23	1.2	1.70	210	10
AUG-70	58.2	502	26.0	27	1.7	2.00		10
SEP-70	53.3	485	26.0	33	1.8	1.80	200	40
OCT-70	53.0	493	24.5	27	1.9	2.00	260	100
NOV-70	53.8	518	25.0	30	2.3	2.00	230	20
DEC-70	54.5							
JAN-71	51.6							
FEB-71	45.8							
MAR-71	49.2	530	23.5	28	1.0	2.00	230	30
APR-71	45.2	556	26.0	30	2.5	2.60	230	10
MAY-71	70.5	434	23.5	23	1.8	1.50	170	20
JUN-71	102.0	279	20.5	17	0.91	0.90	80	40
JUL-71	72.4	374	26.5	24	1.3	1.40	140	30
AUG-71	52.0	520	30.5	28	2.0	2.10	220	10
SEP-71	45.6	521	26.0	28		2.10	200	100
OCT-71	49.5	504	22.0	26	1.9	2.00	270	40
NOV-71	49.2	515	21.5	26	1.7	1.90	190	20
DEC-71	45.2	550	21.0	29	2.2	2.10	210	30
JAN-72	45.4							
FEB-72	41.6							
MAR-72	46.9	538	24.5	27	2.0	2.20	170	30
APR-72	42.2	532	23.0	27		2.10	200	10
MAY-72	52.5	450	26.5	28		2.10	170	40

JUN-72	76.9	395	26.5	21	1.6	1.50	120	20
JUL-72	44.7	527	32.5	26	2.1	2.30	200	20
AUG-72	38.4	578	32.0	30	2.2	2.50	230	60
SEP-72	47.1	490	26.0	26	1.7	1.80	180	200
OCT-72	47.2	508	24.5	25	1.6	1.70	210	10
NOV-72	44.1							
DEC-72	45.4							
JAN-73	45.6							
FEB-73	42.3							
MAR-73	44.7							
APR-73	60.0							
MAY-73	120.8	215	13.5	11	0.62	0.38	70	150
JUN-73	146.6	258	18.0	17	0.69	0.85	80	60
JUL-73	92.4	420	26.0	21	1.4	1.40	150	40
AUG-73	61.8	482	27.0	26	1.6	1.80	210	40
SEP-73	52.8	496	26.0	25	1.5	2.00		20
OCT-73	51.5	508	24.5	27	1.6	2.00	130	100
NOV-73	59.6	327	12.0	18	0.96	1.00	110	200
DEC-73	51.7							
JAN-74	52.1							
FEB-74	44.1							
MAR-74	50.4	513	23.0	24	1.7	2.00	220	60
APR-74	49.6	470	21.5	26	1.5	1.80	170	20
MAY-74	101.0	302	16.0	16	0.83	1.10	90	40
JUN-74	147.9	200	14.5	11	0.54	0.64	50	100
JUL-74	90.8	366	23.0	17	1.1	1.40	100	40
AUG-74	63.1	436	24.5	22	1.3	1.60	180	60
SEP-74	51.7	505	28.5	22	1.6	1.80	210	100
OCT-74	52.3	512	27.5	28	1.6	2.10	210	40
NOV-74	46.2	516	21.5	28	1.6	2.00	230	40
DEC-74	45.6							
JAN-75	45.3							
FEB-75	38.2							
MAR-75	44.8							
APR-75	43.0	490	26.0	25	1.4	2.20	290	40
MAY-75	78.0	438	22.0	20	1.1	2.00	170	100
JUN-75	153.8	174	14.0	9.4	0.35	0.55	40	200
JUL-75	94.0	398	25.0	22	1.2	1.30	130	30
AUG-75	59.4	434	23.0	22	1.0	1.40	20	100
SEP-75	53.9	465	24.5	24	1.1	1.50	150	30
OCT-75	59.7	436	20.0	19	0.71	1.80	120	
NOV-75	49.5	518	19.5	28	1.4	2.00	30	100
DEC-75	48.1	528	21.0	24	1.4	1.10	80	100
JAN-76	46.1	540	20.5	28	1.4	1.90	120	100
FEB-76	43.0							
MAR-76	48.4	523	25.5	26	1.2	2.20	160	600
APR-76	39.8	516	23.5	25	1.6	2.30	230	40
MAY-76	57.4	457	23.0	21	1.3	1.80	200	10
JUN-76	43.9	540	25.0	25	1.6	2.20	220	100
JUL-76	40.9	568	28.5	26	1.7	2.40	90	400
AUG-76	40.0	586	29.0	27	1.8	2.50	250	200
SEP-76	38.6	572	26.0	26	1.8	2.30	130	200

OCT-76	39.9	583	29.0	26	1.5	2.30	240	40
NOV-76	36.4	574	25.0	31	1.6	1.70	140	150
DEC-76	35.7	633	19.5	37	2.0	2.60	170	100
JAN-77	35.0	606	24.5	33	1.7	2.70	280	150
FEB-77	33.9	614	25.0	30	1.8	2.70	280	80
MAR-77	37.4	584	25.0	29	1.7	2.60	260	30
APR-77	34.8	590	24.5	30	1.9	2.50	280	300
MAY-77	30.2	634	22.0	28	2.0	2.30	180	100
JUN-77	41.5	561	29.0	29	1.5	2.30	190	200
JUL-77	36.9	672	27.0	33	1.9	2.70		40
AUG-77	34.0	620	31.5	33	1.8	2.50	180	20
SEP-77	34.3	656	25.0	33	1.9	2.70	300	80
OCT-77	34.2	640	31.0	33	2.2	2.60	50	20
NOV-77	32.1	650	24.5	35	2.9	2.40	110	80
DEC-77	32.2	657	27.0	35	2.9	2.70	100	100
JAN-78	31.5							
FEB-78	28.8							
MAR-78	34.1							
APR-78	53.2							
MAY-78	88.9	360	14.5	21	0.64	1.20	130	100
JUN-78	189.6	198	15.0	11	0.50	0.44	40	60
JUL-78	154.4	198	18.0	9.8	0.60	0.56	80	100
AUG-78	95.2	300	20.5	16	1.0	1.00	140	100
SEP-78	95.1	306	16.5	16	1.0	1.10	70	200
OCT-78	68.9	422	19.0	21	1.4	1.50	170	80
NOV-78	59.6	454	19.5	23	1.6	1.80	230	10
DEC-78	54.9							
JAN-79	58.2							
FEB-79	51.5							
MAR-79	57.6	518	24.5	28	1.2	1.80	260	100
APR-79	55.8	472	19.0	24	1.9	1.70	130	10
MAY-79	99.9	254	18.0	12	0.82	0.78	120	200
JUN-79	106.5	316	20.5	16	1.1	1.10	90	100
JUL-79	73.0	436	30.0	22	1.7	1.70	210	100
AUG-79	56.2	496	29.5	25	2.0	2.00	240	150
SEP-79	51.6	518	28.8	25	1.9	2.00	280	40
OCT-79	48.3	511	26.0	26	1.9	1.90	200	200
NOV-79	44.6	552	19.5	30	2.0	2.00	240	20
DEC-79	44.4	560	21.2	28	2.5	2.20	290	30
JAN-80	51.3							
FEB-80	43.9							
MAR-80	47.0							
APR-80	60.3	414	18.0	20	1.6	1.40	140	20
MAY-80	99.8	236	16.0	12	0.64	0.70	90	30
JUN-80	175.6	252	18.0	12	1.1	0.74	60	30
JUL-80	179.1	234	22.2	9.2		0.78	50	20
AUG-80	95.4	356		16		1.11	100	10
SEP-80	69.0	398	25.5	20		1.40	190	10
OCT-80	61.1	432	20.5	21		0.56	150	30
NOV-80	52.4	462	19.8	23		1.98	50	10
DEC-80	51.3	471	21.0	24		2.10	80	10
JAN-81	50.2	494	18.0	23		2.00	180	10

FEB-81	47.1							
MAR-81	51.2	512	24.0	25	2.0	2.10	200	10
APR-81	49.1	466	24.5	22		1.80	160	10
MAY-81	67.6	422	22.0	20		1.60	200	10
JUN-81	78.0	384	22.0	18		1.40	160	10
JUL-81	52.8	533	27.5	26		2.10	290	10
AUG-81	45.3	552	28.5	24		2.30	240	10
SEP-81	45.1	556	27.0	28	2.3	3.80	280	10
OCT-81	47.8							
NOV-81	46.7	484	18.5	25	2.0	2.00	110	10
DEC-81	46.1	532	19.2	26	1.96	2.10	250	10
JAN-82	40.7							
FEB-82	41.0							
MAR-82	44.2							
APR-82	77.3	408	17.5	21		1.50	190	40
MAY-82	126.0	344	19.5	17	1.1	1.20	150	60
JUN-82	178.6	215	17.5	15		0.57	40	50
JUL-82	170.6	252	19.0	10		0.77	50	70
AUG-82	111.9	338	22.5	32		1.10	140	50
SEP-82	107.1				1.1	1.30	110	
OCT-82	98.2							
NOV-82	85.4				1.2	1.40	100	
DEC-82	74.6		16.5		1.6	0.52	160	
JAN-83	65.4							
FEB-83	59.8							
MAR-83	65.7							
APR-83	68.5							
MAY-83	122.6		19.0		1.3	0.57		
JUN-83	273.0					0.52	50	
JUL-83	245.9		18.0		0.4	0.51	50	
AUG-83	153.9		19.0		0.64	0.72	55	
SEP-83	104.2		22.2		1.60	1.10	120	
OCT-83	92.3		19.0		0.85	1.20	110	
NOV-83	82.7		17.5		1.0	1.35	90	
DEC-83	78.2							
JAN-84	77.6							
FEB-84	63.4							
MAR-84	71.6							
APR-84	65.8				1.2	1.50	140	
MAY-84	120.4				0.78	0.87	80	
JUN-84	128.1				1.1	1.10	130	
JUL-84	108.7				0.98	1.30	50	
AUG-84	77.6				1.4	1.60	150	
SEP-84	64.1				1.9	2.10	290	
OCT-84	71.5				1.6	1.40	140	
NOV-84	60.4				2.7	2.00	220	
DEC-84	59.0							
JAN-85	54.8		21.5		2.3	1.90	180	
FEB-85	50.1							
MAR-85	54.5		22.0		2.2	2.10	10	
APR-85	61.4		28.0		1.4	2.10	100	
MAY-85	82.6				1.4	1.60	170	

JUN-85	86.5		25.5		1.3	1.50	120	
JUL-85	63.5		30.0		1.4	2.00	150	
AUG-85	54.0		30.8		1.5	1.60	120	
SEP-85	54.2		28.0		1.3	2.10	170	
OCT-85	54.0							
NOV-85	50.8	502	27.0	28	1.6	2.20	100	10
DEC-85	52.6		26.0		1.5	2.10	280	
JAN-86	50.6	588	26.0		1.8	2.20	150	
FEB-86	47.7		25.0		2.0	2.20	170	
MAR-86	62.0							
APR-86	81.8	466	25.0	26	1.5	1.70	20	20
MAY-86	138.3	358	17.5		1.0	1.10	100	
JUN-86	225.9		22.8		0.39	0.61	30	
JUL-86	138.0		23.0		0.84	0.88	50	
AUG-86	90.2		27.0		1.2	1.10	110	
SEP-86	76.3	410	29.0	18	1.2	1.40	170	20
OCT-86	78.9		23.2		1.3	1.40	120	
NOV-86	63.7		24.5		1.4	1.50	170	
DEC-86	63.3		25.5		1.6	1.80	210	
JAN-87	61.0		24.0		1.4	1.80	190	
FEB-87	55.2		25.2		1.6	1.70	230	
MAR-87	61.7	498	28.0	26	1.8	1.80	200	
APR-87	45.5		31.2		1.7	2.10	230	
MAY-87	63.4		33.0		2.0	0.44	150	
JUN-87	55.5		27.0		1.5	1.60		
JUL-87	49.6		34.0		1.7	1.90	200	
AUG-87	44.8		33.0		1.8	1.50	220	
SEP-87	44.2	589	31.0	30	1.4	1.80	190	10
OCT-87	45.0		31.5		1.8	1.50	210	
NOV-87	44.6		29.0		1.6	1.10	250	
DEC-87	43.9		25.5		1.8	0.96	260	
JAN-88	45.3		23.0		1.6	1.70	80	
FEB-88	40.3		27.0		1.6	1.80	170	
MAR-88	44.5	554	27.0	29	1.6	1.60	200	20
APR-88	39.6		29.5			2.10	260	
MAY-88	43.8		30.2		1.8	2.10	240	
JUN-88	49.6		24.5		1.4	1.60	140	
JUL-88	47.2		29.5		1.8	2.00	170	
AUG-88	38.7		31.2		1.9	2.30	170	
SEP-88	37.4	596	30.5	29	1.2	2.50	200	10
OCT-88	37.6		32.0		2.1	2.20	240	
NOV-88	35.2		25.0		2.8	2.40	290	
DEC-88	36.0		28.0		2.0	2.80	200	
JAN-89	36.4							
FEB-89	32.8		27.0		2.3	2.40	210	
MAR-89	39.2	579	29.0	76	2.1	2.20	270	40
APR-89	42.0		31.0		2.0	2.10	310	
MAY-89	49.6		30.0		2.2	2.40	200	
JUN-89	51.5		30.0		1.9	1.90	200	
JUL-89	42.1		32.0		2.1	2.60	260	
AUG-89	38.7							
SEP-89	38.5	608	33.5	29	2.6	2.60	230	180

OCT-89	39.5		30.0		2.1	2.30	240	
NOV-89	38.2		27.5		2.4	2.10	250	
DEC-89	36.5		26.5		2.2	2.00	220	
JAN-90	36.3		28.5		2.2	2.30	200	
FEB-90	33.3		25.2		2.3	2.00	220	
MAR-90	37.0	562	28.0	33	2.0	1.80	300	50
APR-90	40.8		30.5		2.4	2.40	370	
MAY-90	47.9		30.0		1.9	2.40	290	
JUN-90	67.3		31.0		1.6	1.90	240	
JUL-90			34.5		1.9	2.50	200	
AUG-90	37.0							
SEP-90	33.0							
OCT-90	33.0							
NOV-90	34.0							
DEC-91	37.0							
JAN-91	31.0							
FEB-91	35.0							
01-May-91	38.0							
17-May-91	37.0							
05-Jun-91	73.0							
21-Jun-91	71.0							
12-Jul-91	54.0							
25-Jul-91	42.0							
15-Aug-91	43.0							
29-Aug-91	44.0							

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STATISTICS:	Field EC µS/cm	Field Temp. °C	Lab SO4 mg/l	Lab B mg/l	Lab F mg/l	Lab As µg/l	Lab Fe µg/l
Samples	224	219	163	191	233	201	161
Mean	464	24.2	23	1.6	1.71	172	67
Minimum (0% IQR)	174	12.0	8.2	0.35	0.38	10	10
25% IQR	384	21.0	19	1.2	1.35	120	20
Median (50% IQR)	485	24.5	24	1.6	1.80	180	40
75% IQR	533	27.5	28	1.9	2.10	230	100
Maximum (100% IQF	672	34.5	76	2.9	3.80	370	600
Detection Limit							
% > Detection Limit							

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HOT CREEK at County Road at bridge

Comments: All flows were measured at Hot Creek Flume

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The following data was collected by U.S. Geological Survey

FIELD DATA ---->

Sampling Date	Flow cfs	Temp. °C	B mg/l	F mg/l	As µg/l	Fe µg/l	Hg µg/l
NOV-82	89	19.5	1.3	1.2	140		
DEC-82							
JAN-83	74	22.0			160		
FEB-83	70	24.5	1.7	2.1	170		
MAR-83	72	21.5	1.8	1.9	170		
APR-83							
MAY-83	79	22.5	1.6	1.7	160		
JUN-83	216	17.0	0.59	0.6	70		
JUL-83	312	22.5	0.42	0.5	52		
AUG-83	183	18.5	0.74	0.7	88		
SEP-83		21					
OCT-83	100	21.5	1.3		120	32	
NOV-83	84	20.5	1.4		150	27	0.1
DEC-83	89	16.5	1.4		130	38	
JAN-84	68	24.5	1.9		150		
FEB-84							
MAR-84							
APR-84	63	23.5	1.8		170	20	
MAY-84	73	25.5	1.5		160	31	
JUN-84	118	21.0	0.98		83	40	
JUL-84	100	27.5	1.2		120	70	
AUG-84							
SEP-84	67	24.5	1.7		160	14	
OCT-84	60	24.5	1.6		160	19	
NOV-84	62	24.0			150	21	
DEC-84	57	24.0	2.2				
JAN-85							
FEB-85	58	24.0	2.125				
MAR-85							
APR-85							
MAY-85							
JUN-85		24.0	1.5				
JUL-85		33.0	1.9				
AUG-85	48		2				
SEP-85	48		2.05				
OCT-85	44	32.5	2.2	2.2	240	20.0	
NOV-85	45		2.2				
DEC-85	48	26.5	2.1				

JAN-86	51		2.1			
FEB-86	53	26.5	2.05			
MAR-86	61		1.9			
APR-86	71	25.0	1.6	180	30	
MAY-86	180	13.5	0.72			
JUN-86	165		0.81			
JUL-86	113	27.5	1.1	110		
AUG-86	83	26.0	1.4			
SEP-86	69		1.6			
OCT-86	79	21.5	1.5			
NOV-86	57	25.5	1.8			
DEC-86	48		2.1			
JAN-87	46	25.0	2.1			
FEB-87	49	26.0	2.2			
MAR-87			2.4			
APR-87	48	35.0	2.3			
MAY-87	59	28.0	1.7			
JUN-87	58	27.5	1.8			
JUL-87	42	36.0	2.3	110	6	0.3
AUG-87	41	36.0	2.4			
SEP-87			2.4			
OCT-87			2.5			
NOV-87	32		2.3			
DEC-87	42	32.0	2.4			
JAN-88			2.2			
FEB-88			2.2			
MAR-88	46	30.0	2.3			
APR-88	47	29.0	2.2	290		
MAY-88	42		2.3			
JUN-88		31.0	1.6	150		
JUL-88	55	34.0	1.7	230	17	0.1
AUG-88	47	35.5	2.2	260		
SEP-88	46	35.5	2.4	295		
OCT-88		36.0	2.6	250		
NOV-88		27.5	2.1	240		
DEC-88		29.5	2.5	110		
JAN-89		30.5	2.4	330		
FEB-89		32.0	2.4	310		
MAR-89		34.0	2.4			
APR-89	43	34.0	2.3	260		
MAY-89	57	32.0	1.9	190		
JUN-89	48	28.0	2	130		
JUL-89	42	37.0	2.3	270	10	
AUG-89	40	36.5	2.4	290		
SEP-89	43	30.0	2.3	300		
OCT-89	36	34.0	2.7	250		
NOV-89	41	29.0	2.5	340		
DEC-89	36	29.0	2.7	250		
JAN-90		29.5	2.6	250		
FEB-90	39	30.5	2.5	55		
MAR-90	40	32.5	2.7	190		
APR-90			2.7			

MAY-90	43	28.0	2.2		350		
JUN-90	59	30.5	1.7		160		
JUL-90		33.0	2.6		280	16	
	37	34.5	2.6		220		
	33	29.5	2.5				
	33	33.0	2.6				
	34	31.5	2.6				
	37	25.5	2.9				
	31	34.0	2.8				
	35	33.5					

STATISTICS:		Field Temp. °C	Lab B mg/l	Lab F mg/l	Lab As µg/l	Lab Fe µg/l	Lab Hg µg/l
Samples		75	87	8	49	16	3.0
Mean		28	2.0	1.4	193	26	0.2
Minimum (0% IQR)		14	0.4	0.5	52	6	0.1
25% IQR		25	1.7	0.7	140	17	0.1
Median (50% IQR)		28	2.1	1.7	170	21	0.1
75% IQR		33	2.4	2.1	260	32	0.3
Maximum (100% IQR)		37	2.9	2.2	350	70	0.3
Detection Limit							
% > Detection Limit							

Mn µg/l	Zn µg/l	
	10	
	220	
	19	
32	12	
26	7	
37	7	
16	8	
13	11	
26	4	
20		
15	7	
30		
26	7	
	5	

16

31

10

9

20

Lab Mn µg/l	Lab Zn µg/l	
15	12	
22	26	
9	4	
16	7	
20	8	
30	12	
37	220	

HOT CREEK at gage below hot springs
Comments:
The following data was collected by Jones & Stokes Associates, Inc.

FIELD DATA ---->

Sampling Date	Hrd mg/l	SO4 mg/l	B mg/l	F mg/l	Bromide mg/l	Al µg/l	As µg/l	Ba µg/l	Fe µg/l	Mn µg/l
01-May-91	58	33	2.6	2.6		110	330	36	89	51
17-May-91	59	31	2.5	2.5	0.12	ND	320	33	83	73
05-Jun-91	43	19	1.2	1.2	0.07	180	130	35	36	ND
21-Jun-91	48	17	1.3	1.2	0.06	95	120	ND	42	ND
12-Jul-91	53	22	1.6	1.6	0.08	78	140	26	42	ND
25-Jul-91	58	32	2.2	2.2	0.10	ND	240	31	ND	ND
15-Aug-91	55	28	2.2	2.4	0.11	65	250	27	ND	26
29-Aug-91	54	26	2.1	2.2	0.11	56	260	27	ND	ND

STATISTICS	Lab Hrd mg/l	Lab SO4 mg/l	Lab B mg/l	Lab F mg/l	Lab Bromide mg/l	Lab Al µg/l	Lab As µg/l	Lab Ba µg/l	Lab Fe µg/l	Lab Mn µg/l
Samples (n)	8	8	8	8	7	8	8	8	8	8
Mean	54	26	2.0	2.0	0.09	97	224	31	58	50
Minimum (0%	43	17	1.2	1.2	0.06	ND	120	ND	ND	ND
25% IQR	53	22	1.6	1.6	0.08	56	140	27	ND	ND
Median (50%	55	28	2.2	2.2	0.10	78	250	31	42	ND
75% IQR	58	32	2.5	2.5	0.11	110	320	35	83	51
Maximum (1(	59	33	2.6	2.6	0.12	180	330	36	89	73
Detection Lin	1	2	0.02	0.1	0.01	50	4	10	30	10
% > Detectio	100	100	100	100	100	75	100	88	63	38

MAMMOTH CREEK above hot springs west of highway 395

Comments:

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The following data was collected by Los Angeles Department of Water and Power

FIELD DATA ---->

Sampling Date	Flow cfs	Temp. °C	Hrd mg/l	SO4 mg/l	B mg/l	F mg/l	As µg/l	Fe µg/l	
Jul-33			29	4	0.05				
Aug-33			27	1	0.01	0.3			
Sep-33			27	2	0.03				
Oct-33			45	3	0.08				
Dec-33			57	5	0.08				
Dec-33			51	5	0.41				
Jan-34			54	6	0.02				
Feb-34			63	5	0.06				
Feb-34			57	5	0.02				
Mar-34			52	5	0.05				
Apr-34			53	6	0.01				
Apr-34			41	5	0.02				
May-34			32	4	0				
Jun-34			31	3	0.01				
Jun-34			32	4	0				
Jul-34			41	7	0.01				
Aug-34			38	3	0				
Aug-34			64	5	0				
Sep-34			50	7	0.06				
Oct-34			41	5	0.07			0	
Oct-34			50	7	0.02				
Nov-34			60	4	0.03				
Dec-34			59	5	0.03			0	
Dec-34			59	4	0.02				
Apr-35			47	0	0.04			0	
Jun-35			27	0	0.02			0	
Aug-36			33	1	0			0	
Oct-36			44	2	0.04	0.5		0	
Dec-36			55	5	0.03	0.3			
Apr-37			53	3	0.02	0.15		100	
Jun-37			28	1	0	0.15		0	
Aug-37			29	0	0	0.15		150	
Oct-37			38	4	0.09	0		300	
Dec-37			34	4	0.12	0.25		0	
Apr-38			51	6	0.05	0.25		100	
Jun-38			29	6	0.02	0		0	
Aug-38			31	3	0.14	0.25		0	

Oct-38			48	5	0.04	0.25		0
Dec-38			47	9	0.38	0.5		100
Feb-39			54	12	0.43	0.5		150
Apr-39			55	4	0.04	0.1		0
Jun-39			41	3	0.08	0.2		0
Jul-39			45	3		0		50
Aug-39			34	4		0.2		0
Sep-39			40	6		0		0
Oct-39			51	5		0		0
Nov-39			46	4		0		0
Dec-39			62	5		0		0
Jan-40	10.0		52	6		0		0
Mar-40	8.9		63	9		0		0
Apr-40	18.6		76	8		0		0
May-40	68.5		36	3		0		0
Jun-40	77.0		25	5		0.2		0
Jul-40	32.4		34	4		0		0
Aug-40	11.6		30	5		0		0
Sep-40	7.7		47	2		0		0
Oct-40	8.8		47	6		0		100
Nov-40	8.1		59	3		0		0
Jan-41	9.9		50	13		0.2		0
Feb-41	8.4		54	13		0		0
Mar-41	8.7		61	16		0		0
Apr-41	11.6		62	9		0		0
Jul-49	20.8		27	3			10	100
Oct-62	9.1	7.5	34		0	0.16	3	
Nov-62	6.6							
Nov-62	6.6	3						
Nov-62	6.6	4						
Nov-62	6.6	1						
Nov-62	6.6	0.4						
Dec-62	7.2	2			0.08	0.08		
Dec-62	7.2	0.5			0	0	3	
Mar-63	7.1		47		0.04	0.24	0	
Mar-63	7.1		50	6.5	0.04	0.24	0	100
Mar-63	7.1		52	2.2	0.2	0.34	0	200
Apr-63	9.9		52					
Apr-63	9.9		56	12	0.16	0.28	0	200
May-63	36.8		50	11	0	0.08		
May-63	36.8		54	2.7	0.15	0.12	4	40
May-63	36.8		64	8.2	0.08	0.3	39	60
May-63	36.8		44					
Jun-63	104.9		40	3.7	0.23	0.12	1	150
Jun-63	104.9		34					
Jul-63	73.0		28	7	0.02	0.09		
Jul-63	73.0		24					
Sep-63	14.7		42	7	0.05	0.22	2	30
Sep-63	14.7		26					
Oct-63	10.8		32					
Oct-63	10.8		38	7	0.18	0.06		70
Nov-63	14.4		36					

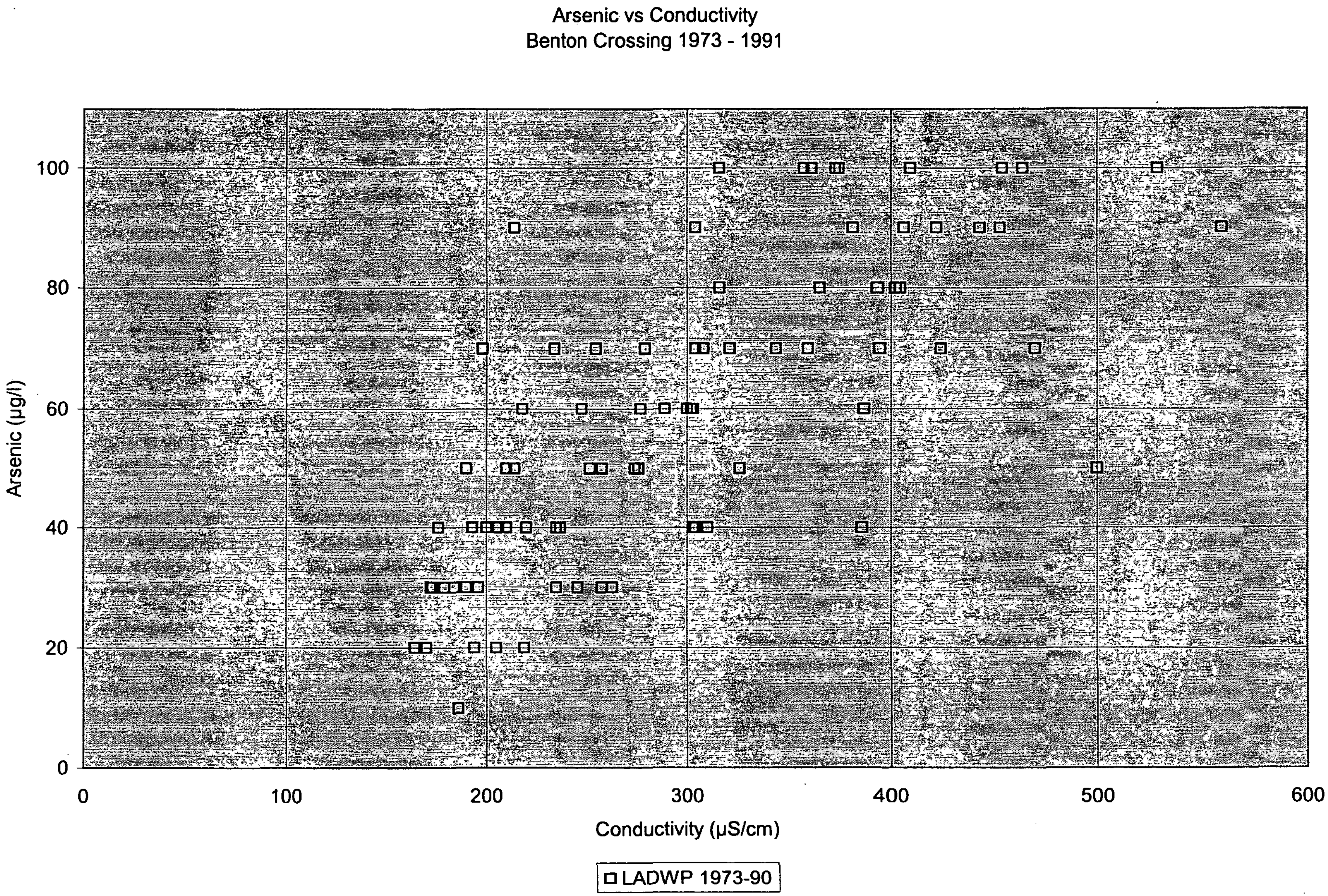
Nov-63	14.4		40	7	0.2	0.02	5	80
Nov-63	14.4		36	3.7	0.02	0.02		40
Nov-63	14.4		34	4.1	0.02	0.19	5	60
Nov-63	14.4		46	4.9	0.12	0.19	12	110
Nov-63	14.4		36					
Dec-63	10.7		42	12		0.27	10	50
Dec-63	10.7		50	10		0.16	35	100
Dec-63	10.7		42	7		0.24	13	50
Dec-63	10.7		46					
Jan-64	7.1		42					
Jan-64	7.1		46	6.5		0.21	6	60
Feb-64	5.2		48	3.3		0.16		200
Feb-64	5.2		40	4.1		0.02		40
Feb-64	5.2		60	4.5	0.22	0.14	25	100
Feb-64	5.2		58	4.9		0.26	15	80
Feb-64	5.2		50	4.9		0.14	10	30
Mar-64	7.9		52					
Mar-64	7.9		58					
Mar-64	7.9		50	9.9	0.19	0.27		200
Apr-64	10.1		72					
Apr-64	10.1		70	4.5	0.1	0.02	8	100
Apr-64	10.1		48	5.4	0.07	0.11	9	100
Apr-64	10.1		46					
May-64	25.1		42	3	0.12	0.58	13	60
May-64	25.1		44					
May-64	25.1		40	6	0.07	0.16	10	60
Mar-70	13.1	5.6					10	
Mar-70	13.1	4.5					10	
Mar-70	13.1	4.5					0	
Mar-70	13.1	7					6	
Apr-70	15.3							
Apr-70	15.3						10	
Apr-70	15.3	0					0	
May-70	42.9	8					30	
May-70	42.9	8					30	
Jun-70	73.1	14.5					10	
Jun-70	73.1	13					10	
Jul-70	36.2	15					30	
Jul-70	36.2	18					0	
Jul-70	36.2	15.6					0	
Jul-70	36.2	14.5					0	
Aug-70	12.6	15.5					20	
Aug-70	12.6	14.5					50	
Aug-70	12.6	14.5					50	
Aug-70	12.6	14					50	
Sep-70	8.1	10.5					30	
Sep-70	8.1	11					40	
Sep-70	8.1						10	
Sep-70	8.1	7.5					10	
Oct-70	7.6	4					20	
Oct-70	7.6	8.5					30	
Oct-70	7.6	0					10	

Oct-70	7.6	0	10
Nov-70	9.9	5	10
Nov-70	9.9	4.5	10
Dec-70	8.8	0.5	10
Dec-70	8.8	0.5	10
Feb-71	5.6	0	10
Feb-71	5.6	0.5	10
Mar-71	8.4	2.5	10
Mar-71	8.4	5	10
Mar-71	8.4		10
Apr-71	10.0	4	10
Apr-71	10.0	2.5	10
May-71	30.5	11	10
May-71	30.5	9	10
Jun-71	72.4	11.5	10
Jun-71	72.4	12.5	10
Jul-71	35.3	18.5	10
Jul-71	35.3	16.5	10
Aug-71	12.6	13.5	10
Aug-71	12.6	13.5	10
Sep-71	6.8	4.5	10
Sep-71	6.8	4.5	10
Oct-71	8.3	2.5	10
Oct-71	8.3		10
Nov-71	8.7	1.5	10
Nov-71	8.7	2.5	10
Mar-72	6.7	0	10
Apr-72	9.9	4	
Apr-72	9.9		10
May-72	26.7	7	
May-72	26.7		20
May-72	26.7	7	
Jun-72	46.5	13	
Jun-72	46.5		10
Jul-72	11.8		
Jul-72	11.8		20
Jul-72	11.8	17.5	
Aug-72	3.2	15	
Aug-72	3.2	15.5	10
Sep-72	11.2	11.5	
Sep-72	11.2		10
Oct-72	8.7		10
Oct-72	8.7	2.5	
Nov-72	6.1		10
Nov-72	6.1	0	
Dec-72	7.6		10
Dec-72	7.6	0	
May-73	80.8	6	10
Jun-73	106.2	14	10
Jun-73	106.2	14	
Jul-73	39.0	17	
Jul-73	39.0	19	10

Aug-73	16.8	16	
Aug-73	16.8	16	10
Sep-73	8.3	13.5	
Sep-73	8.3	14.5	30
Oct-73	8.8	5.5	
Oct-73	8.8	5	10
Nov-73	17.7	0	
Nov-73	17.7	0	10
Feb-74	6.6	0	10
Feb-74	6.6	0	
Mar-74	8.9	1	10
Mar-74	8.9	1.5	
Apr-74	13.5	8	10
Apr-74	13.5	10	
May-74	73.2	5	10
May-74	73.2	4.5	
Jun-74	119.6	10.5	
Jun-74	119.6	11	10
Jul-74	50.6	13	10
Jul-74	50.6	12.5	
Aug-74	22.1	9.5	10
Aug-74	22.1	10	
Sep-74	10.2	10.5	10
Sep-74	10.2	9.5	
Oct-74	8.7	10.5	20
Oct-74	8.7	8	
Nov-74	5.7	2	10
Nov-74	5.7	2	
Dec-74	6.1	0	10
Dec-74	6.1	2	10
Apr-75	8.0	2	10
Apr-75	8.0	2.5	10
May-75	45.5	3	10
May-75	45.5	6	10
Jun-75	119.7	9.5	10
Jun-75	119.7	10	10
Jul-75	52.5	12	10
Jul-75	52.5	12.5	10
Aug-75	17.8		10
Aug-75	17.8	11	10
Sep-75	11.7	11	10
Sep-75	11.7	11	10
Oct-75	17.1	8	10
Oct-75	17.1	10	10
Mar-76	7.9	3	10
Mar-76	7.9	2.5	10
Apr-76	7.1	6	10
Apr-76	7.1	8	10
May-76	30.4	10.5	10
May-76	30.4	10	10
Jun-76	15.6	12.5	10
Jun-76	15.6	14.5	10

Jul-76	6.4	14				10	
Jul-76	6.4	13.5	3.3			10	
Aug-76	5.5	13.5				10	
Aug-76	5.5	13				10	
Sep-76	3.6	9				10	
Sep-76	3.6	9.3				10	
Oct-76	4.6	8.5				10	
Oct-76	4.6	12.5				10	
Nov-76	3.3	7.5				10	
Nov-76	3.3	5				10	
Mar-77	3.8	4				10	
Mar-77	3.8	5				10	
Apr-77	4.4	7				10	
Apr-77	4.4	7				10	
May-77	5.0					10	
May-77	5.0	2				10	
Jun-77	15.2	14					
Jun-77	15.2	17				10	
Jul-77	4.8	17				10	
Jul-77	4.8	16.5				10	
Aug-77	2.0	15.5				10	
Aug-77	2.0	14.5				10	
Sep-77	1.8	11					
Sep-77	1.8	9.5				10	
Oct-77	1.4	3.5				10	
Oct-77	1.4	12.5				10	
Apr-78	7.1					10	
Apr-78	7.1	2.5				10	
May-78	50.8	4.5				10	
May-78	50.8					10	
Jun-78	149.8					10	
Jun-78	149.8	10				10	
Jul-78	105.9	14				10	
Jul-78	105.9					10	
Aug-78	46.6	14.5				10	
Aug-78	46.6					30	
Sep-78	45.8					10	
Sep-78	45.8	5.5				10	
Oct-78	19.2	4.5				10	
Oct-78	19.2					10	
Oct-79	19.2	17.5	2	0.01	0.1	10	150
Nov-79	12.9	0	3.9	0.06	0.1	10	20
Jun-80	73.5	10	2.3	0.01	0.1	10	10
02-May-91	6.7						
17-May-91	10.3						
04-Jun-91	40.5						
21-Jun-91	44.2						
12-Jul-91	24.5						
24-Jul-91	14.0						
15-Aug-91	7.5						
27-Aug-91	5.2						

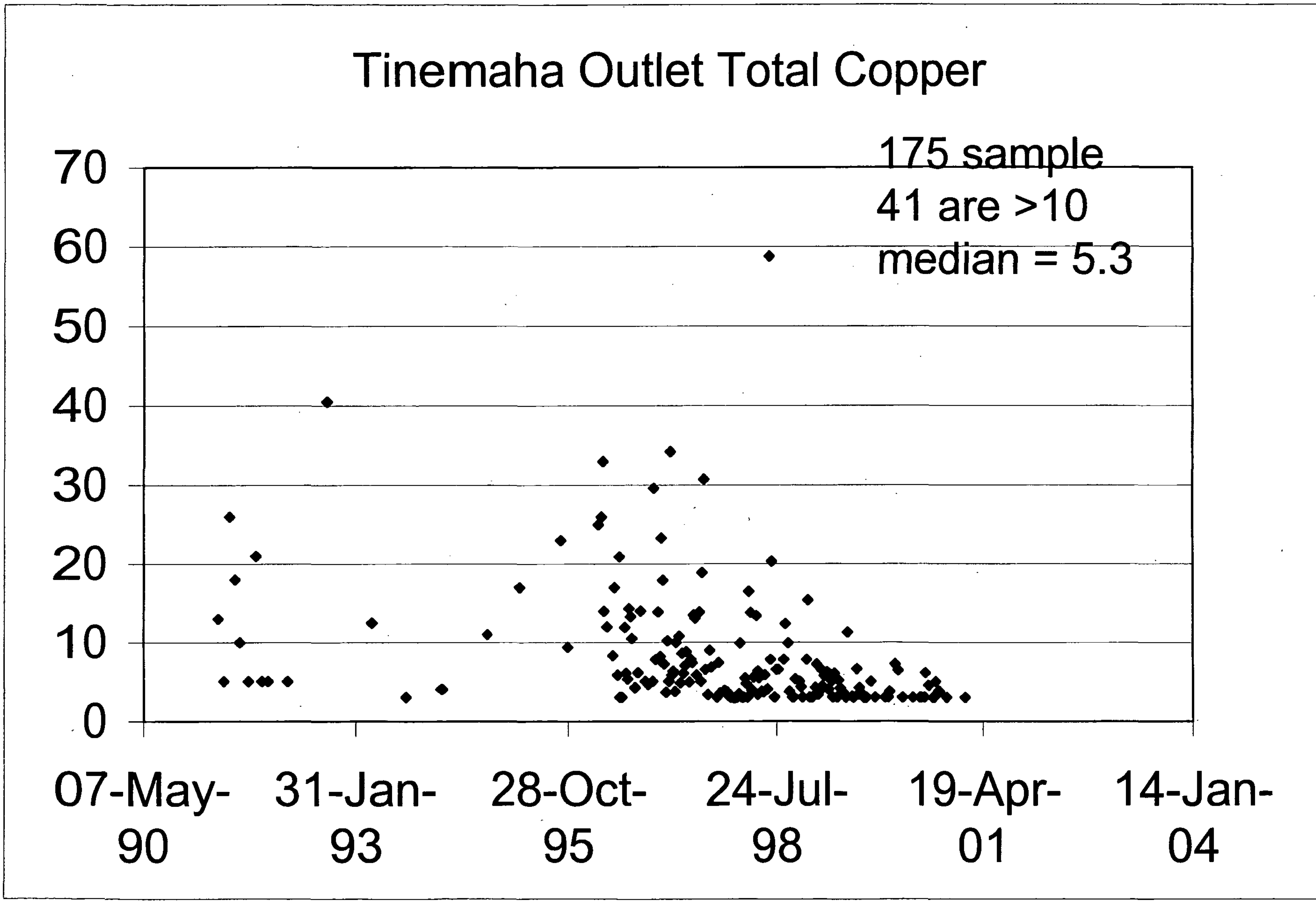
STATISTICS:	Field Temp. °C	Lab Hrd mg/l	Lab SO4 mg/l	Lab B mg/l	Lab F mg/l	Lab As µg/l	Lab Fe µg/l
Samples	157	60	47	27	49	168	44
Mean	8.2	46	6.2	0.09	0.13	12	63
Minimum (0% IQR)	0.0	24	2.0	0.00	0.00	0	0
25% IQR	3.5	38	3.7	0.02	0.00	10	0
Median (50% IQR)	8.0	46	5.0	0.07	0.11	10	60
75% IQR	13.0	52	8.0	0.16	0.21	10	100
Maximum (100% IQF	19.0	76	16	0.23	0.58	50	200
Detection Limit							
% > Detection Limit							

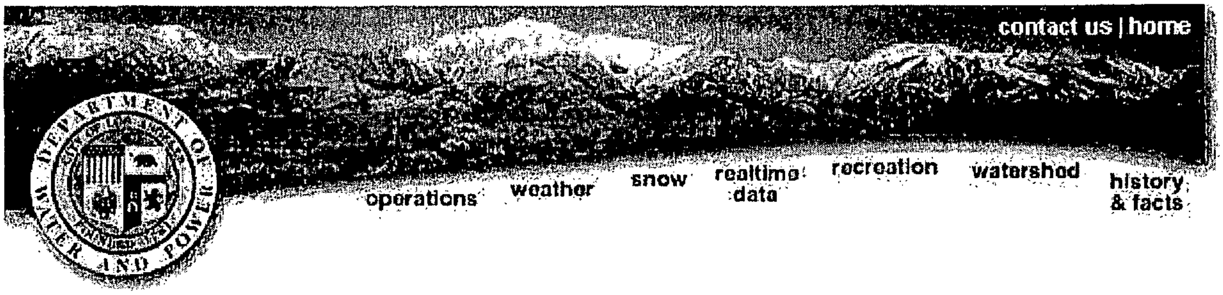


Arsenic vs Conductivity
Benton Crossing 1973 - 1991
Arsenic (µg/l)
0
20
40
60
80
100
0
100
200
300
400
500
600
Conductivity (µS/cm)
LADWP 1973-90

Aqueduct Treatments - Total Copper Residuals			
Date	**Treatment #**	**ug/l**	**Location**
3-Oct-95	1	207	Alabama Gates
27-Feb-96	2	249	Alabama Gates 250 YARDS SOUTH
28-Feb-96	3	269	Alabama Gates 250 YARDS SOUTH
19-May-98	4	215	Alabama Gates Metering Bridge
20-May-98	5	215	Alabama Gates Metering Bridge
23-Jun-98	6	255	Cottonwood 200 YARDS SOUTH
24-Jun-98	7	263	Alabama Gates Metering Bridge
25-Jun-98	8	237	Alabama Gates Metering Bridge
18-May-00	9	24	Cottonwood Bridge

207.00
249.00
269.00
215.00
215.00
255.00
263.00
237.00
24.0

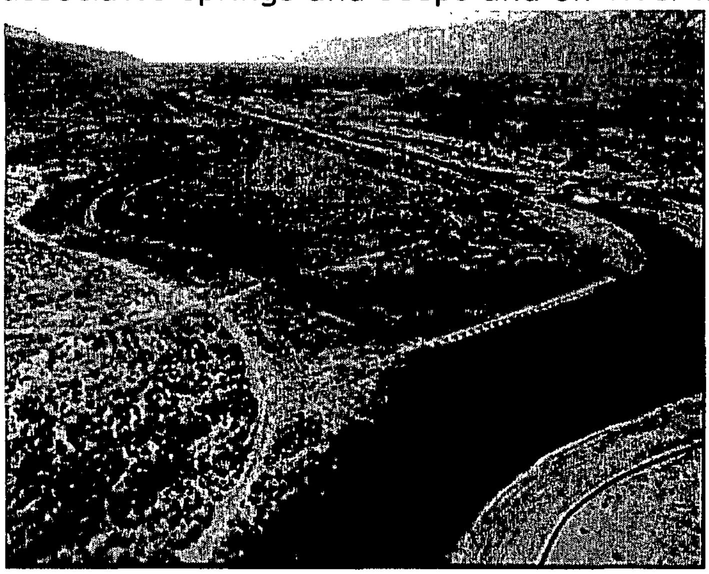

Tinemaha Outlet Total Copper
175 sample
41 are >10
median = 5.3
70
60
50
40
30
20
10
0
07-May-90
31-Jan-93
28-Oct-95
24-Jul-98
19-Apr-01
14-Jan-04



Lower Owens River Watershed

The Lower Owens River Project

The Lower Owens River Project settles more than 24 years of litigation between the Department and Inyo County over groundwater pumping and water exports. The project is intended to mitigate for a host of lost environmental values in the reach of the Owens River from the Los Angeles Aqueduct Intake to Owens Lake, and associated springs and seeps and off-river lakes and ponds. The project is the larges



restoration effort undertaken by the Department. It has an extensive scope and includes a geographic area 65 miles long and across the Valley from the Whit Mountains to the Sierra Nevada Mountains. This area has been designated the Lower Owens River Conservation area and consists entirely o LADWP property. The project includes nc only restoration of the river but developing habitat connectivity with off river habitats (numerous ponds and lakes) and thousands of acres of wetlands, riparian pasture and upland grazing management, sanctuaries for T&E bird, fish, and plant species, recreation plans, and a pumpback facility. The project was initiated in 1993 with a controlled flow study, data acquisition, and GIS data development. The DWP and consultants are now in the final stages of developing management plans for all resource components in the ecosystem.

River Management

The Lower Owens River will be managed with a base flow of 40 cfs and an annual riparian (freshet period) flow of up to 200 cfs. These flows will allow natural processes to create diverse and complex fisheries and riparian habitat.

Wildlife/Wetlands Management

The LORP will result in the creation of hundreds of acres of new wetland habitat for the benefit of wading birds, shore birds, and riparian species. Elk, deer, and other animals will benefit from the extensive wildlife habitat that will accompany the water and land management actions.

Spring & Seep Habitat Management

Over 100 springs and seeps have been inventoried in detail. Representative springs and seeps will be selected for long-term monitoring to measure changes caused by groundwater pumping. Some springs will be identified for restoration.

T&E Species Conservation

Development of a plan for indigenous threatened and endangered (T & E) species of fish, wildlife and plants, forms a part of the overall goal of the project to benefit biodiversity and comply with federal and state laws. The T & E plan focuses on the occurrence, distribution and habitat requirements of the federally listed species, as well as for selected federal and state species of concern. To ensure that the plan is not in conflict with the habitat requirements of other species of the planning area, information on candidate species of concern in addition to the federal T & E are being incorporated. The preliminary plan will identify conservation areas within the Lower Owens River planning area and incorporate all the actions planned to support recovery of T&E species. Most if not all of the planned actions within the Lower Owens project will benefit identified threatened and endangered species and measures are being taken to fully integrate T&E species into all elements of the planning process.

Monitoring & Adaptive Management

The LORP is a long-term commitment to monitoring trends, measuring attainment of goals, and decision-making on a host of ecological issues through adaptive management. Monitoring and adaptive management represents a major effort over many years to reach goals set for the LORP.

Baker and Hogback Creek Management

Two high quality riparian systems, Baker and Hogback creeks, in the Lower Owens River will be managed for their unique values for threatened and endangered bird species and associated habitat.

Habitat Conservation Plans (HCPs)

One of the many programs the Department performs on an ecosystem-wide basis that benefits the whole watershed management effort includes managing threatened and endangered species. While there are some existing sanctuaries for T&E species, and others in the development stage, the effort to maintain water deliveries to the city without creating conflicts with T&E species is too often piecemeal. The Department will initiate habitat conservation plans for all T&E species, on all

Department lands, beginning with fish in 1999. Successful implementation of HCPs will allow the Department to continue water delivery operations for perhaps 40 years without risk of conflict with T&E species and issues.

Resource Monitoring

Vegetation Mapping: Another ecosystem-wide program is the development of new vegetation maps at regular intervals for all Department lands in the Valley. These maps illustrate vegetation changes over time that is essential information for watershed management and planning. These maps and associated data, like most Department databases, are available to other agencies, universities, and researchers

Aerial Photography: The Department also updates its library of aerial photography and satellite images at prescribed intervals. Again, this information is essential in watershed management and photos and data are always made available to interestec parties.

Land Use Management

Water export, grazing/ irrigation, and recreation are the three primary uses of the Lower Owens watershed. The future quality and quantity of water to be supplied to the city is dependent on the management of both the water and the land. Grazing lease management plans are being prepared for each of the leases so as to meet bes management practices and to conform to the stated goals and objectives of the Lowe Owens River Project. Elements covered in the plans and future implementation include threatened and endangered species, livestock and elk grazing, waterfowl management, recreation and water quality both in the uplands and the riparian areas. Management plans are being designed to promote biodiversity and a healthy ecosystem while allowing for the continuation of sustainable land uses. The individua lease plans will be used to build the land use management plan for the Lower Owens River and to continue to be in compliance with state and federal laws that protect water quality and threatened and endangered species.

Recreation Management

As the restoration effort proceeds and the river and wetlands increase in biomass anc diversity, the area will undoubtedly attract an increasing number of tourists and othe outdoor recreation enthusiasts. Any increase in tourism and other recreation will be an economic boom to retailers and hotels in Lone Pine, Independence, and Bishop. The Department will adaptively manage recreation to prevent harm to the ecosystem and to minimize user conflicts. The Department expects to be proactive in our management as recreation use increases. Klondike, Warren, and Diaz lakes are valued recreation areas in the Lower Owens River. The Department will continue to provide management that promotes water sports, fishing, and hunting opportunities on these large lakes

University of California, Santa Barbara

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Sierra nevada aquatic research laboratory (SNARL)

Route 1, Box 198
1016 Mt. Morrison Road
Mammoth Lakes, CA 93546
http://nrs.ucop.edu/reserves/snarl.html

January 4, 2002

Thomas Suk, Environmental Specialist
California Regional Water Quality Control Board
2501 Lake Tahoe Blvd.
South Lake Tahoe, CA 96150

SUBJECT: PROGRESS REPORT FOR CONTRACT # 9-183-160-0, Arsenic Sources and the Feasibility of Using Nitrogen Isotopes to Determine Nitrogen Sources to Crowley Lake

Dear Tom,

Following is a progress report for the above-referenced contract. During the 4th quarter of 2001 we completed the analysis for arsenic on our 3rd quarter samples. This more spatially detailed sampling allows us to pinpoint the arsenic sources with better precision. Twenty-nine samples were taken on Mammoth Creek, Hot Creek, the Owens River, and Crowley Lake. Arsenic concentration varied from 1 to 189 ppb (0.1 to 2.52. micromolar). The data are provided in the attached table. This largely concludes the work in Task 2.

<u>Project Management and Administration</u>	
Task 1.1, Technical and Administrative Services	in progress
Task 1.2, Quality Assurance Plan	completed & approved, filed as part of SWRCB contract No. 91752500
Task 1.3, Quarterly Reports	in progress, this is our sixth required report
<u>WQ Monitoring for Arsenic Control</u>	
Task 2.1, Conduct Initial Sampling	completed
Task 2.2, Conduct Sample Analysis	completed
Task 2.3, Conduct Follow-up Sampling & Analysis	completed
<u>Isotope Feasibility & Technology Transfer</u>	
Task 3.1, Review Literature	in progress
Task 3.2, Select Study Locations	completed
Task 3.3, Conduct Sampling & Analysis	completed
Task 3.4, Data Evaluation & Technology Transfer	in progress

Geographic Information System

Task 4.1, GIS coverage preparation	in progress
Task 4.2, Compile existing data	in progress

Reports

Task 5.1, Draft Report	pending, due 12/30/02
Task 5.2, Final Report	pending, due 02/15/03

Please call me at 760 935-4334 if you have any questions regarding this progress report.

Sincerely,

Daniel R. Dawson

Daniel R. Dawson
Director and Co-Principal Investigator

TABLE 1
Arsenic Concentrations As Determined By Graphic Furnace Atomic Absorption Spectroscopy, 7/17/2001 Sampling

station code	water body	location	As (ppb)	As (microM)
OW0	Owens	at edge of lake	52	0.70
OW1	Owens	Benton Crossing	41	0.54
OW1.25B	Owens	just upstream of main Hot Ck. input	22	0.29
OW1.25C	Owens	just downstream of main Hot Ck input	36	0.48
OW1.5B	Owens	just upstream of westernmost Hot Ck. input	9	0.12
OW1.5C	Owens	just downstream of westernmost Hot Ck. input	13	0.18
OW2	Owens	downstream end of Howard Arcularius prop.	9	0.11
OW6A	Owens	upstream end of Alpers Ranch	11	0.15
OW7	Owens	culvert below Big Springs	9	0.11
OW8B	Owens	western primary spring at Big Springs	11	0.14
OW10A	Glass	just above confluence with Deadman Ck.	1	0.01
MA0A	Mammoth/Hot	westernmost Hot Ck input to Owens	111	1.49
MA0B	Mammoth/Hot	main Hot Ck. input to Owens	119	1.58
MA1	Mammoth/Hot	USGS gauge below thermal area	120	1.60
MA2A	Mammoth/Hot	above confluence of Hot Creek and hatchery inputs	8	0.11
MA2B	Mammoth/Hot	Hatchery inputs above confluence with Hot Creek	17	0.23
MA2C	Mammoth/Hot	below confluence of Hot Creek and hatchery inputs	19	0.25
MA2.5A	Mammoth/Hot	hatchery AB springs	19	0.26
MA2.5C	Mammoth/Hot	hatchery CD springs	20	0.27
MA3	Mammoth/Hot	gauging station at US395	2	0.02
320A	Mammoth/Hot	downstream fence, Hot Creek Ranch	16	0.21
320B	Mammoth/Hot	beginning of visible geothermal area	18	0.24
321A	Mammoth/Hot	above upper swimming hole	21	0.28
321B	Mammoth/Hot	below lower swimming hole	121	1.62
321C	Mammoth/Hot	200 m below geothermal area fence	137	1.83
322B	Mammoth/Hot	directly out of boiling pool	189	2.52
S500	Crowley Lake	south station	58	0.78
W500	Crowley Lake	west station	58	0.77
OUT	Crowley Lake	outlet	49	0.65

THE LOS ANGELES DEPARTMENT OF WATER AND POWER

WATER QUALITY REPORT FOR 2000

Table of Contents

page

COVER PHOTO Snowmelt from the eastern Sierra Nevada and groundwater from the Owens Valley provided 39 percent of the City's water in 2000.

The Los Angeles Board of Water and Power Commissioners (Board) meets regularly on the first and third Tuesday of each month at 10 a.m. The meetings are held at:

Los Angeles Department of Water and Power
111 North Hope St., Rm. 1555H
Los Angeles, CA 90012-2694

The meeting agenda is available to the public on the Friday before the meeting. You can access the Board agenda at **www.ladwp.com/whatsnew/index. htm** under Public Meetings.

For questions regarding water quality, please call our Water Quality Investigators, supervised by Mr. George Miller, at (213) 367-3182. For questions regarding the preparation of this annual report, please call Mr. Cesar Vitangcol at (213) 367-1767.

OTHER HELPFUL TELEPHONE NUMBERS

For schedules of LADWP Board meetings . . . (213) 367-1351

To request a LADWP speaker for your group . . (800) 322-8830

For a tour of the Los Angeles Aqueduct Filtration Plant (LAAFP) . . . . (213) 367-1361

For other informative brochures, such as water conservation . . . . (213) 367-1361

For all other LADWP-related inquiries . . . . . (800) 342-5397

For more information about LADWP, please visit our website – **www.ladwp.com**

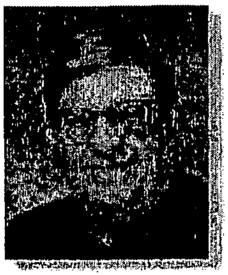
Additional information about drinking water and related regulations can be found at these websites:

California Department of Health Services – **www.dhs.gov/**

United States Environmental Protection Agency – **www.epa.gov/**

WATER TESTING

If you have great concern about your drinking water and desire to have your water tested, you can call DHS at (213) 580-5723 for a listing of state certified laboratories.



GERALD GEWE

Dear Customers:

I am pleased to present to you the Los Angeles Department of Water and Power (LADWP) Annual Water Quality Report (AWQR) for the year 2000. Now in its eleventh year, this report provides customers with important information regarding water quality in Los Angeles. In 2000, we again provided all our customers with drinking water that met or surpassed all state and federal drinking water standards.

As you read through this booklet, you will find reference charts that depict the actual levels of specific substances or "constituents" we have found in the City's water supply. Information regarding substances you may have heard or read about recently, such as radon and chromium 6, is presented in this publication. We have also provided information on where your water comes from and programs LADWP implements to maintain the quality of our water.

Our mission is to deliver a dependable supply of safe, quality water to our customers in an efficient and publicly responsible manner.

I would like to take this opportunity to thank those of you who responded to the survey enclosed in the 1999 report. Much of the information included in this year's report has been provided in response to questions and feedback received through the surveys. All public water providers like LADWP must deliver an annual drinking water quality report to their customers. We decided to go beyond the minimum requirements and take full advantage of this opportunity to present as much information as possible. We hope that this additional information will help you evaluate the quality of drinking water served to you. We believe that by providing this information, you can make informed choices about your drinking water.

In addition, I invite you to read our report as it also contains special notifications to persons with specific health conditions and other customers who have specific water quality needs.

We welcome any comments and questions you have regarding this 2000 report. A postage-paid postcard is included with the report for your convenience. If you have further questions or concerns regarding water quality in the City of Los Angeles, you can reach us at the Water Quality Office at (213) 367-3182.

Sincerely,

Gerald A. Gewe
Assistant General Manager – Water

A Summary of the State of Our Water Quality

We are pleased to report that the Los Angeles Department of Water and Power (LADWP) consistently provided the City of Los Angeles with high quality drinking water in the year 2000. Last year, all 220 billion gallons of water supplied to our 3.8 million customers ***met or surpassed all drinking water standards*** set by the U.S. Environmental Protection Agency (EPA) and the State of California Department of Health Services (DHS). This accomplishment is largely due to application of state-of-the-art water treatment processes, prudent facility maintenance and operation, and vigilant monitoring and testing of our water. LADWP conducted more than 207,000 tests on 25,000 sample throughout the year to monitor the quality of our water in Los Angeles.

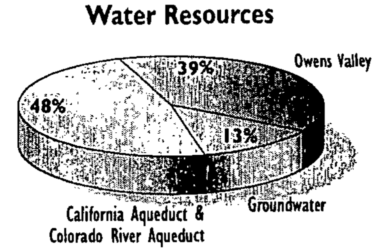
"...LADWP consistently provided the City of Los Angeles with high quality drinking water in the year 2000."

Los Angeles Water Sources

The LADWP water supply comes from several sources. In 2000, snowmelt from the eastern Sierra Nevada and groundwater transported from the Owens Valley via the Los Angeles Aqueduct provided 39 percent of the City's water. An additional 13 percent was groundwater from local wells, and the remaining 48 percent was water from the California State Water Project and the Colorado River purchased from Metropolitan Water District (MWD).

In the future, LADWP plans to augment its San Fernando groundwater source with recycled water from the East Valley Water Recycling Project. The recycled water will be treated to drinking water standards before it is transported by a pipeline from the Donald C. Tillman Water Reclamation Plant to what are known as "spreading grounds" in the San Fernando Valley. The recycled water will help "drought-proof" the basin, which is subject to water shortages from lack of rainfall and availability of imported water.

Water Resources



The Los Angeles Water System

Most major cities in the world have local supplies for their drinking water. However, the semi-desert climate of the City of Los Angeles requires that a greater part of its water be imported. The water is transported from hundreds of miles away via waterways called aqueducts. This imported water undergoes treatment, including disinfection, in our state-of-the-art filtration plant before distribution. Water pumped from wells is generally clean, but it is disinfected as a safeguard against harmful bacteria. Groundwater with traces of contaminants is also treated before it enters the distribution system. The water distribution system covers over 465 square miles of mountains, hills and valleys. Ensuring reliability of water supply in this geographically diverse area requires the use of huge tanks, reservoirs, valves, pumps, pressure regulators and a network of more than 7,500 miles of main distribution pipes.

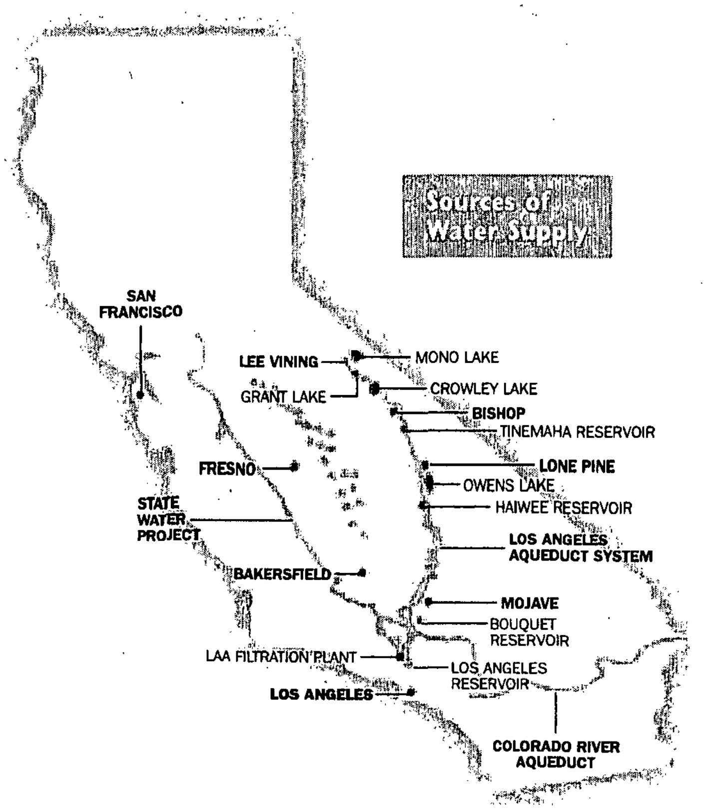
Important Messages for Our Customers

Special Notice to Immuno-Compromised Customers Some people may be more vulnerable to contaminants in drinking water than the general population. Immuno-compromised persons such as persons with cancer undergoing chemotherapy, persons who have undergone organ transplants, people with HIV/AIDS or other immune system disorders, some elderly and infants can be particularly at risk from infection. These people should seek advice about drinking water from their health care providers. EPA/Centers for Disease Control (CDC) guidelines on appropriate means to lessen the risk of infection by Cryptosporidium and other microbial contaminants are available from the Safe Drinking Water Hotline (800) 426-4791.

Special Notice to Users of Kidney Dialysis Machines and Fish Owners LADWP may provide Metropolitan Water District (MWD) water from time to time anywhere in the City. MWD water is treated with chloramines, a disinfectant that produces fewer disinfection by-products such as trihalomethanes. This change is necessary to accommodate seasonal changes and operational requirements.

LADWP water contains one of two types of disinfectants to safeguard the water supplied to our customers' tap – chlorine and chloramine. Historically, the Northern, Eastern, and Western parts of the City are chlorinated, and the Southern part is chloraminated. Over the next several years, LADWP will be phasing-in a system-wide conversion to chloramines as an alternate disinfectant.

All customers are advised to assume that LADWP water contains chloramines at all times. As such, customers who have unique water quality needs and who use specialized treatments such as kidney dialysis machines or fish owners should make the necessary adjustments to remove chloramines as well.



The Los Angeles water system is not a single water system, but over one hundred small water systems interconnected by large pipes called trunk lines. Each small system serves a specific neighborhood. Each neighborhood receives water from different distribution facilities depending on the availability of supplies. These small systems vary in age according to when the community was built. For example, Highland Park was built in the early 1900s and the San Fernando Valley was built after World War II. The age of a system, as well as the plumbing condition of the building, can impact the quality of water that reaches the customer's tap. LADWP has a program to continuously upgrade, replace, and maintain these water systems to safeguard the quality of the water.

How We Determine Water Quality

The quality and safety of drinking water is defined by the results of a series of bacteriological, chemical, physical, and radiological tests conducted by chemists, microbiologists, water biologists and technical water quality specialists. Results of these analyses are compared to drinking water standards established by EPA and DHS. Our monitoring program involves collecting and testing water samples from untreated source water, treated water, reservoirs, tanks, pipelines and customer residences. LADWP collects more samples than required by law to ensure the high quality of the water and protect the health of our customers. These thousands of water samples from throughout the City pass through LADWP's state certified Water Quality Laboratory in Sun Valley.

Monitoring of Regulated Constituents and Contaminants

Currently, there are over 110 constituents and contaminants regulated in drinking water. They are grouped into two categories according to standards set by EPA or DHS. Primary drinking water standards are health related while secondary standards are based on aesthetic qualities like taste and appearance. LADWP and other water providers monitor for each constituent on varying schedules based on the type of constituent and the source of water. Contaminants that pose an immediate risk require more frequent monitoring. For example, bacteriological sampling is required daily since the presence of harmful bacteria can have an immediate impact on a person's health, while calcium sampling is required annually as it does not have an immediate effect on health.

After thoroughly testing for the more than 110 regulated contaminants, LADWP found that most of these substances were not detected in our water supply. Only those contaminants that were detected are listed in the tables. (See Tables I and II on pages 8 and 9.)

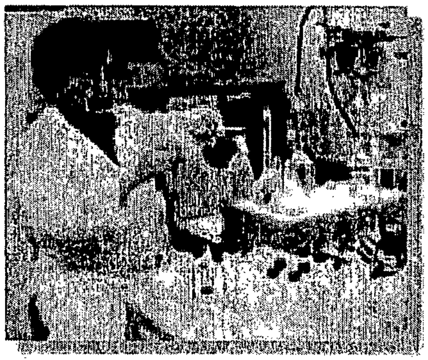
Table I contains the primary drinking water contaminants found and their health-based standards. Table II contains the secondary drinking water constituents and their aesthetic-based standards. A comparison between the standard and the average value determines whether the drinking water meets or does not meet the allowable limit for each constituent or contaminant.

Monitoring for Unregulated Constituents and Contaminants

LADWP water sources are also tested for more than 60 constituents and contaminants currently not regulated by either the state or the federal government. By monitoring unregulated contaminants, LADWP helps the state and federal health agencies determine the need for future regulations and setting of standards. (See Table III on page 10)

Some Background on Contaminants

LADWP tests the water for more than 170 constituents and contaminants. Many constituents of drinking water are naturally-occurring substances, such as calcium, magnesium, and chloride. These substances define the general characteristics of drinking water such as taste. Contaminants, whether man-made or naturally-occurring, are substances which can affect our health or acceptability of the water. All drinking water, including bottled water, may reasonably be expected to contain at least small amounts of some contaminants. Why? Because the sources of drinking water (both tap and bottled water) include rivers, lakes, streams, ponds, reservoirs, springs, and wells. As water travels over the surface of the land or through the ground, it dissolves naturally-occurring minerals and in some cases, radioactive materials, and can pick up substances resulting from the presence of animal or human activity.



"All drinking water, including bottled water, may reasonably be expected to contain at least small amounts of some contaminants."

The presence of contaminants does not necessarily indicate that the water poses a health risk.

In order to ensure that tap water is safe to drink, the EPA and the State Department of Health Services prescribe regulations that limit the amount of certain contaminants in water provided by public water systems. DHS regulations also establish limits for contaminants in bottled water that must provide the same protection for public health.

Contaminants that may be present in source water before treatment include:

- **Microbial contaminants,** such as viruses and bacteria, may come from sewage treatment plants, septic systems, agricultural livestock operations and wildlife.
- **Inorganic contaminants,** such as salts and metals, can be naturally occurring or result from urban storm water runoff, industrial or domestic wastewater discharges, oil and gas production, mining or farming.
- **Pesticides and herbicides,** that may come from a variety of sources such as agriculture, urban storm water runoff and residential uses.
- **Organic chemical contaminants,** including synthetic and volatile chemicals, that are by-products of industrial processes and petroleum production, and can also come from gas stations, urban storm-water runoff, agricultural application, and septic systems.
- **Radioactive contaminants,** that can be naturally-occurring or be the result of oil and gas production and mining activities.

More information about contaminants and potential health effects can be obtained by calling EPA's Safe Drinking Water Hotline at (800) 426-4791.

Is There Anything in My Water I Should Know About?

Last year, 11 contaminants were detected in the treated water that have associated health risk. Test results showed that these contaminants were far below the maximum contaminant levels (MCLs), which are the health protective standards set by the EPA and DHS. The following low-level contaminants were detected in the treated water last year: aluminum, arsenic, fluoride, nitrate, turbidity, radionuclides (alpha, beta, radium, and uranium), total coliform, and total trihalomethanes.

For more information on these constituents/contaminants, please refer to Table 1 on page 8 and 9. The lead and copper data on this table are the results of at-the-tap monitoring conducted in 1992 as required by the Lead and Copper Rule. There were no lead and copper detected in our finished water last year.

How Safe is Safe?

Drinking water, containing levels of contaminants that are less than federal and state health-based standards, is considered safe for the general population. The water from your tap meets these requirements. Does this mean our water can be deemed "pure"? No, because for any water to be qualified as pure, it must contain only hydrogen and oxygen, the components of water. Pure water is flat and tasteless. Pure water robs the body of essential minerals, such as calcium, and is so corrosive that it will dissolve harmful metals in household pipes.

The next time you fill a glass with water, think about the fact that this water has existed on the planet for millions of years and through nature's process has been continuously recycled. The water we drink travels over the surface of the land and ground, dissolving and picking up substances that are naturally occurring or introduced by human activity. While several of these substances are essential to our health and contribute to pleasant taste, some of

them contribute to the risks in the drinking water. These substances are present whether you drink tap or bottled water. Yet, the presence of these substances does not necessarily mean that the water is not safe. It is a question of how much of a particular substance is present in the water. Today's advanced water analytical capabilities and treatment technologies, combined with stringent drinking water standards, work together to ensure that the treated water served to our customers contains the smallest possible amount of substances which might be considered harmful.

The safety of water is measured using standards. These standards are the results of years of scientific research, studies, and advances in technology. The standard may be a number, a treatment process, or an action level (see "Terms Used in the Tables" on page 8). Standards can be primary or secondary. Primary standards for contaminants are health-based and must be both technologically and economically feasible. Primary standards are based according to whether a water contaminant has long-term or short-term effects, is carcinogenic, or causes other health problems, such as birth defects. Secondary standards are for contaminants that can affect the taste, appearance, and odor (aesthetic qualities) of the water. Water providers in California must comply with both primary and secondary drinking water standards.

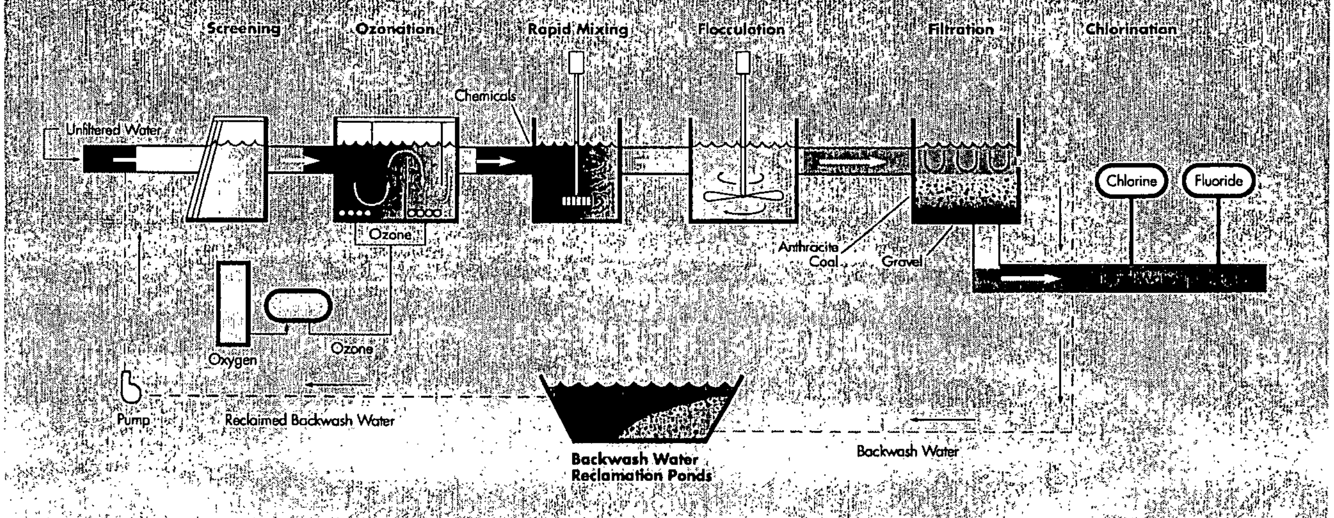
Making Drinking Water Safe

Surface Water Treatment All water coming from the Los Angeles Aqueduct, the California Aqueduct, and the Colorado River Aqueduct is treated to ensure a safe drinking water supply. The water treatment process used at the LAAFP is described below.

Groundwater Treatment The City of Los Angeles has a vast groundwater resource held in an aquifer in the San Fernando Valley. Water pumped from these wells is generally clean and clear. However, it is disinfected with chlorine as a safeguard against microorganisms. In the 1980s, some of the wells in the San Fernando Valley area were found to contain traces of industrial solvents trichloroethylene (TCE) and perchloroethylene (PCE). Some wells were shut off. In 1989 a treatment facility was constructed in the North Hollywood-Burbank area to remove the plume of contaminants in the affected parts of the aquifer. In 1999, a separate treatment facility was built to remove similar contaminants at the Pollock Well field.

Recycling Water Water is one of our most precious and finite resources and should be conserved and recycled whenever possible. One of the many safe ways to reuse water is to recharge our groundwater basin with recycled water. After extensive processing at advanced treatment plants to meet drinking water standards, recycled water can be put back into the earth. DWP plans to utilize a naturally formed biological surface filter to further remove some contaminants from water used for recycling. Additionally, the recharging would only be done in areas which have been naturally and safely recharged with rain and surface runoff for many years.

The Treatment Process



Water flows into the plant by gravity and travels through a screener to remove environmental debris such as twigs and dead leaves. Ozone, a souped-up oxygen molecule and a powerful disinfecting agent, is injected into the water to destroy bacteria and other impurities that affect the its taste, odor, and color. Chemicals are quickly dispersed into the water to make fine particles cluster together and form larger particles called flocs. These impurity-containing flocs, together with the previously added chemicals are removed when the water passes through a filter. The filter is a six-foot deep layer of crushed coal over a layer of gravel. The filtered water is then chlorinated to ensure lasting disinfection and protect the water as it travels through the City's distribution system.

Terms Used in the Tables

Maximum Contaminant Level (MCL): The highest amount of a contaminant that is allowed in drinking water. Primary MCLs are set as close to the Public Health Goals (PHGs) (or MCLGs) as is economically and technologically feasible. Secondary MCLs are set to protect odor, taste, and appearance of drinking water. For certain contaminants, compliance with the MCL is based on the average of all samples taken throughout the year.

Maximum Contaminant Level Goal (MCLG): The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs are set by the U.S. Environmental Protection Agency. For known or suspected carcinogens, EPA automatically sets the level at zero.

Public Health Goal (PHG): The level of a contaminant in drinking water below which there is no known or expected risk to health. PHGs are set by the California Environmental Protection Agency.

Detection Limit for Reporting Purposes (DLR): The DLR is the lowest level at which all DHS certified laboratories can accurately and reliably detect a compound. The DLR provides a standardized basis for reporting purposes. For example, if two separate laboratories report that lead is "not detected," it is understood that the amount of lead in both waters was less than the DLR for lead.

Regulatory Action Level (AL): The concentration of a contaminant that, if exceeded, triggers treatment or other requirements which a water system must follow.

TT (Treatment Technique): A required treatment process which will reduce the level of a contaminant in drinking water. For example, the filtration process is a treatment technique used to reduce turbidity (the cloudiness in water) and microbial contaminants from surface water. High turbidities may be indicative of poor or inadequate filtration.

milligram per liter(mg/L), microgram per liter(ug/L): These are units of measure used to indicate the amount of a contaminant in a certain volume of water. One milligram per liter is equivalent to one part per million (ppm). Likewise, one microgram per liter is equivalent to one part per billion (ppb).

2000 Water Quality

TABLE I – PRIMARY DRINKING WATER CONSTITUENT

Harbor Area – Cal

Constituents/Contaminants	Units	State DLR	State PHG or Federal MCLG	State Primary Standard (MCL)	Diemer Filtration Plant Range	Diemer Filtration Plant Average
Aluminum	ug/L	50.0	60 (h)	1000	<50-169	123
Arsenic	ug/L	2	none	50	<2-3.1	2.3
Fluoride	mg/L	0.1	1.0	2	0.17-0.26	0.20
Nitrate (as N)	mg/L	0.4	10	10	<0.4-0.95	<0.4
Turbidity	NTU	none	none	TT	0.05-0.07	0.06
Alpha Emitters (a)	pCi/L	1	0	15	1.2-6.0	3.6
Beta Emitters (a)	pCi/L	4	0	50	5.2-7.8	6.2
Radium (Total) (a)	pCi/L	1	0	5	<1.0-1.9	<1.0
Uranium (a)	pCi/L	2	0.2 (h)	20	<2.0-3.8	2.6
Total Coliform Bacteria	CFU/ 100ml	none	0	5% of samples coliform positive	Range: 0-0.30% (b)	
Total Trihalomethanes (TTHM)	ug/L	0.5	0	100	Range: 50-74 (c)	
Lead (at-the-tap)	ug/L	5	2	AL=15 (e)	Range: 12-13 (b, d)	
Copper (at-the-tap)	ug/L	50	170	AL=1300 (e)	Range: 320-760 (b, d)	

TABLE II – SECONDARY DRINKING WATER CONSTITUE

Harbor Area – Ca

Contituents/Contaminants	Units	State DLR	State Secondary Standard (MCL)	Diemer Filtraton Plant Range	Diemer Filtraton Plant Average
Aluminum	ug/L	50	200	<50-169	123
Chloride	mg/L	none	500 (f)	60-80	69
Color	Units	none	15	1	1
Conductivity	umhos/cm	none	1600 (f)	645-831	732
Corrosivity (g)	LSI	none	non-corrosive	-0.01-0.34	0.22
pH	Units	none	8.5 (f)	8.00-8.03	8.02
Sulfate	mg/L	0.5	500 (f)	111-173	149
Total Dissolved Solids (TDS)	mg/L	none	1000 (f)	373-491	432
Turbidity	NTU	none	5	0.05-0.07	0.06

Monitoring Results

'S/CONTAMINANTS DETECTED IN TREATED WATER
lendar Year 2000

Weymouth Filtration Plant Range	Weymouth Filtration Plant Average	Jensen Filtration Plant Range	Jensen Filtration Plant Average	Major Sources in Our Drinking Water
<50-189	127	55-80	70	Erosion of natural deposits; residue from some surface water treatment process
<2-3.0	2.1	<2-2.5	2.1	Erosion of natural deposits; runoff from orchards, glass and electronic production wastes
).17-0.23	0.21	0.13-0.23	0.18	Erosion of natural deposits; water additive that promotes strong teeth
<0.4-01.1	<0.4	<0.4-0.56	<0.4	Erosion of natural deposits; Runoff and leaching from fertilizer use
).06-0.08	0.07	0.04-0.05	0.04	Soil runoff
1.7-6.3	4.6	1.5-3.2	2.4	Erosion of natural deposits
<4.0-6.6	4.7	<4-4.4	<4	Decay of natural and man-made deposits
<1.0	<1.0	<1.0-2.9	1.0	Erosion of natural deposits
2.4-4.0	3.2	<2-2.1	<2	Erosion of natural deposits
	Average = 0.08% (b)			Naturally present in the environment
	Average = 62 (c)			Disinfection by-product of chlorination
	Average = 12.5 (b, d)			Internal corrosion of household water plumbing systems
	Average = 540 (b, d)			Internal corrosion of household water plumbing systems

NTS/CONTAMINANTS DETECTED IN TREATED WATER
lendar Year 2000

Weymouth Filtraton Plant Range	Weymouth Filtraton Plant Average	Jensen Filtraton Plant Range	Jensen Filtraton Plant Average	Major Sources in Our Drinking Water
<50-189	127	55-80	70	Erosion of natural deposits; residue from some surface water treatment process
61-81	69	52-60	58	Runnoff/leaching from natural deposits; seawater infuence
	1	1	1	Naturally-occurring organic matter
654-833	740	457-525	503	Substances that form ions when in water, seawater influence
0.1-0.43	0.32	-0.01-0.27	0.19	Natural or industrially influenced balance of hydrogen, carbon and oxygen in the water; affected by temperature and other factors
3.10-8.12	8.11	8.23-8.37	8.31	Physical characteristic
116-169	151	46-73	62	Runoff/leaching from natural deposits
379-488	437	251-296	281	Runoff/leaching from natural deposit
).06-0.08	0.07	0.04-0.05	0.04	Soil runoff

Abbreviations and Footnotes

< = less than (example: In Table 1, Aluminum has an average value of <50 for combined wells. This means that the average value is less than 50 microgram per liter, which is the limit of detection for reporting for Aluminum.)

CFU/100 ml = colony forming units per 100 milliliters of sample. This is the unit for reporting of coliform bacteria, but compliance is reported as percentage of positive samples.

LSI Units = Langelier Saturation Index (an indicator of corrosivity)

mg/L = milligrams per Liter (equivalent to ppm)

NA = Not analyzed

NTU = Nephelometric Turbidity Units; Turbidity is a measure of the cloudiness of the water. It is a good indicator of water quality. High turbidity can hinder the effectiveness of disinfectants.

pCi/L = picoCuries per Liter

ug/L = micrograms per Liter (equivalent to ppb)

umhos/cm = micromhos per centimeter

(a) MWD sampling occurred between August, 1998 and April, 1999. Because radioactivity changes very little over time, monitoring for it is required once every 4 years.

(b) Values reflect city-wide results.

(c) Compliance is based on a weighted system-wide average, however, these results are specific to this water quality area.

(d) At-the-tap monitoring was conducted in 1992 as required by the Lead and Copper Rule. Although the City's source water has little or no detectable lead, studies were conducted and corrosion control is scheduled for implementation

(e) A system is out of compliance when more than 10% of the samples taken are above the Action Level.

(f) Upper limit for the secondary MCLs

(g) Corrosivity values were taken from calculated Langelier Index: negative value means that the water maybe corrosive, positive value means that the water is non-corrosive.

(h) Proposed PHGs.

TABLE III – UNREGULATED DRINKING WATER CONSTITUENTS/CONTAMINANTS DETECTED IN TREATED WATER

Harbor Area – Calendar Year 2000

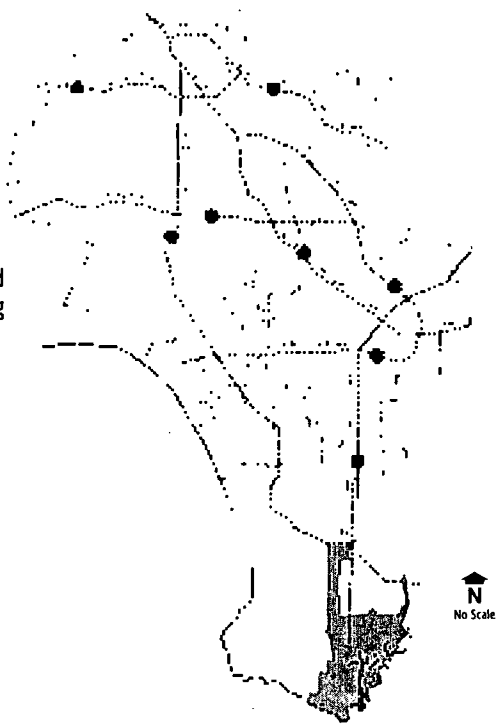
Constituents/ Contaminants	Units	Diemer Filtration Plant		Weymouth Filtration Plant		Jensen Filtration Plant		Major Sources in Our Drinking Water
		Range	Average	Range	Average	Range	Average	
Alkalinity	mg/L	91-114	104	81-104	92	81-92	88	Erosion of natural deposits
Boron	mg/L	0.11-0.12	0.12	0.27-0.53	0.43	0.19-0.26	0.24	Erosion of natural deposits
Calcium	mg/L	40-57	49	41-56	49	23-32	28	Erosion of natural deposits
Magnesium	mg/L	17-22	20	17-22	20	12-15	14	Rocket fuel and chemical fertilizer
Perchlorate	ug/L	<5.0-5.0	<5.0	<5.0-7.3	<5.0	<5.0	<5.0	Rocket fuel and chemical fertilizer
Potassium	mg/L	3.4-3.8	3.5	3.4-3.8	3.5	2.6-2.9	2.8	Erosion of natural deposits of chlorination
Sodium	mg/L	56-76	65	60-76	67	45-50	47	Erosion of natural deposits of chlorination
Total Hardness (as $CaCO_3$)	mg/L	170-233	207	172-230	207	111-140	127	Erosion of natural deposits of chlorination
Bromodichloromethane	ug/L	Range: 15-25 (c)			Average: 20 (c)			Disinfection by-product
Bromoform	ug/L	Range: 0.5-7.1 (c)			Average: 4.3 (c)			Disinfection by-product
Chloroform	ug/L	Range: 13-28 (c)			Average: 18 (c)			Disinfection by-product
Dibromochlormethane	ug/L	Range: 8.3-34 (c)			Average: 20 (c)			Disinfection by-product

Where Your Water Comes From

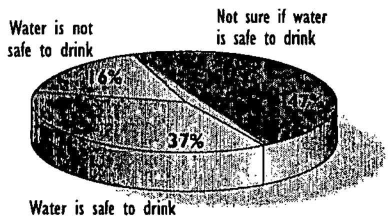
The **Harbor Area** only receives Metropolitan Water District (MWD) water from the California Aqueduct and Colorado River Aqueduct, and is treated at MWD facilities before being served to customers.

Harbor Area Communities

- East San Pedro (Terminal Island)
- Harbor City
- Harbor Gateway
- LA City Strip (parts of)
- San Pedro
- Wilmington



Customer Questions from the 1999 Water Quality Report Survey



Customer Perception of Drinking Water

Nearly 10,000 LADWP customers responded to the brief questionnaire attached to the 1999 Annual Water Quality Report survey. We thought it would be interesting and informative to share with you in this report some of the most frequently asked questions about water quality and our answers to those questions. For a more detailed discussion of these issues and other frequently asked water quality questions, please visit our webpage: **www.ladwp.com/water/quality/FAQ/FAQ.htm**

"Is My Water Hard?" Water hardness varies greatly throughout the City of Los Angeles because our water comes from different sources. In 2000, water hardness varied from 86 to 323 milligrams per liter measured as calcium carbonate ($CaCO_3$). Table III contains the value for total hardness of the water in your area. The water hardness table below will tell you the level of hardness of your water.

Levels of Water Hardness expressed in mg/L as $CaCO_3$

- less than 75 mg/L — Soft
- 75-150 mg/L — Moderately Hard
- 150-300 mg/L — Hard
- greater than 300 mg/L — Very Hard

"LADWP programs such as main flushing, cement lining, and by-passing some uncovered reservoirs also help ensure that our water will have acceptable taste and odor."

Hard water may be objectionable to some people because it leaves spots on glassware and uses more detergent for washing. On the other hand, it contains minerals that the body needs and it prevents corrosion by creating a protective coating inside pipes. Soft water can be corrosive and can shorten the life of home plumbing and fixtures. The decision to use a water softener depends upon the individual's preference and needs.

"Why Does My Water Taste And Smell Bad?" The most commonly detectable tastes and odors in the water can be grouped into one of three categories: bleachy (chlorine), sulfurous (sewage-like), or musty (moldy). Bleachy taste and odor comes from the chlorine that is used to disinfect the water. Disinfection of the water is one of the processes that eliminate disease-causing bacteria. A small quantity of chlorine in the water ensures lasting protection against these bacteria all the way to your tap.

Improving the taste of tap water can be simply done by refrigerating it before drinking.

The common cause of sulfurous and musty taste and odor are from bacteria that can grow in household drains and water heaters. Odorous gases caused by these bacteria usually accumulate in the drain and are expelled when the tap is turned on. Disinfecting the drain can eliminate odor problems like these. Water allowed to stand in a water heater that is not heated to recommended temperatures (usually around 130 degrees F), can also develop an unpleasant taste and odor. This problem can be solved by proper heating of the water heater. Call us at (213) 367-3182 or check out our website at **www.ladwp.com/water/quality/HowTo/index.htm** for instructions.

In 2000, less than 4 percent of nearly two thousand daily samples tested throughout the city had a discernable odor. LADWP programs such as main flushing, cement lining, and by-passing some uncovered reservoirs also help ensure that our water will have acceptable taste and odor.

"What is Chromium? Is It In LADWP Water?" The success of the "Erin Brockovich" movie has placed the subject of chromium 6 in drinking water into the spotlight of public health concerns. There are two forms of chromium that exist in drinking water: chromium 6, a known carcinogen when inhaled, and chromium 3, an essential nutrient. Chromium can occur naturally through the erosion of natural deposits or enter drinking water sources through discharges from industrial activities such as electroplating, pigment manufacture, and leather tanning. It can also be introduced from the presence of hazardous waste sites.

In 2000, special, monthly low-level chromium monitoring in the LADWP well systems showed the highest values of 4.2 parts per billion (ppb) and 4.0 ppb for chromium 6 and total chromium, respectively.

Currently, there is no standard for chromium 6. The DHS standard for total chromium is 50 ppb. Total chromium includes both forms of chromium 3 and chromium 6. LADWP will not serve any water that has a chromium content greater than 10.0 ppb, one-fifth the state standard. In comparison, the chromium levels reported in Hinkley Wells were as high as 24,000 ppb.

On March 27, 2001, Cal/EPA requested that the University of California convene an expert panel to address the carcinogenicity of ingested chromium 6. At the same time, DHS requested that the California Office of Environmental Health Hazard Assessment prepare a Public Health Goal (PHG) that is specific for chromium 6. A PHG is needed for the development of a chromium 6 drinking water standard. LADWP intends to comply with any standard established for chromium 6.

"How [Reliable] Is Our Water Supply?" Los Angeles, being a semi-desert region, has to import most of its water. New water sources are difficult to find while the capacity of current sources continues to decline. It is LADWP's responsibility to ensure reliability of our water supply. With careful planning, LADWP will continue to provide the City with an adequate supply of water to accommodate our growing population, business, and industry. Read on to learn about what LADWP is doing to augment and maintain the City's water supply.

"How Can I Conserve Water?" As a concerned customer, you can participate in water conservation and make a difference by doing the following:

- Check pipes, faucets and toilets for leaks. Even a small drip wastes more than 1500 gallons a month. Repair leaks immediately.
- Consider buying a LADWP approved, ultra-low-flush toilet. The unit uses only 1.6 instead of 3.5 to 5 gallons per flush. LADWP offers rebates of $75 to $100.
- Install a water-saving showerhead and take shorter showers. LADWP residential customers can receive these showerheads for free. Call 1-(800) U-ASK-DWP (827-5397) or 1-(800) 342-5397 for the location of the nearest customer service office.

"LADWP and all other water providers throughout the world are actively working on recycling water."

- Turn off the water while you are shaving or brushing your teeth and save up to 3 gallons each time.
- Use your dishwasher for full loads only. Every load uses about 15 gallons.
- Use your automatic washing machine for full loads only. It uses up to 60 gallons per load.
- Do not let the faucet run while you clean vegetables. Instead rinse them in a sink full of clean water.
- If you wash dishes by hand, do not leave the water running for rinsing.
- Adjust sprinklers to water the lawn, not the pavement. Water your lawn deeply and less frequently. Water early in the morning or late in the evening. Change watering schedule seasonally.

"Are You Really Going To Give Us Toilet Water?" The answer is, No. However, there has been some confusion about the East Valley Water Recycling Project which the media has called "toilet to tap". While the term might be catchy, we have no intention of taking sewer water and piping it directly to homes and businesses. LADWP and many other water providers around the world are actively working on recycling water. This is a multi-faceted process that actually involves treating the water so that it is suitable for human consumption and then piping this clean water to spreading grounds where it will take at least five years to percolate into the ground (where it is naturally cleansed again). The water is then extracted from the ground and treated again before being blended into the distribution system. We need to keep in mind that all water is recycled water and is used over and over again.

In the year 2000, the City used 41,750 acre-feet of recycled water for irrigation, industrial, and recreational purposes. This is about six percent of the total water supplied to Los Angeles. There are currently several water recycling projects in development to increase our use of recycled water. They will be evaluated according to feasibility, cost-effectiveness, compliance to regulatory requirements, and public acceptance. It is the LADWP's goal to use 102,000 acre-feet of recycled water by the year 2020.

"How Do Our Water Rates Compare to Those of Other Cities?" Water is a vital and precious resource, yet its cost to the consumer is relatively low. One of our customer requests from the 1999 AWQR survey was to show a rate comparison of other cities with LADWP. As you can see, LADWP had the second lowest water rate among the seven similarly situated cities.

December 2000	Cost per 1,200 cubic feet
Burbank	$20.04
LADWP	$22.69
San Francisco	$24.52
Glendale	$26.42
Long Beach	$26.63
San Diego	$27.26
Oakland	$30.97

What LADWP Is Doing to Improve Water Quality

LADWP has an ongoing capital program to improve reliability and safeguard water for Los Angeles. Over the next ten years, LADWP will invest more than $2 billion in this program. Nearly $500 million will be spent on improving water quality and complying with drinking water regulations such as Surface Water Treatment Rule, Total Coliform Rule, and Lead and Copper Rule. More than $700 million will be invested in the replacement and improvement of infrastructure such as trunk lines, main pipes, meters, and service lines. Aging facilities such as pumping stations, chlorination stations, and regulator stations will be upgraded or replaced.

"LADWP had the second lowest water rate among the seven similarly situated cities."

Flushing

Water main flushing is a process of cleaning pipes by forcing water through at high speeds. Flushing removes sediment that can cause water to appear dirty or discolored. Water main flushing may also improve the water's taste. The flow of water to your homes and businesses will be redirected so those pipes can be isolated for flushing. During this time, your water may appear dirty for a few hours. This is a temporary condition and not a health risk.

You will be notified of flushing in your area. When flushing work is done in your area, please run your taps for a couple of minutes until the water is clear. Even though you should avoid wasting water, it is necessary to run the taps for a very short time to restore water quality. Avoid using hot water during this period to prevent dirty water from filling the water heater. For a daily schedule of flushing locations, please call the **Project Hotline** at (213) 367- 4477.

Chloramine Conversion

Drinking water standards for disinfection by-products (DBPs) are expected to be more stringent in the near future. DBPs are produced in the water when a disinfectant like chlorine combines with naturally-occurring materials in the water. DBPs may pose long-term health risks.

In an effort to reduce the levels of DBPs that result from chlorine disinfection, and to improve the taste and odor of the water, LADWP is phasing in a system-wide conversion to chloramines as an alternative disinfectant. Mixing ammonia and chlorine forms chloramines. Unlike chlorine, chloramines are considered less reactive and do not form as much disinfection by-products.

Drinking Water Source Assessment and Protection Program (DWSAP)

This program, initiated by the EPA and administered by each state, is intended to encourage water suppliers to develop a comprehensive program to protect their drinking water sources from contamination. The assessment program includes identification of zones around a drinking water source in which con-taminants might move and reach the drinking water supply; an inventory of possible contaminating activities that might lead to the release of microbial or chemical contaminants within the defined zones; and a determination of the vulnerability of the water supply to the activities identified.

In 2001, LADWP will conduct the assessment of groundwater sources in the Owens Valley that supplement the Los Angeles Aqueduct supply. Local groundwater supplies in the San Fernando and Central Basins will be assessed in 2002. All assessments will be completed by May 2003 and reported to DHS by July 1, 2003.

Information Collection Rule (ICR)

Information Collection Rule is a special data-gathering program administered by the EPA to guide future regulatory and public health decisions on pathogens, disinfectants, and disinfection by-products in drinking water. From July 1997 to December 1998, participating water systems nationwide collected data on their raw and finished water. The collected data was sent to EPA for evaluation and is available through the internet. This report contains the results obtained by LADWP from the samples collected during the ICR program. (See Table IV and V on page 15.)

The Surface Water Treatment Rule & LADWP

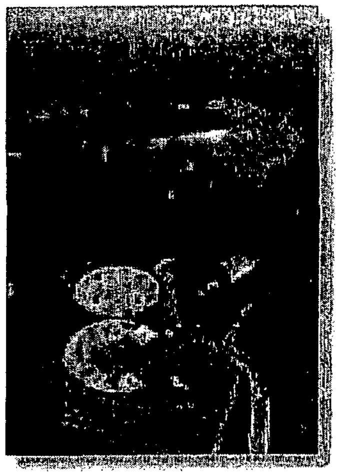
The Surface Water Treatment Rule (SWTR) administered by the State Department of Health Services (DHS) is a drinking water regulation designed to help safeguard reservoir supplies from microbiological contamination that may occur when rain runoff from nearby hillsides and slopes enters the water. In Los Angeles, four open water reservoirs are subject to the SWTR – Lower Stone Canyon, Encino, and Upper and Lower Hollywood.

LADWP plans to comply with the SWTR by removing these reservoirs from regular service through construction of larger pipelines and storage facilities that will allow water from other LADWP facilities to be supplied to the reservoirs' service areas. These "by-passed' reservoirs will be maintained for use as reserve water supplies in emergency conditions.

LADWP operates the water from these reservoirs under strict DHS guidelines that, among other things, call for more frequent monitoring and treatment. According to DHS, "Drinking water which is treated to meet DHS requirements . . . should be considered safe." Following is a progress report for each of the reservoirs affected by SWTR.

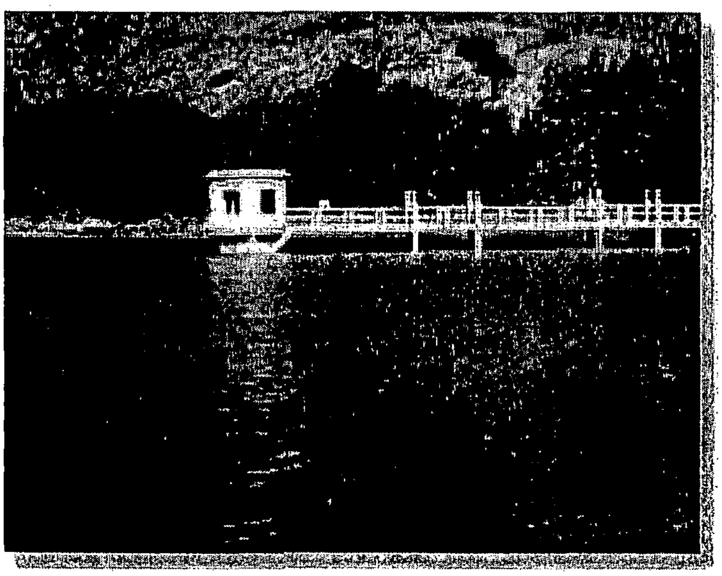
Upper and Lower Hollywood: The project involves construction of two 30 million-gallon Toyon Tanks that will be hidden from community view. Construction of the two tanks was completed in May 2001. Additionally, LADWP has constructed a one-mile by-pass tunnel and two of three segments of a six-mile trunk line. The third segment is currently 70% completed. LADWP must finish the project by November 2001. This project is currently ahead of the scheduled compliance deadline.

> *"Drinking water which is treated to meet DHS requirements is associated with little to none of this risk and should be considered safe."*



Encino: LADWP must comply with the SWTR by January 2003. The final environmental impact report to remove the reservoir from regular service and construct by-pass facilities was approved by the Board on June 20, 2000. Design of the project is now underway with construction to begin in the fall of 2001. The project is on schedule to meet the state deadline.

Lower Stone Canyon: The project must be completed by December 2004. LADWP plans to construct facilities to by-pass the reservoir and remove it from regular service. The Board approved the final environmental impact report for this project on June 20, 2000 and design has begun. This project is also on schedule to meet the mandated deadline. *(On March 27, 1998, DHS issued a citation to DWP for failing to meet an interim project milestone. The citation was not due to any changes in water quality, but serves notice that penalties will be imposed if future milestones are not met.)*



Additional Information from DHS: Until December 2004, when all projects are completed, DHS requires LADWP to periodically provide the following information that explains why it is important to comply with the SWTR and also provides a perspective on microbial risk in our environment.

"The DHS sets drinking water standards and has determined the presence of microbiological contaminants are a health concern at certain levels of exposure. If water is inadequately treated, microbiological contaminants in that water may cause disease. Disease symptoms may include diarrhea, cramps, nausea and possibly jaundice, and any associated headaches and fatigue.

These symptoms, however, are not just associated with disease-causing organisms in drinking water, but also may be caused by a number of factors other than your drinking water. DHS has set enforceable requirements for treating drinking water to reduce the risk of these adverse health effects. Treatment, such as filtering and disinfecting the water, removes or destroys microbiological contaminants. Drinking water which is treated to meet DHS requirements is associated with little to none of this risk and should be considered safe."

TABLE IV – ICR DISINFECTANT/DISINFECTION BY-PRODUCTS (DBP) DATA ON TREATED WATER
July 1997 to December 1998

	Unit	DLR	LAA Filtration Plant Area		Eagle Rock Reservoir Area		Lower Stone Canyon Reservoir Area		Combined Wells Area		Upper Hollywood Reservoir Area	
Disinfectant			Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
Chlorine Free	mg/L	0.02	0.41-1.54	1.07	0.10-3.80	1.18	0.70-3.60	2.45	0.65-2.10	1.55	0.49-2.80	1.53
Chlorine Total	mg/L	0.02	0.50-1.64	1.17	0.24-3.89	1.29	1.13-3.65	2.69	0.70-2.30	1.73	0.53-3.00	1.63
Disinfectant By-Product (DPBs)												
Aldehyde	ug/L	1.00	14.6-18.5	16.7	NR	NR	NR	NR	NR	NR	NR	NR
Bromate	ug/L	0.20	0.86-10.4	2.68	NR	NR	NR	NR	NR	NR	NR	NR
Chloral Hydrate	ug/L	0.50	5.79-17.0	11.5	7.02-21.2	12.3	0.89-26.5	7.35	ND-2.10	4.52	7.62-54.1	21.4
Chloropicrin	ug/L	0.50	ND-3.51	1.50	ND-1.51	0.66	ND-2.13	0.88	ND-1.24	0.22	ND-2.81	1.37
Total Haloacetic Acids	ug/L	1.00	5.65-27.0	14.8	15.5-61.5	30.8	10.6-33.2	20.8	2.42-26.7	11.4	13.7-104	37.8
Total Haloacetonitrites	ug/L	0.50	1.76-5.89	3.34	2.88-12.5	6.67	ND-3.42	1.97	0.59-6.63	2.88	2.28-5.93	3.70
Total Haloketones	ug/L	0.50	1.65-8.46	5.27	ND-11.1	3.84	0.78-15.4	4.28	ND-17.9	4.07	2.80-15.5	8.15
Total Organic Halides	ug/L	50.0	51.0-180	92.8	60.0-240	163	90.0-160	115	ND-150	43.5	85.0-195	124
Total Trihalomethanes	ug/L	1.00	15.2-53.0	30.3	22.0-124	75.4	24.4-66.8	41.2	9.00-59.2	26.8	26.1-103	53.0

TABLE V – ICR MICROBIAL DATA ON UNTREATED WATER
July 1997 to December 1998

Microbials	Unit	Detection Limit	LAA Filtration Plant Area		Upper Hollywood Reservoir Area*		Lower Stone Canyon Reservoir Area*	
			Range	Average	Range	Average	Range	Average
Escherichia Coliform	number/100 ml	1	ND-10	1.8	ND	ND	ND	ND
Fecal Coliform	number/100 ml	1	ND-4	ND	NR	NR	NR	NR
Total Coliform	number/100 ml	1	12-8310	1538	ND-1	ND	ND-2	ND
Total Cryptosporidium	#oocysts/100 L	5	ND	ND	ND	ND	ND	ND
Total Giardia	#cysts/100 L	5	ND-50	2.9	ND-76	ND	ND	ND
Total Culturable Virus	mpn/100 ml	1	ND-1.03	ND	NR	NR	NR	NR

ND – not detected NR – not required
*Water supplied to these reservoirs was previously treated, but stored in open reservoirs.

SUGGESTED READING

Consumer's Guide to California Drinking Water
(a MUST for anyone who is concerned about their drinking water)
Prepared by Local Government Commission
909 12th Street, Suite 205
Sacramento, California 95814
(916) 448-1198

Water on Tap: A Consumer's Guide to the Nation's Drinking Water
Prepared by United States Environmental Protection Agency
Available at
http://www.epa.gov/safewater/Pubs/general.html
(This publication provides a lot of information and references for drinking water)

LADWP Speakers Bureau
http://www.ladwp.com
Visit our website for information about presentations on water and power issues.

The Sierra Club Guide to Safe Drinking Water
by Scott Alan Lewis
Sierra Club
730 Polk Street
San Francisco, CA 94109
www.sierraclub.org

Plain Talk About Drinking Water
by Dr. James M. Symons
American Water Works Association
6666 West Quincy Avenue
Denver, CO 80235-3098
1-800-926-7337

Annual Water Quality Report
Los Angeles Department of Water and Power
P.O. Box 51111 Room 1213
Los Angeles, California 90051-0100

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Los Angeles, CA

ABOUT THIS REPORT • The 2000 Annual Water Quality Report contains important information about your drinking water. The report is required by the California Department of Health Services. It was produced and mailed to you at a cost of 33 cents a copy:

Este informe contiene información muy importante sobre su agua potable. Tradúzcalo o hable con alguien que lo entienda bien. Puede usted conseguir esta información en español en las oficinas del Department of Water and Power o puede llamar (800) 342-5397.

此份有關你的食水報告,內有重要資料和訊息,請找他人為你翻譯及解釋清楚。

Chi tiết này thật quan trọng. Xin nhờ người dịch cho quý vị.

이 안내는 매우 중요합니다. 본인을 위해 번역인을 사용하십시요.

この情報は重要です。翻訳を依頼してください。

Данный рапорт содержит важную информацию о вашей питьевой воде. Переведите его или проконсультируйтесь с тем, кто его понимает.

Los Angeles Department of Water and Power

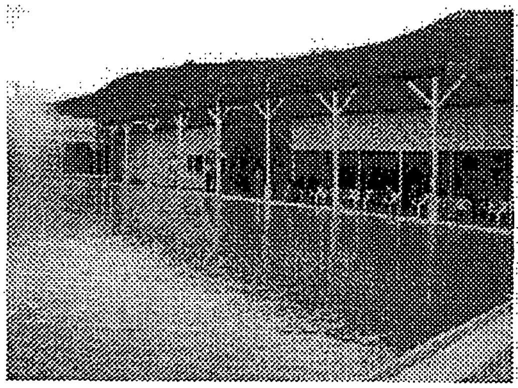
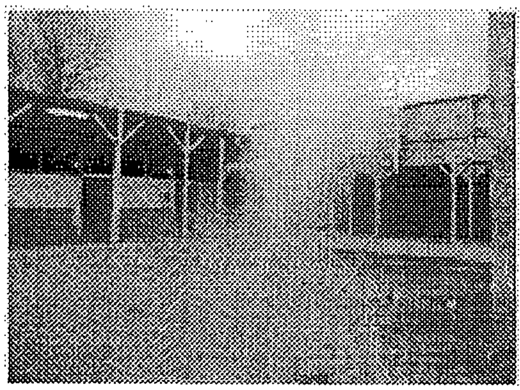
Printed on recycled paper

From: Thomas Suk
To: cmitton.RB6VPost.Region6V
Date: 11/30/00 3:56PM
Subject: exotic snail found in Owens Riv

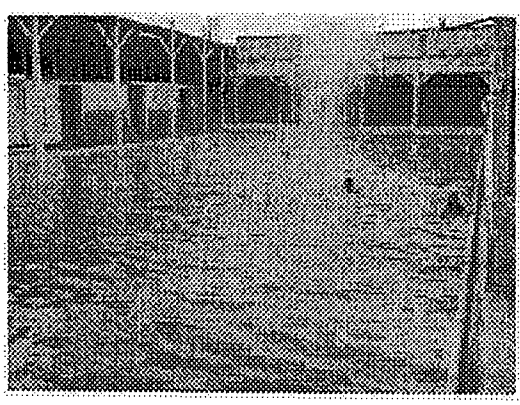
FYI, it has come to my attention that a researcher at the Smithsonian Institution recently identified an invasive aquatic snail, the New Zealand mud snail (Potomapyrgus antipodarium), in samples from the Upper Owens River upstream of Crowley Lake. According to staff at CDFG, the snail's known distribution in the Owens currently extends from approximately Benton Crossing upstream to the Hot Creek confluence. It is a small conical shaped snail that can occur in extremely high densities, and can essentially overwhelm native aquatic ecosystems. This is the first record from the Great Basin except for portions of Idaho. It has colonized portions of the Snake River where it now dominates the benthic fauna. The vehicle and approximate timing for the introduction are unknown at this time. This is not good news. The Owens Basin has many aquatic habitats that contain sensitive species, including native springsnails, that could be impacted by this exotic species. Benthic invertebrate production for fisheries could be impacted as well.

Our region's bioassessment monitoring program will help to document the extent and effects of this introduced species, but I have no plans to accelerate our studies in the Owens due to this discovery. That's all I know at this time. Please keep me posted (copies, please) if you hear of reports on this. ts

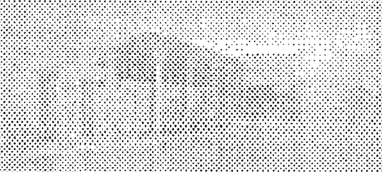
CC: unsij,rofec

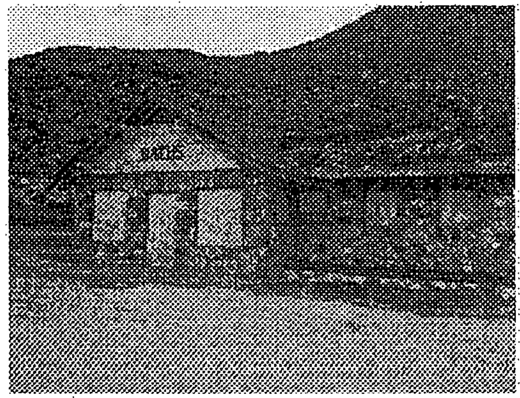
The Brown family of Bishop has purchased and is currently renovating the entire facility. The main pool is the "largest natural hot springs pool in the Eastern Sierra." Six hundred gallons of 127^{a} water flows from the ground each minute. Locals and tourists alike are invited to swim. play and relax in the friendly surroundings. There is a snack bar serving cold drinks, sandwiches and an array of appetizing snacks. A campground is planned as well as cabins and other lodging facilities.

Click here for a brief history of Keough's Hot Springs

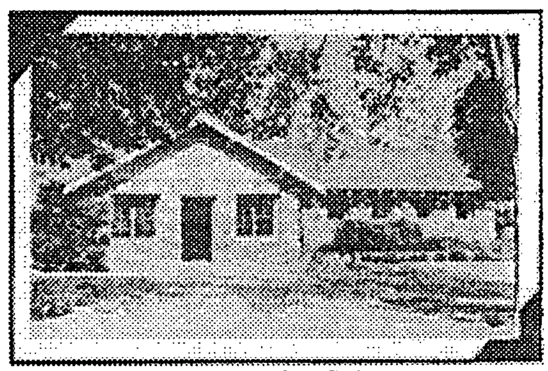


NEW HOURS beginning Tuesday Sept. 7th
11am-7pm Wednesday - Sunday
Closed Mondays & Tuesdays
Located 7 miles south of Bishop (just off US 395)
For Information Call 872-4670

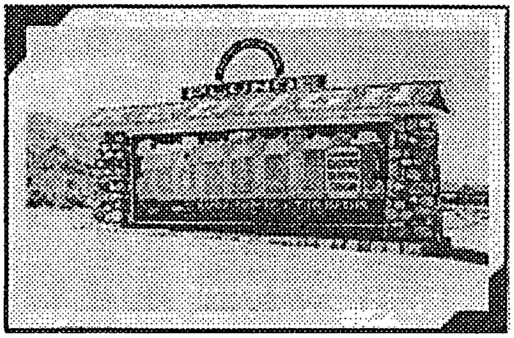


The site first had historical significance since its geothermal spring water was used for medicinal and healing purposes. This traditional use stretches back hundreds of years. With the settlement of the Owens Valley in the late 1800s and with the land ethic of private ownership the springs passed into the hands of those who used the surrounding land for agriculture and ranching. (Longyear and 4-C Ranches). In 1919 the property was purchased by Phillip Keough, an Eastern Sierra pioneer. A leader in civic affairs and owner of the City Market in Bishop, Keough had a vision for a first class health resort.

During its heyday in the 1920 and 30s it was just that, a complete health and leisure resort, where visitors could not only soak their aches and cares away, but also fish, dine, dance and stay in a cabin. Keough's Hot Springs became the chief social institution for the people of the Owens Valley.


Two of the Old Cabins

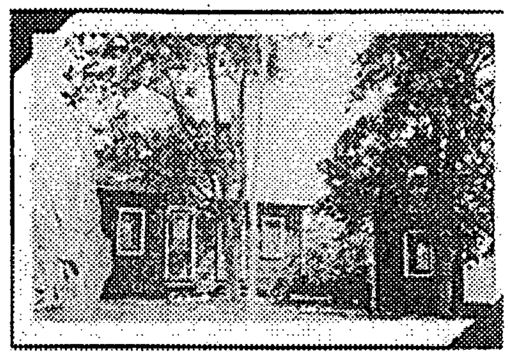
Hundreds of valley residents flocked to celebrate important holidays at Keough's.Many recall the barbecues, dancing and fireworks that characterized the 4th of July and the Easter Egg hunts that were held on the grounds each spring.



The Famous Sign

Local children learned to swim at the end of the school year parties held at Keough's from 1933 to 1937, when Civilian Conservation Corps camps were located near by, a big night out for the lads was traveling to Keough's to dance or for a ball game. Boxing matches were also held at Keough's and movie stars from Hollywood would vacation at Keough's.

Later, Richard and Liz Denniss, took over the lease and have run it as a private health spa. Liz Denniss had come from a 30 year career in Hollywood and Dick Denniss had a background in mining and millwork, that was essential to the job of renovating the swimming pool and other buildings.



The Bath House

In September of 1998, the Brown family of Bishop purchased the site and are currently renovating the entire facility. Keough's Hot Springs will become a premiere recreational
destination in the Eastern Sierra.

The Brown Family


NEW HOURS beginning Tuesday Sept. 7th
11am-7pm Wednesday - Sunday
Closed Mondays & Tuesdays
Located 7 miles south of Bishop (just off US 395)
For Information Call 872-4670

Keough Hot Springs

Latitude	37.2538
Longitude	118.3765
Elevation	4530
Temperature	51 C
Flow Rate	2000 liters/minute
Dissolved Solids	510 mg/liter
7.5 Quadrangle	?
State	California
County	Inyo

Sorry I haven't made a map yet.

Keough Hot Springs

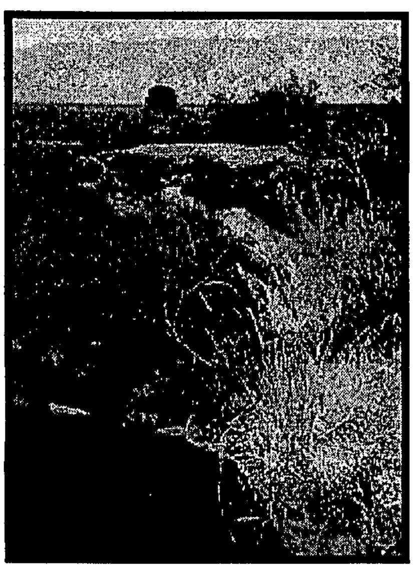
Total Escape

Jim Lang's Keough Hot Springs Page

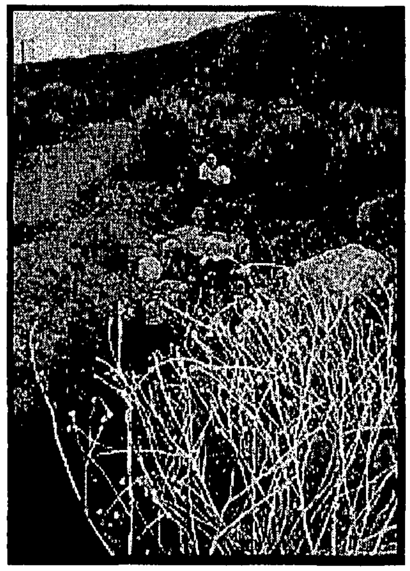
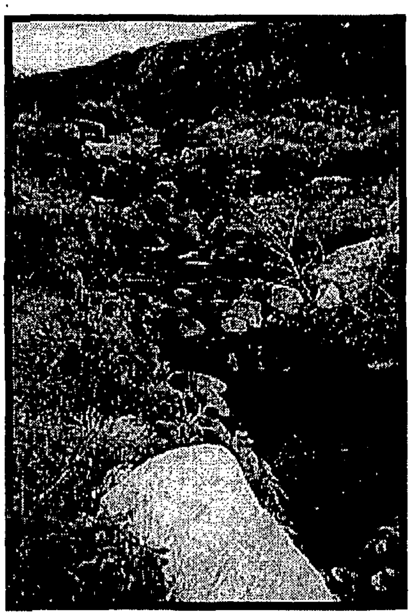
#1 3-D stereo pair of Keough Hot Springs

#2 3-D stereo pair of Keough Hot Springs

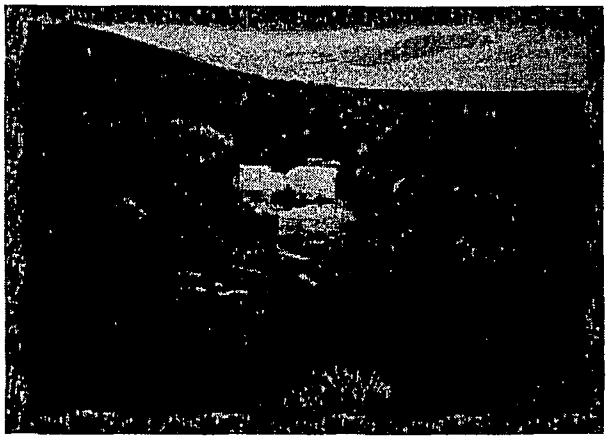
Steve's HotSprings Home Page

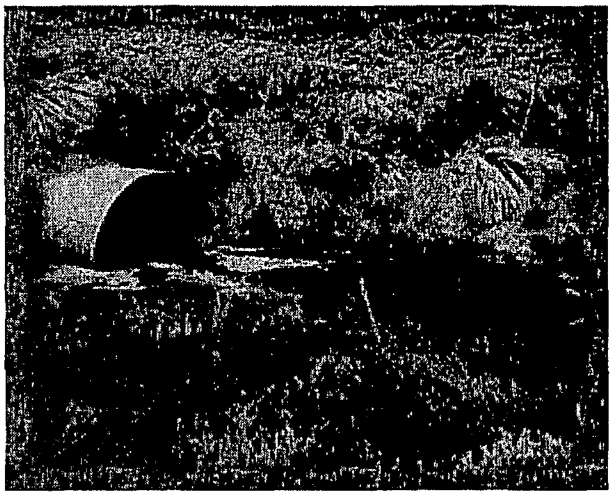


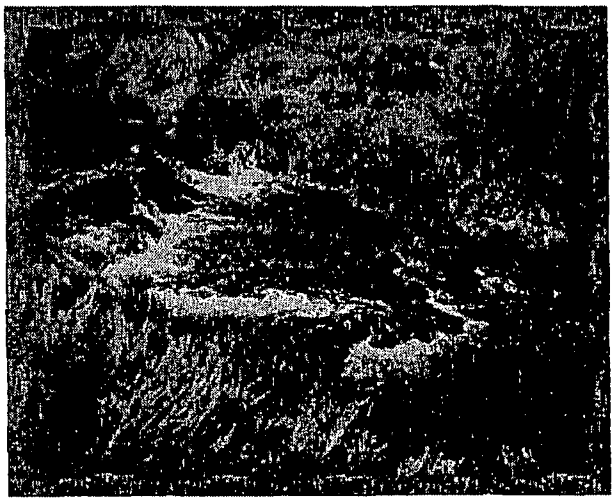
Keough Hot Springs should actually be renamed as Keough Hot Creek. The original springs are a developed resort, but they are so hot and plentiful that everyone uses the runoff. The springs are about eight miles south of Bishop, on the West Side of Highway 395. To get there turn off on Keough Hot Springs road and head west about 0.5 mile. You will come to a dirt road intersection. Turn right heading north in will cross over the creek in only 0.1-mile. The latitude and longitude of the pools is 37 15.52' 118 22.24'. You will see some high power lines to the west. Some of the hotter pools are under these lines. Find yourself a suitable spring. These springs are actually on private property belonging to the city of Los Angeles. There are signs about no overnight camping, but day use seems to be allowed. The source seems to be about a half mile to the west with the creek running to the east. There are a lot of pools made along the creek. If a pool is to hot or cold you simply move east or west to another one. You can hike along the stream to see just how many pools there are.


Last Update 7/5/98







Keough Hot Springs

Location	10 mi. S. of Bishop, Inyo Co.	
Application	Resorts and Spas	
Temperature	128 F	53.3 C
Flow	528 gpm	2001.1 L/min
Capacity	0.5×10^6 Btu/hr	0.15 MWt
Annual Energy	3.9×10^9 Btu/hr	1.1 GWh/yr

Load Factor: 0.89
Delta T: 1.9 F
Date:

Contact Person:

Icon Listing California Listing California Map US Map Main Page All Resort and Spas

For correspondence please include proper e-mail address with text
geoheat@oit.edu

Geo-Heat Center
3201 Campus Drive
Klamath Falls, OR 97601
Phone: (541) 885-1750
Fax: (541) 885-1754
geoheat@oit.edu

This pages was last updated on January 4, 1999 by Tonya "Toni" Boyd

Keough Hot Springs

Location 10 mi. S. of Bishop, Inyo Co.

Temperature	128°F	53.3°C
Flow	528 gpm	2001.1 L/min
Capacity	0.5 X 10^6 Btu/hr	0.15 MWt
Annual Energy	3.9 X 10^9 Btu	1.1 GWh/yr

Load Factor: 0.89
Delta T: 1.9 F
Date:

Contact Person:

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This pages was last updated on January 3, 2000 by the Geo-Heat Center

HOT CREEK at gage below hot springs

Comments: All flows were measured at County Road

The following data was collected by Jones & Stokes Associates, Inc.

FIELD DATA --->

Sampling Date	Flow cfs	Temp. °C	Hrd mg/l	SO4 mg/l	Al µg/l	As µg/l	Ba µg/l	Cd µg/l	Fe µg/l	Hg µg/l	Mn µg/l	Pb µg/l
02-May-91	6.7	0.0	58	7	ND	6	ND	ND	74	ND	ND	ND
17-May-91	10.3	3.9	47	5					130		39	
04-Jun-91	40.5	15.5	32	4	300	6	29	0.8	ND	0.8	ND	2
21-Jun-91	44.2	8.1	21	2.8	77	ND	ND	ND	ND	ND	ND	ND
12-Jul-91	24.5	14.4	23	3.1					ND		ND	
24-Jul-91	14.0	16.8	26	3.1					ND		ND	
15-Aug-91	7.5	14.2	32	3.7					48		ND	
27-Aug-91	5.2	15.3	32	3.4	ND	ND	ND	ND	ND	ND	ND	ND

STATISTICS:	Field Temp. °C	Lab Hrd mg/l	Lab SO4 mg/l	Lab Al µg/l	Lab As µg/l	Lab Ba µg/l	Lab Cd µg/l	Lab Fe µg/l	Lab Hg µg/l	Lab Mn µg/l	Lab Pb µg/l
Samples (n)	8	8	8	4	4	4	4	8	4	8	4
Mean	11.0	34	4.0	189	6	29	0.8	84	0.8	39	2
Minimum (0% IQR)	0.0	21	2.8	ND	ND	ND	ND	ND	ND	ND	ND
25% IQR	8.1	26	3.1	ND	ND	ND	ND	ND	ND	ND	ND
Median (50% IQR)	14.4	32	3.7	77	6	ND	ND	ND	ND	ND	ND
75% IQR	15.5	47	5.0	300	6	29	0.8	74	0.8	ND	2
Maximum (100% IQR)	16.8	58	7.0	300	6	29	0.8	130	0.8	39	2
Detection Limit	0.1	1	2	50	4	10	0.1	30	0.1	10	1
% > Detection Limit	100	100	100	50	50	25	25	38	25	13	25

FREQUENTLY ASKED QUESTIONS ABOUT HOT CREEK

HOW HOT IS THE WATER?

The temperature of the water flowing from the largest of the springs is 200 degrees Fahrenheit (93 degrees Centigrade) which is boiling at this elevation. Water in the smaller springs may have lower temperatures because the water loses heat to the rock or mixes with cooler surface water. Water cannot be hotter than boiling temperature unless kept under pressure and is then called steam. Steam, which vents from fumeroles, can be hotter than 200 degrees.

WHAT MAKES THE WATER THE COLOR IT IS?

There are two schools of thought on this. The first states the water contains calcium carbonate and a second states that the water contains a warm water algea. The first is most likely the correct answer. Calcium carbonate is a naturally occuring chemical and is responsible for building the "tufa" towers of Mono Lake and is responsible for building rocks here at Hot Creek and at other hot springs in the eastern Sierras.

WHAT ARE THE LITTLE FISH IN THE CREEK?

The small minnow-looking fish is the mosquito fish. This fish is not native to the waters of the eastern Sierra. Man brought this fish here to control mosquitos in ponds and lakes and it has since migrated into many other bodies of water. This fish eats the larvea of mosquitos fioating on the surface of the water.

WHY DON'T YOU RECOMMEND SWIMMING?

There are too many hazards to recommend entering the water here. Hot springs discharge boiling water up through the sandy stream bottom. It is possible to walk across the bottom of the stream and accidently step directly into a boiling spring. Swimmers can get serious burns on their feet and legs. The chemical content of the water is not monitored. The last tests of the water in the early 1980's indicated arsenic levels of 250 parts per million. The bacterial content of the water is not monitored, however, tests in the early 80's suggested that the water is subject to periodic high bacterial levels.

IF YOU DON'T RECOMMEND SWIMMING, WHY DON'T YOU DO SOMETHING ABOUT THOSE PEOPLE IN THE WATER?

Entering the water is not recommended but is not prohibited. There is a great deal of difference between these words. Persons are not prohibited from entering the water but do so at their own risk after being informed, through signing, of the hazards present here. This allows people to enjoy bathing and swimming once they have accepted the risk

IS THE ARSENIC IN THE WATER BAD FOR YOU?

Based on water samples taken many years ago there were 50-60 parts per million arsenic in the creek above the hot spring activity. One mile below the hot springs the level was greater than 250 parts per million. The water will not meet safe drinking water standards and the long term effect of exposure to this element in the water is unknown. Arsenic is a naturally occuring element in hot springs water.

ARE THERE ANY OTHER HOT SPRINGS IN THE AREA?

There are several other hot springs a few miles away. All of them are rather small and are not like Hot Creek. Hot Creek is unique in having such a large flow of hot water, part of which flows directly out of the bottom of the creek

IT SURE LOOKS DIFFERENT FROM THE LAST TIME I WAS HERE, WHAT HAPPENED?

The only consistent thing about Hot Creek is that it is constantly changing. The reason for these changes is not completly understood but probably involves the opening and closing of the cracks through which water flows to the surface. Minerals desposited by the hot water probably close cracks. Local earthquakes likely open new cracks or reopen old ones. The result can be very dramatic changes in the location of springs in the gorge and the amount of water flow from the springs.

WHY IS THE FOREST SERVICE SO STRICT ABOUT DOGS BEING ON LEASHES?

Three reasons: First, more than 70% of the people polled at developed recreation sites comment that they dislike unleashed dogs. The leash law is enforced to promote consideration for the majority of users. Second, here at Hot Creek at least 4 loose dogs have died in hot water when they fell in after wandering too close to the edges of pools. In two of these cases their owners were seriously burned and scarred for life when they jumped into the pools in an attempt to save the dog. Third, loose dogs can step into small hot steam vents as they cannot detect scalding conditions as people can.

WHY ARE SOME AREAS FENCED OFF?

The fences designate areas closed to any public use. These areas contain the most active hot springs. The constantly changing activity results in ground which appears cool and dry on the surface but has steaming, scalding water just a few inches below. The weight of even a small person can be sufficient to cause a person to break through and fall into boiling water. The edges of pools can be especially dangerous. Ongoing natural processes cause sloughing and undercutting of the banks which are prone to collapsing easily under the additional weight of a person or animal. Due to these hazards the closure of these areas is enforced and persons entering are issued citations by Forest Officers.

WHY IS THE AREA CLOSED AT NIGHT?

It is difficult to be aware of Hot Creek's hazards at night. The majority of the most serious accidents and deaths prior to 1978 involved nighttime use. That year a decision was made to close the area at night to reduce this accident rate. In the years since, the accidents have been reduced but not eliminated.

HOW HAVE THE PEOPLE DIED OR BEEN INJURED?

As of December of 1994 the actual count of deaths or serious injuries is 28, of which 13 have been fatalities. The majority of these incidents have involved people engaged in an activity that is in violation of the posted regulations such as nighttime use, being in a closed area, or having a dog off leash. Many have also involved persons under the influence of alcohol or drugs.

WHAT HAPPENS IF I STAY PAST SUNSET?

The Forest Service no longer closes the gates leading to the area at sunset and asks that people leave on their own at that time. The Forest Service makes random patrols during the nighttime and issues citations to anyone found in the area after sunset. Normally, every occupant of a car is issued an individual citation, not just the "leader" or driver of a group. In 1989 over 110 people were cited at Hot Creek for remaining after sunset, which is the record year for this type of citation. In spite of the number of people cited that year the number of people violating the nighttime closure is very few.

WHEN DO YOU CLOSE THE GATES?

The gates on the road and those at the parking lot entrances are no longer closed on a daily basis at sunset. See the above question, What Happens If I Stay Past Sunset?, for additional information. The gates located on the road leading to Hot Creek are closed in the winter anytime the road is not safely or conveniently passable to a two-wheel drive vehicle without chains. In drought winters this closure may only be for 1-2 week periods but in heavy winters can be as long as 4-5 months. The gates at the parking lot entrances are closed when Hot Creek is closed to entry during periods when heavy maintenance tasks are being completed. This type of closure only occurs every 2-3 years and only lasts 1-2 weeks.

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The High Sierra

L.A. Strikes Deal With Owens Valley to End Dust Woes

■ **Water: Historic compromise promises relief from storms by 2006. City will restore part of lake bed, giving up 80,000 acre-feet of water.**

LA Times 7/16/98

By MARLA CONE, TIMES ENVIRONMENTAL WRITER

Culminating decades of bitter conflict, the Owens Valley and Los Angeles struck a historic deal Wednesday designed to bring an end to massive dust storms at Owens Lake by 2006.

The battle over the dry lake is the last major hurdle to mending the environmental damage that Los Angeles inflicted when it opened its aqueduct 85 years ago and drained the Owens Valley of its mountain-fed water.

The two sides reached a compromise when the Los Angeles Department of Water and Power agreed to begin work at Owens Lake by 2001 and set a firm date—eight years from now—for ensuring that people living near the lake are breathing air that meets federal health standards. In turn, Owens Valley air pollution officials agreed to scale back the improvements they had sought and allow them to be phased in gradually.

"Some folks said it couldn't be done, some said it wouldn't be done, but we now have an agreement that it can be done," said S. David Freeman, general manager of the Los Angeles DWP. "We are now pledged, if the City Council approves this, to stay with the job until the job gets done."

Ruth Galanter, the council's lead member on water issues, called the deal a "historic moment" and a "great breakthrough" for Angelenos as well as Owens Valley residents.

"This avoids probably 20 years of litigation," she said, adding, "I don't see why anyone would oppose it."

Officials of the Great Basin Unified Air Pollution Control District also pronounced themselves thrilled with the deal, saying it guarantees that residents of Inyo County and Ridgecrest will finally breathe healthful air—although the pace of improvement will be slower than they originally demanded a year ago.

"It's a victory," said Great Basin project manager Ted Schade. "This is a very simple concept, and it provides for [clean-air] attainment, and it provides little or no loopholes for the city."

Owens Lake is by far the single largest source of particle air pollution in the United States.

For decades, people living in the shadow of the Sierra Nevada have periodically been exposed to giant swirling funnels of toxic white dust that blows off the parched lake.

Particle pollution can cause respiratory infections, asthma attacks and serious—perhaps deadly—complications from respiratory and heart ailments.

The truce in the water wars signals the first time that Los Angeles has agreed to surrender some Owens Valley water without a lengthy court fight.

Under the agreement, 10 square miles of the 110-square mile lake bed will be treated by the end of 2001, another 3½ square miles in 2002 and 3 more in 2003. Then, at least 2 square miles must be treated every year until the Great Basin air agency determines that federal clean-air standards are met. The plan will be revised in 2003 to see if the pace must be stepped up to achieve the standards by 2006.

Los Angeles can design its dust-control strategy with a mix of three different techniques—shallow flooding of parts of the lakebed, planting vegetation and depositing gravel. The lake will not be refilled, but the first 10 square miles are likely to be permanently wetted with a few inches of water, enough to stop the dust, Freeman said.

The project is expected to cost $120 million, and the city might permanently lose around 40,000 acre-feet of water a year—enough to serve 80,000 households, Freeman said. He said he hopes that most can be accomplished with Owens Valley ground water, instead of aqueduct water headed to Los Angeles. But until the project is designed by engineers, the city doesn't know how much water it will take.

"I view this as solving a problem in a cost-effective manner, and I'm hopeful at least in the next few years that we can absorb it within the existing water rates," Freeman said. "Financially, the settlement is clearly a victory for the city."

(CONT) 2

plan will achieve healthful air for residents of his area.

"This is a good product," Dorame said. "Pe---'e here were expecting that we would have to compromise in some fashion to get started on this, and I don't think we gave up a great deal to get there."

His "only reservation," Dorame said, is "what may happen with the [Los Angeles] City Council." If changes are made, the whole deal could fall apart, he warned.

In addition to the council, the plan must also be approved by the Great Basin board—steps expected to be accomplished within two weeks—as well as the California Air Resources Board.

The new plan also hinges on the U.S. Environmental Protection Agency granting a 5-year extension of the Clean Air Act, which requires states to clean up particle pollution by 2001 or seek an extension until 2006.

A 20-Year Debate

The debate over Owens Lake, which has raged for nearly 20 years, has focused on how far and how fast Los Angeles must go to stop the lake from polluting the area's air.

Under the new deal, 22½ square miles of the lake bed will be treated by 2006—plus whatever more might become necessary to bring the particle pollution down to levels that meet federal standards.

That compares with 35 square miles that the Great Basin pollution board had ordered Los Angeles to treat by 2001, at a cost of to $300 million. The city, calling that plan exorbitant and technically flawed, had offered to treat only 9 square miles. When its offer was refused, the city appealed to the California Air Resources Board.

In May, when the Air Resources Board split 5 to 4 over whose side to take, its chairman, John Dunlap, urged the two sides to work out a quick deal. That's when negotiations began in earnest.

In a sign of its simplicity, the agreement is defined in slightly over two typed pages.

The major breakthrough in negotiations came when Los Angeles DWP promised to attain air pollution standards at Owens Lake by the Clean Air Act's deadline of 2006, officials from both sides said. In the past, the city had always balked at making such a guarantee. In the agreement, the city takes the unprecedented step of waiving its right to sue over the plan.

"We represent people who have long-standing resentment toward [each other], and both sides said to hell with that and decided to work together to solve a legitimate problem," Galanter said.

Credit for Breaking Impasse

Officials involved in the deal credited Freeman, who took over the helm of DWP last September, with helping break the logjam.

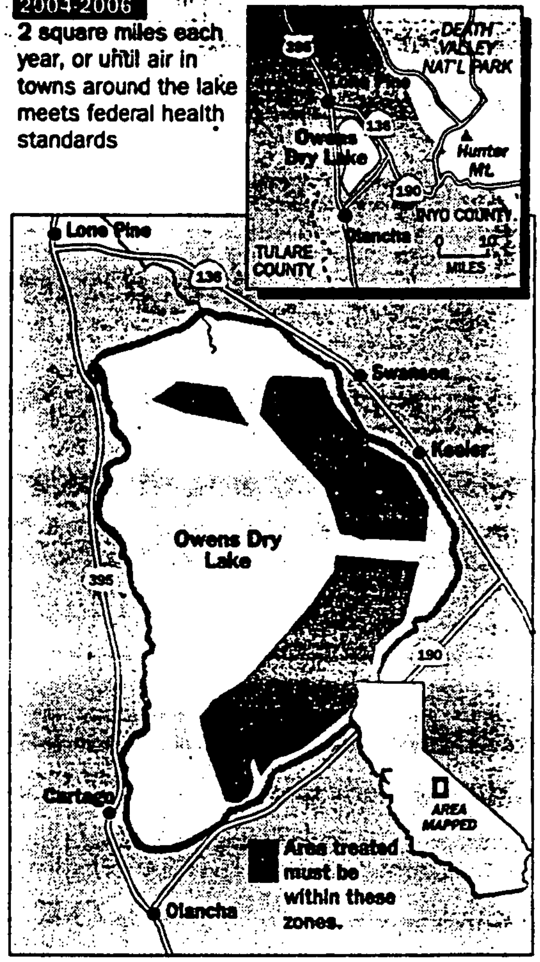
DWP leaders had long argued that it shouldn't have to give up any of its water supply to meet the air pollution law. But Freeman, who earlier in his career helped heal the troubled Tennessee Valley Authority and had experience in clean-air disputes, altered that stance when he took over negotiations. He decided, with the advice of B.J. Kirwin, an attorney with Latham & Watkins, who specializes in the Clean Air Act, that the city would have to comply with the federal law's deadlines.

Until now, DWP engineers focused on the cost to city residents and discounted the health risk to about 40,000 people in the Owens Valley.

Freeman said reading such past comments "made

Los Angeles has agreed to curb giant dust storms at Owens Lake by treating part of the dry lake with a mix of water, vegetation and gravel. Under the terms, Los Angeles will treat at least 22 square miles within 35 designated square miles of the lake bed. This is the timetable:

2001	10 square miles by end of the year
2002	3.5 square miles
2003	3 square miles
2004-2006	2 square miles each year, or until air in towns around the lake meets federal health standards



Source: Memorandum of agreement between Los Angeles and the Great Basin Unified Air Pollution Control District

Los Angeles Times

me cringe."

"Everybody in this country is entitled to healthful air quality," he said. "The fact that there's not that many people up there doesn't make any difference."

Worth millions of dollars a year, Owens Valley water is one of Los Angeles' most precious assets—a cheap and reliable source of water in a city that has little of its own.

Owens Valley residents have long had bitter feelings toward Los Angeles, especially the DWP, because city officials around the turn of the century bought up the valley's valuable water rights using practices considered deceptive. Since then, the Owens Valley has struggled with a sluggish economy and devastated environment, whereas Los Angeles thrived with the water that allowed development of the San Fernando Valley.

The agreement is considered as momentous as earlier agreements by the city to surrender water to Mono Lake and the lower Owens River. Those deals, however, followed legal challenges that dragged on for years.

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SIERRA NEVADA AQUATIC RESEARCH LABORATORY (SNARL)

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January 16, 2001

Thomas Suk, Environmental Specialist
California Regional Water Quality Control Board
2501 Lake Tahoe Blvd.
South Lake Tahoe, CA 96150

SUBJECT: PROGRESS REPORT FOR CONTRACT # 9-183-160-0, ARSENIC SOURCES AND THE FEASIBILITY OF USING NITROGEN ISOTOPES TO DETERMINE NITROGEN SOURCES TO CROWLEY LAKE

Dear Tom,

Following is a progress report for the above-referenced contract.

<u>Project Management and Administration</u>	
Task 1.1, Technical and Administrative Services	in progress
Task 1.2, Quality Assurance Plan	completed & approved, filed as part of SWRCB contract No. 91752500
Task 1.3, Quarterly Reports	in progress, this is our second required report
<u>WQ Monitoring for Arsenic Control</u>	
Task 2.1, Conduct Initial Sampling	completed
Task 2.2, Conduct Sample Analysis	completed, data attached
Task 2.3, Conduct Follow-up Sampling & Analysis	to take place next summer
<u>Isotope Feasibility & Technology Transfer</u>	
Task 3.1, Review Literature	in progress
Task 3.2, Select Study Locations	completed
Task 3.3, Conduct Sampling & Analysis	in progress, all sampling has taken place, analysis is in progress to be completed in Feb. 2001
Task 3.4, Data Evaluation & Technology Transfer	not yet begun
<u>Geographic Information System</u>	
Task 4.1, GIS coverage preparation	in progress
Task 4.2, Compile existing data	in progress

Reports

Task 5.1, Draft Report	pending, due 12/30/02
Task 5.2, Final Report	pending, due 02/15/03

Our original research plan was to analyze arsenic at SNARL using a method that employs arsenic reduction followed by phospho-molbydate complex formation and spectrophotometric analysis. The concentration of arsenic is measured by the difference in absorption of two fractions and requires that all the arsenic in the sample be oxidized as As(V). These results would have been available as a by-product of the arsenic correction we perform for our Soluble Reactive Phosphate analysis. As it turns out, this was not the case. Comparison of the wet method results with spot analyses by atomic absorption indicated that the wet method results were consistently low. This would imply not all of the arsenic is fully oxidized and our wet method is not adequate for the analysis.

Consequently, while results from our first two longitudinal samplings provide us with data about arsenic speciation they were not adequate to assess total arsenic. During October, as part of our third sampling of the season, a sample for arsenic analysis was taken at every one of our sampling sites in the watershed. These samples were preserved with ultrapure nitric acid and transported cold to UCSB for analysis using graphite furnace atomic absorption.

The results from this October sampling are shown in Table 1 and Figure 1. Starting from the right side of the figure on Mammoth Creek we see that arsenic concentration is virtually zero at the outlet of Twin Lakes and down to old 395. Concentration rises to 0.20 uM downstream of Chance Ranch and is 0.33 uM coming out of the Fish Hatchery. At the flume below the thermal area the concentration rises to 3.44 uM. Arsenic concentration in the Owens River is zero above Big Springs. There is a small, 0.20 uM input from Big Springs with concentration remaining at that level to the downstream end of the Howard Arcularius ranch. At Benton Crossing the high input from Hot Creek has been added resulting in 0.98 uM arsenic which then rises slightly to a value of 1.09 at the lake edge. This may be due to distributed inputs from other thermal sources. The data clearly show that almost all the arsenic in the watershed enters from the Hot Creek thermal area. While there is measurable arsenic entering the system at Big Springs and downstream of Big Springs, this contribution is relatively small

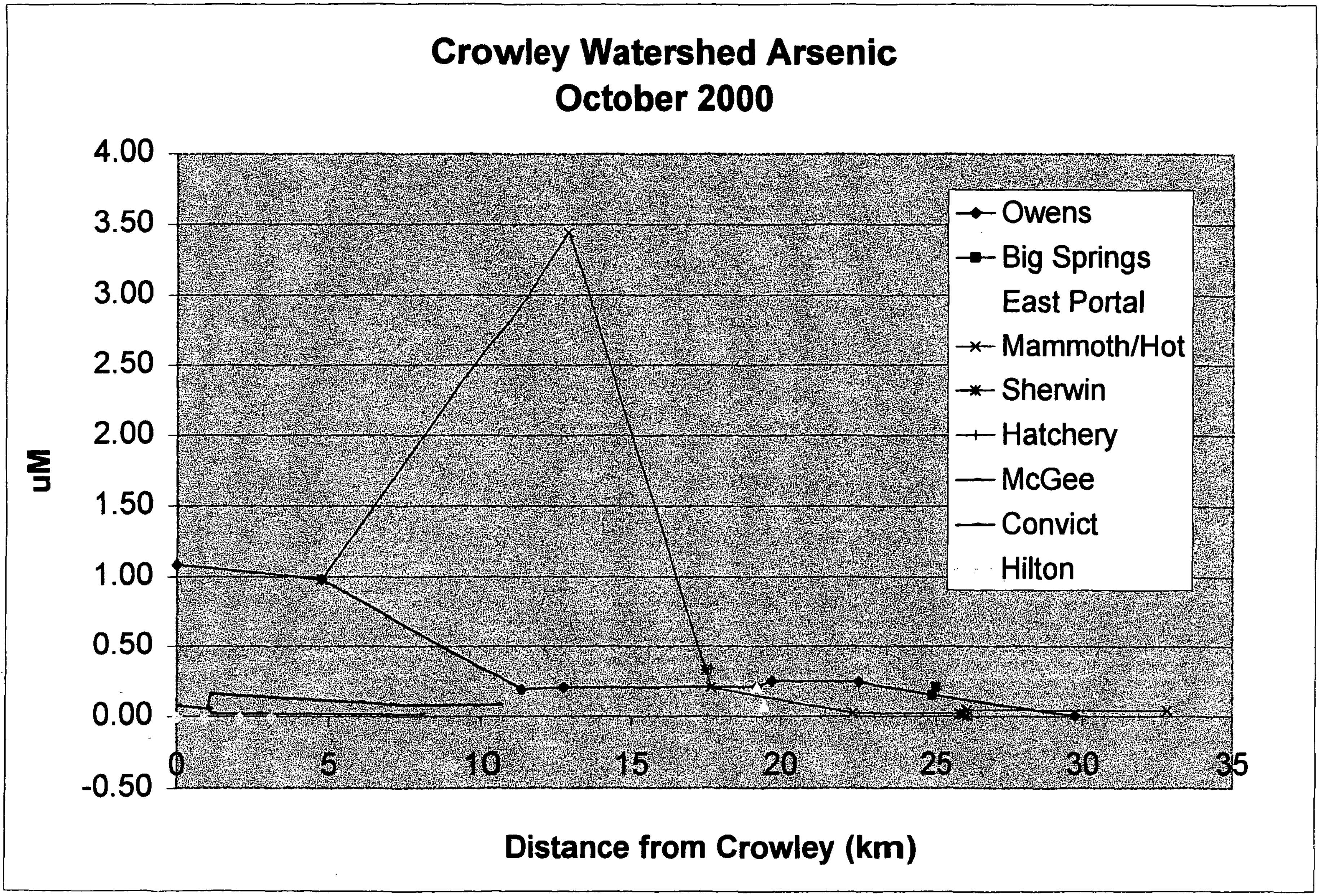
The nitrogen isotope analysis is complex. A large volume, up to 20 l, of water is collected and filtered. It is then dripped though both anion and cation exchange columns at a slow rate resulting in total adsorption of nitrate onto the anion column. The nitrate is desorbed from the column with dilute HCl which is then neutralized with Ag_2O. Prior to use the Ag_2O has to be washed multiple times to get it clean enough for this procedure. The sample is then filtered to remove AgCl and $BaCl_2$ is added to precipitate SO_4 and PO_4. The sample is refrigerated and filtered once more to remove barium precipitate. The sample is then passed through a cation exchange column to absorb any soluble barium. It is neutralized once more with Ag_2O, filtered and freeze-dried for isotope analysis.

At this time samples have been collected from all sites with adequate nitrate concentrations. Nitrate concentration must be approximately 0.2 uM as 4 umols of nitrogen are required for analysis and only 20 liters of water can be passed through the ion exchange column. An additional laboratory assistant has been hired and the samples are being processed, as described above, at UCSB. We expect to send them for isotope analysis in February. End member samples of such materials as periphyton, emergent aquatic vegetation, fish food, and manure have also been collected. These will be dried and sent for analysis with the samples.

TABLE 1
Arsenic Concentrations As Determined By Graphic Furnace Atomic Absorption Spectroscopy

station code	river	location	station distance from Crowley (km)	As (um)
OW0	Owens	at edge of lake	0	1.09
OW1	Owens	Benton Crossing	4.75	0.98
OW2	Owens	downstream end of H. Arcularius ranch	11.18	0.19
OW3	Owens	top end of H. Arcularius ranch	12.68	0.20
OW4C	Owens	at LADWP gauge below East Portal	19.2	0.21
OW4A	Owens	above East Portal on Gottwald ranch	19.7	0.25
OW5	Owens	downstream end of Alpers ranch	22.58	0.24
OW7	Owens	at culvert below Big Springs	24.84	0.15
OW10A	Owens	Glass Creek above confluence	29.73	0.00
OW7	Big Springs	at culvert below Big Springs	24.84	0.15
OW8A	Big Springs	Big Springs	24.97	0.20
OW4C	East Portal	at LADWP gauge below East Portal	19.2	0.21
OW4B	East Portal	East Portal	19.45	0.07
OW1	Mammoth/Hot	Benton Crossing	4.75	0.98
MA1	Mammoth/Hot	at flume below thermal area	12.82	3.44
MA2C	Mammoth/Hot	below Mammoth/Hot confluence	17.47	0.33
MA2A	Mammoth/Hot	Mammoth Creek below just below Chance	17.66	0.20
MA3	Mammoth/Hot	at old 395 flume	22.4	0.02
MA5C	Mammoth/Hot	below confluence with Sherwin	25.83	0.02
MA5A	Mammoth/Hot	above confluence with Sherwin	26.08	0.04
MA6	Mammoth/Hot	outllet of Twin Lakes	32.84	0.04
MA5C	Sherwin	below confluence with Sherwin	25.83	0.02
MA5B	Sherwin	Sherwin Creek	26.08	0.00
MA2C	Hatchery	below Mammoth/Hot confluence	17.47	0.33
MA2B	Hatchery	hatchery outflow above confluence	17.64	0.34
MG0	McGee	at lake	0	0.08
MG1	McGee	just below Convict confluence	1.03	0.05
MG2	McGee	just above Convict confluence	1.16	0.02
MG3	McGee	at 395	2.69	0.02
MG5	McGee	above pack station	7.98	0.02
MG1	Convict	just below Convict confluence	1.03	0.05
CO0	Convict	just above McGee confluence	1.11	0.16
CO1	Convict	just below SNARL	6.02	0.10
CO2	Convict	just above SNARL	7.02	0.09
CO3	Convict	outlet of Convict Lake	10.42	0.08
HL0	Hilton	at lake edge	0	0.00
HL1A	Hilton	at 395	0.93	-0.01
HL2A	Hilton	at old 395	2.09	-0.01
HL3	Hilton	above community at LADWP gauge	3.12	-0.01
OW10A	Glass	Glass	29.73	0.00

note: several stations are repeated in this table with different labels in the "River" column. This is necessary to get them to graph properly in the following chart.


Crowley Watershed Arsenic
October 2000
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
-0.50
uM
0
5
10
15
20
25
30
35
Distance from Crowley (km)
Owens
Big Springs
East Portal
Mammoth/Hot
Sherwin
Hatchery
McGee
Convict
Hilton

U.S GEOLOGICAL SURVEY VOLCANO HAZARDS PROGRAM

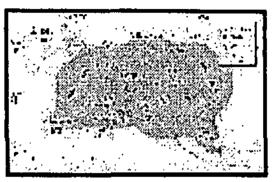
U.S. Geological Survey
Earth Science in the Public Service

Hydrologic Studies in Long Valley Caldera

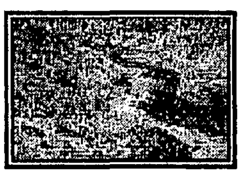
Index

Hydrothermal System

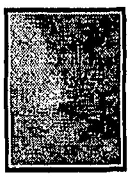
Long Valley caldera hosts an active hydrothermal system that includes hot springs, fumaroles (steam vents), and mineral deposits. Hot springs occur primarily in the eastern half of the caldera where land-surface elevations are relatively low; fumaroles occur primarily in the western half where elevations are relatively high. The springs located in the gorge along Hot Creek provide opportunities for public bathing in an area administered by the U.S. Forest Service. Although bathing in this area is safe with proper precautions, the hot springs can pose life-threatening hazards. Many people have been injured by boiling water from hot springs and deaths have occurred in Hot Creek.



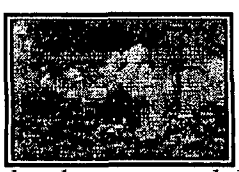
(Click on image for larger version (127k) with expanded caption)
Map of Long Valley caldera showing locations and descriptions of selected USGS hydrologic monitoring sites, the geothermal well field at Casa Diablo, and various geologic features referred to in the text.



(Click on image for larger version - 98k)
View of the gorge cut by Hot Creek, located northeast of the Mammoth airport, showing the areas of hot-spring discharge along the banks of the creek and in the bed of the creek (feature #6 on caldera map). The area just downstream from the bridge in the middle background is a popular site for recreational bathing.



(Click on image for larger version - 41k)
View of scientists sampling a boiling hot spring in Hot Creek gorge. Samples are analyzed to determine the concentration of minerals dissolved in the water, and the composition of dissolved gases.



(Click on image for larger version - 76k)
View of a U.S. Geological Survey drill rig completing a well near the Hot Creek gorge. Wells are monitored to detect changes in temperature and pressure that may occur from natural hydrologic variations in ground-water recharge, crustal strain (earthquakes and magmatic intrusions), and ground-water pumpage for geothermal development and domestic consumption.

Hot springs discharge in Long Valley primarily in Hot Creek gorge (feature #6), along Little Hot Creek (feature #7), and in the Alkalai Lakes area (feature #1). Springs at the Hot Creek Fish Hatchery (feature #4) supply fresh water at temperatures near 16 degrees Celsius - slightly elevated compared with other springs in the area due to the presence of a small component of thermal water.

The USGS began monitoring hot springs and wells in Long Valley in 1982 in order to study how the hydrologic system responds to volcanic and tectonic processes and natural hydrologic variations. The USGS currently collects data on water levels and temperatures in wells, and discharge, temperature, and water chemistry in springs at over a dozen sites. At many sites we make only periodic measurements each year, but at other sites we have made continuous measurements for almost 10 years.

Many hot springs and fumaroles in Long Valley are hot enough to cause severe burns or even death. Hot-spring formations and ecosystems are also very fragile. Thermal features should always be approached with extreme caution and care.

The USGS is the owner and operating agency for the Long Valley Exploration Well (LVEW - feature #13) on the resurgent dome. This scientific drill hole was originally envisioned to penetrate the near-magmatic environment to investigate the potential for energy extraction in Long Valley caldera. The well was drilled to a depth of 2.3 km in 1991, and is to be deepened in 1998 to a depth of ~4 km. The primary goals of this drilling are:

- Obtain a complete core section for studies of the petrology, fracture state, and pore fluids.
- Determine the temperature profile below the hydrologic convective regime that appears to control temperatures shallower than 2 km, and evaluate the potential for geothermal energy recovery at depths below 2 km.
- Determine the state of stress within the earthquake zone and estimate the temperature at the brittle/ductile transition.

In the long term, we plan to use the borehole as a geophysical observatory with a number of down-hole instrument packages to track processes occurring directly above the inflating magma chamber that are driving unrest in the caldera. We are currently monitoring water level in the Santa Fe (SF) water-supply well located on the same well pad.

Sources of additional information on the caldera's hydrologic system:

- See the Long Valley caldera hydrology reference list

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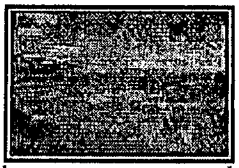
Go back to Index

Geothermal Development

Wells drilled at Casa Diablo, on the southwest side of the resurgent dome (caldera map, 127k) tap into the caldera's hydrothermal system by pumping hot water at temperatures near 170 C to supply three geothermal power plants that generate about 40 megawatts of electricity. Cooled geothermal water from the plants is reinjected underground. The power plants use a binary technology involving a secondary fluid (isobutane) that is heated by the pressurized geothermal water, vaporized, and then run through the generating turbines.


(Click on image for larger version - 68k)
View of the Casa Diablo area in Long Valley caldera, near the intersection of U.S. Highway 395 and State Highway 203 to the town of Mammoth Lakes. Mammoth Mountain can be seen in the center background, and in the foreground are three geothermal power plants currently producing about 40 megawatts of electricity using hot water pumped from shallow wells.

The hydrologic monitoring program has also been adapted to detect changes caused by geothermal development and the pumpage of ground water for domestic consumption. We have, for example, been able to delineate decreases in thermal-spring discharge at sites within about 5 km to the east of Casa Diablo that are caused by subsurface pressure declines originating in the geothermal well field. There has also been an increase in steam discharge at Casa Diablo and sites farther to the west as a result of increased boiling of heated fluids. In contrast, no changes have as yet been detected in the springs in Hot Creek gorge.

Go back to Index

Hydrologic Monitoring Data

Selected hydrologic monitoring sites are shown on the caldera map.

Most recent data:

- Last 30 days of water level and barometric pressure changes at wells SF, CH-10B, and LKT (unfiltered)
- Last 90 days of water level and barometric pressure changes at wells SF, CH-10B, and LKT (unfiltered)

Long-term records from periodic data collection sites:

- SC-1: well near Sherwin Creek campground
- SC-2: well near Sherwin Creek campground
- Hot Creek Gorge: hot springs
- Mammoth Ranger Station: precipitation (operated by U.S. Forest Service)

Long-term records from continuous data collection sites:

- LKT: well near Lookout Mountain
- SF: Santa Fe well (located on the LVEW well pad)
- CH-10B: Geothermal observation well near Hot Creek gorge
- CW-3: Chance well number 3 near the Fish Hatchery
- HCF: streamflow site on Hot Creek at Hot Creek Flume

  At the continuous sites, data are collected at intervals of 15 minutes to 1 hour. As of January 1998, data collected at the first four sites are being telemetered via satellite. Telemetry equipment will be installed on HCF in early 1998.

Additional water-level data are collected 3 times per year from a network of about 30 wells within and adjacent to the Long Valley caldera. Data from these sites are used for various purposes, including evaluations of the effect of water-table variations on repeat gravity surveys aimed at identifying inputs of magma at depth.

Causes of Variations in the Hydrologic System

- **Precipitation and ground-water recharge:** Streamflow at HCF and ground-water levels in wells SC-1 and SC-2 show large-scale variations (both short-term and long-term) primarily related to precipitation and ground-water recharge. These processes also influence water levels in wells tapping deeper aquifers, but to a lesser degree.

- **Geothermal fluid production:** Water levels in geothermal well CW-3 (5 km east of Casa Diablo, show the effects of pressure reductions caused by geothermal fluid production at Casa Diablo; water levels declined significantly in 1991 when the production rate was increased to supply two new power plants. A similar water level decline has not yet occurred in geothermal observation well CH-10B, located 9 km east of Casa Diablo.

- **Earthquakes:** Water-levels in wells LKT, CH10-B, Santa Fe, and CW-3 show changes in response to relatively large local (>M~4) and regional earthquakes (>M~5) and to large distant earthquakes (>M6). The coseismic responses typically involve rapid water-level drops over periods of days followed by water-level recovery over periods of weeks to months. For example, the hydrograph for well LKT shows responses to earthquakes on July 11, 1989 (M4.6 in Long Valley area), October 11, 1989 (M~7 Loma Prieta), October 24, 1990 (M5.7 north of Long Valley caldera), and June 28, 1992 (M7.3 Landers).

- **Crustal Deformation:** The relatively rapid and large water-level declines seen in wells LKT, CH10-B, Santa Fe, and CW-3 in the fall of 1997 are anomalous compared to the trend of declining water level that typically occurs during the fall in other years. The magnitude of the anomalous declines, which end by November or December, range from 0.5-1.0 ft (15-30 cm). The timing of these changes correlates with the increase in extension rate across the resurgent dome that began in October and continued for the rest of the year, as seen in the geodetic data. Relatively high strain rates may be required to cause measureable responses in the hydrologic system because strain-induced water-level changes tend to be dissipated by the increase in ground-water flow caused by localized fluid-pressure changes. Quantitative analysis of the relationship between strain rate and water-level changes is in progress. To date, no correlation has been delineated between strain rates and measurements of hot-spring discharge in Hot Creek gorge.

- **Barometric pressure and earth tides:** Water-level data from the continuously monitored wells are put through a filtering process to remove the effects of barometric pressure and earth tides.

Sources of additional information on hydrologic monitoring in the caldera:

- See the Long Valley caldera hydrology reference list

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Go back to Index

Return to Long Valley Caldera page
USGS Home Page
USGS Water Resources Headquarters

Last modified: Feb 23, 1998

HOT CREEK			
section			pages
Exectuive Summary			1
Hydrogeologic conditions			2
Biological Inventory			1
Chemical Inventory			1
	graphs		6
Beneficial Uses			2
Total Pages			13

<u>Draft</u> report compiled by Regional Board student assistant Alexandra Lutz summarizing Hot Creek data from various sources.

EXECUTIVE SUMMARY

Hot Creek is located in the geologically active Long Valley in Mono County, California. It flows from the Hot Creek Fish Hatchery, operated by the California Department of Fish and Game (CDFG) to the Owens River, which is received by Lake Crowley (source for the Los Angeles aqueduct). Water exiting the hatchery flows approximately three to four miles before entering the Hot Creek Gorge. Here, water quality and temperature are affected by geothermal springs which discharge into the creek. Since 1982, the United States Geologic Survey (USGS) has been monitoring several sites along Hot Creek. The agency "currently collects data on water levels and temperatures in wells, and discharge, temperature, and water chemistry in springs..." (page 2, webpage: quake.../hydrostu.html). Some reports are done annually, others are done quarterly. This report will summarize available information from detailed surveys.

Ownership of the Hot Creek watershed is divided among: the Los Angeles Department of Water and Power (LADWP), the United States Forest Service (USFS), the Bureau of Land Management (BLM) and private persons. The privately owned and managed Hot Creek Ranch is approximately one mile below the hatchery, and provides their guests with access to fly fishing. The USFS currently manages the Hot Creek bathing pools within the gorge.

Hot Creek is listed as a "water quality limited segment" under Section 303(d) of the Clean Water Act. For listed water bodies, the State of California must either develop Total Maximum Daily Loads (TMDLs) or provide evidence that control actions are in place to justify delisting. Using grant funding, the Lahontan Region Water Quality Control Board (LRWQCB) has collected evidence for delisting as a naturally impaired water body, rather than development as a TMDL.

Currently, the Hot Creek watershed is habitat to federally listed endangered species, and federal and state species of concern. The Endangered Species Act provides protection for endangered species and the ecosystems they occupy. "The ecological uniqueness of this area and recent discoveries of new species... suggest that future surveys may document the presence of additional unique plants and animals in the basin" (page USFWS 1 Species Recovery Plan). The US Fish and Wildlife Service (USFWS) has created a draft species recovery plan proposing a conservancy area within the Hot Creek watershed for several species.

This report summarizes available information about Hot Creek. It will be used to support delisting of Hot Creek in the 1999-2000 review cycle for the Lahontan Region's Section 303(d) list.

HYDROGEOLOGIC CONDITIONS

This section will examine the various springs contributing to Hot Creek. The following information is obtained from LRWQCB files and various reports which will be cited.

The Long Valley Caldera's elevation ranges from 9,000 feet above sea level (adjacent to the eastern slope of the Sierra Nevada) to 6,800 feet within an oval shape measuring approximately 12 miles from north to south and 18 miles east to west. It is a result "of a massive volcanic eruption about 760 thousand years ago" (page 4 USGS Hydro. Data for LVC 1996). Current activity is evidenced by numerous springs and fumaroles which are discharge points for a naturally occurring hydrothermal system.

The fish hatchery springs are considered slightly thermal, being "fed primarily by shallow ground water" (USGS orange p7). Water emerging from springs at the hatchery is within acceptable parameters for fish habitat and does not require treatment. Overall, the hatchery uses between 15 and 25 [cubic feet per second (cfs)] of water from low temperature (15-20 C) thermal springs for raising trout" (page 1, introduction USGS LVC).

The fish hatchery uses water from four sets of springs: AB supply, CD supply, Hatchery I spring group, and Hatchery II spring group. Temperatures are listed under chemical analysis. The AB and CD springs enter production ponds which contain fingerlings to catchables. The production ponds are also fed by recirculation lines which carry used water from sediment pond 451 (fed by the Hatchery I spring group). Used water enters sediment ponds one and two. Water emerging from these ponds forms the Hot Creek headwaters. The Hatchery I spring group is used for a small hatchery, and a two year old broodstock brood pond. Used waters enter sediment pond 451 where they are either recirculated or discharged to form the headwaters. Hatchery II spring group is used for the three year old broodstock brood pond, but some of this water is diverted into hatchery II before entering the pond. From the pond, water is discharged directly into Hot Creek below the headwaters.

Several hundred feet downstream of the fish hatchery is the Mammoth Creek confluence with Hot Creek. At this point, Mammoth Creek is considered to be impaired, having being fed by geothermal springs similar to those near the hatchery. The scope of water quality of Mammoth Creek is not considered in this report, though it is a major tributary to Hot Creek and contributes impaired water. Approximately one more mile downstream, the creek passes by Hot Creek Ranch. Minor springs here are also considered slightly thermal. After another mile, the creek drops into the Hot Creek Gorge.

Within the gorge, springs are fed by deeper geothermal systems. Nearby experimental wells drilled at depths of 630 feet to 1,063 feet produced water up to 181 degrees Celsius. "High concentrations of arsenic, boron, fluoride, and dissolved solids in the effluent from the wells" (USGS orange 7) were also recorded. Temperatures and water quality are altered by the amount of groundwater mixing in. The springs within the gorge are "the hottest of the thermal springs in Long Valley" (USGS orange 7) and drastically affect water quality. USGS makes continuous measurements at a site above the gorge - "# 10265147 HCAB" and a site below the gorge - "# 10265150 HCAF." Springs within the gorge are sampled periodically.

Approximately one mile downstream from the gorge is the confluence with the Owens River.

BIOLOGICAL INVENTORY

Of the many species in the Hot Creek watershed, the ones primarily considered in this report are the Owens Valley sucker, Long Valley speckled dace (*Rhinichthys osculus*) and the hydrobieddae springsnail (*tryonia protea*). None are federally listed endangered species, but they are species of concern. Studies done "in the late 1980s found that speckled dace no longer occupy... Hot Creek" (32) though it was a historic habitat , and general numbers of "Long Valley speckled dace are declining" (USFWS page 31). The Springsnail is one of three known populations, the next closest occurring in the Salton Sea area (CDFG interview with Darryl Long). This suggests that the springsnail may be an archaic species.

The USFWS has created a draft "Owens Basin Wetland and Aquatic Species Recovery Plan" which outlines the specific tasks needed to halt or reverse the decline and begin re-establishment of the species. Restoration of the native species is a goal of the recovery plan. A managed Hot Creek Conservation Area has been proposed.

"Hot Creek Conservation Area lies at approximately 2,100 m (7,000 feet) elevation...and includes springs at CDFG's Hot Creek Fish Hatchery, Hot Creek, and adjacent meadows...vegetation and soils categorized as streambank, sodic meadow, moist floodplain and wet sodic meadow... " (USFWS 59). Estimated water surface fish habitat is 0.6 ha (1.6 a), and linear habitat is projected at 1 km (0.6 mi) (ibid 74). Special sections of Hot Creek have been recognized as wild trout stream, and sport fishing is permitted on a catch and release basis. Brown trout are abundant, rainbow trout are also found, and hybrid tui chub also inhabit the waters.

The proposed conservation area is classified as small, being less that 400 ha (1,000a) in size. Ownership of the land is divided among: LADWP, USFS, BLM, and private. Currently, the Hot Creek project ranks fourth priority of seventeen proposed conservation areas, according to the USFWS. Tasks recommended to take place immediately are: expansion of native fish habitat and distribution, and protection of spring discharge. It is suspected that geothermal development has been decreasing the rate at which springs flow into Hot Creek, altering thermal and chemical characteristics of this water (USFWS 83).

CHEMICAL INVENTORY

A 1976 USGS report determined that geothermal water in the Long Valley is "characterized by: High concentrations of dissolved solids -- mainly sodium, bicarbonate, chloride, boron, and arsenic; a relatively low concentration of magnesium compared to other native water; and high concentrations of a host of trace elements." (Orange p 12).

The Hot Creek Gorge has been identified as a major contributor of arsenic to downstream water supplies. USGS (orange 31) reports that 60% of the arsenic in Lake Crowley is "derived from hot springs in Hot Creek Gorge." Contributions from sources upstream are small in comparison to effluents produced by the springs. Water within the LA Aqueduct carries average levels of 22 ug/l of arsenic. After the water has been treated, the average is 10 ug/L, which is below the drinking standard of 50 ug/L. The EPA may determine a lower setting between 0.5 and 20 ug/L (page 1 webpage: www.ladwp...arsnc.htm) which will require further treatment of water. "A treatment facility at Hot Creek would be more cost-effective, but siting a facility in such an environmentally-sensitive area will be very difficult" (ibid.).

Another water quality issue for the city of LA is lead and copper in sourcewaters (www.ladwp.com/water/quality/wq_ldep.htm). The USGS also record levels at various sites.

ADAPTED FROM UNITED STATES DEPARTMENT OF THE INTERIOR GEOLOGIC SURVEY									
PROCESS DATE 6-10-98									
STATION	DATE	TEMPER-ATURE WATER (DEG C)	DIS-CHARGE, INST. CUBIC FEET PER SECOND	SPE-CIFIC CON-DUCT-ANCE (US/CM)	PH WATER WHOLE FIELD (STAND-ARD UNITS)	PH WATER WHOLE LAB (STAND-ARD UNITS)	ARSENIC DISS OLVED AS	COPPER DISS-OLVED (UG/L AS CU AS	LEAD DISS-OLVED (UG/L AS PB)
		-10	-61	-95	-400	-403	-1000.00	-1040	-1049
10265143	07-13-88	25.7	5.81	146	8.74	8.5	46.00	5	1
HATCHERY	10/19/88	10	E2.1000	221	8.3	8	4.00	5	4
AB SPRINGS	4/11/89	14.5	8.74	165	8.2	7.9	20.00	4	7
	7/18/89	23.5	5.25	135	8.6	8.6	52.00	5	1
	10/18/89	12	2.09	202	8.6	8.1	38.00	3	2
	1/9/90	2.5	5.3	192	7.97	7.9	21.00	3	2
	4/25/90	17	3.49	168	8.7	--	3.00	2	--
	7/17/90	24	3.3	142	8.86	8.4	52.00	6	2
	10/16/90	12.55	1.3	195	8.49	8.1	46.00	6	8
	1/17/91	5.5	1.25	251	8.04	7.7	54.00	28	10
	4/16/91	13.5	3.09	195	7.48	7.9	29.00	13	22
	7/22/91	24.5	2.4	155	8.24	8.2	43.00	4	--
	10/22/91	13.5	2.78	154	8.7	8	27.00	4	1
	1/13/92	0.5	4.57	165	8	7.8	20.00	6	9
	4/14/92	15.5	4.16	187	8.4	8.2	29.00	6	9
	7/6/92	22	5.03	105	8.9	8.2	19.00	6	3
	10/19/92	14.5	2.24	156	8.4	8.1	26.00	3	2
	1/25/93	2.5	3.4	220	7.7	7.7	60.00	23	24
	4/12/93	14	8.7	187	8.3	8.1	24.00	11	12
	7/13/93	13	65.6	71	7.64	7.6	11.00	7	7
	10/13/93	10	9.71	120	7.72	7.5	11.00	6	6
	1/10/94	5.5	3.3	175	8.22	7.7	15.00	10	11
	4/12/94	5.5	5.53	170	8.03	7.6	17.00	8	10
	7/11/94	25	6.74	101	8.52	7.6	16.00	6	8
	10/19/94	5.5	3.18	168	8.14	7.5	23.00	6	7
	1/17/95	0	8.94	166	7.74	7.6	18.00	10	9
	4/18/95	0.5	13.7	186	7.87	7.7	18.00	10	16
	10/16/95	14.5	19.4	127	8.15	7.9	16.00	6	4
	10/16/95	--	--	--	--	7.7	17.00	6	4
	1/24/96	0.5	9.62	150	8	7.7	17.00	7	11
	4/23/96	13	17.4	141	8	7.7	1.00	5	5
	7/16/96	18	38.5	86	7.78	7.4	13.00	8	4
	10/16/96	11	7.11	154	8.18	7.8	20.00	6	8
	1/14/97	1	24.9	133	--	7.4	13.00	5	5
	4/15/97	8.5	13.8	157	8.16	7.819	11.73	4	4
	7/15/97	16	31	89	7.92	7.538	8.81	4	13
	10/20/97	8	9.6	145	8.02	8.106	12.40	4	4
10265147	11/6/84	--	--	--	--	9.6	45.00	3	2
ABOVE GORGE	01-15-97	7.5		195				1	1
	4/16/97	12		212					
	7/16/97	15		169					
	10/22/97	12		214					
	11/19/97	7.5	42.4	219	8.82	8.058	36.00		
	12/18/97	8		227					
	1/16/98	8		231					
	2/12/98	10.5		236					
	3/19/98	14		253					
	4/17/98	11		246					

	DATE	TEMP	CFS	COND	pH FIEL	pH LAB	AS	CU	PB	
10265150	11/16/82	19.5	88.6	340	7.5	7.7	140.00	--	--	
FLUME BELOW	6/3/83	17.1	216	216	7.4	7.5	70.00	--	--	
GORGE	7/6/83	22.5	312	153	6.7	7.3	52.00	--	--	
	8/8/83	18.7	183	246	7.1	7.4	88.00	--	--	
	10/3/83	21.5	100	363	7.3	7.7	120.00	3	3	
	11/2/83	20.3	84	410	7.4	7.5	150.00	2	2	
	12/14/83	16.5	89	416	7.3	7.5	130.00	3	3	
	4/5/84	23.7	63	490	7.5	7.6	170.00	2	1	
	5/10/84	25.5	73	444	7.5	7.6	160.00	3	1	
	6/20/84	21	118	297	--	7.5	83.00	4	2	
	7/24/84	27.5	100	362	7.4	8.2	120.00	7	2	
	9/2/84	24.5	67	445	7.5	7.9	160.00	1	1	
	10/10/84	24.7	60	471	7.4	7.5	160.00	0.000 1	0.000 3	
	11/11/84	24	62	460	7.4	8.6	150.00	0.000 2	0.000 2	
	10/19/85	32.7	44	552	7.6	8	240.00	0.000 2	0.000 1	
	4/12/86	24.8	70.7	447	7.6	7.6	180.00	3	1	
	7/27/87	36	41.8	579	--	8.7	110.00	--	3	
	7/12/88	34	57	470	7.78	7.7	230.00	1	1	
	7/19/89	37	42.2	586	7.7	7.8	270.00	1	--	
	7/18/90	33	38	591	7.59	7.7	280.00	1	2	
	01-15-97	21.8		423						
	4/16/97	23		466						
	7/16/97	25		356						
	10/22/97	30		510						
	12/18/97	24.5		514						
	1/16/98	24		481						
	2/12/98	26.5		511						
	3/19/98	30.5		523						
	4/17/98	27.5		499						
373940118494001	12-18-97	92		1750						
SPRINGS IN	1/16/98	93		1760						
GORGE	2/12/98	92.5		1760						
	3/19/98	92.5		1729						
	4/17/98	92.8		1730						
373942118494201	03-16-83	89	--	2670	8.4	8.5	990.00	--	--	
	8/19/83	91.5	--	2740	8	8.1	1100.00	--	--	
	10/4/83	90.6	--	2520	8.1	8.4	1200.00	--	--	
	12/13/83	88.3	--	2530	8.2	8.4	900.00	4	-- <1	
	5/8/84	91.4	--	2510	8.1	8.4	900.00	--	-- <	
	9/3/84	91	--	--	8.3	8.5	930.00	-- <	--	
	2/4/85	92.4	--	--	8.1	8.5	940.00	10.000 <	10.000 <	
	7/16/85	92.8	--	2030	7.8	8	1100.00	00.00 <6	00.00 <2	
	4/8/86	92.3	--	1820	8	8.2	1100.00	-- <	-- <	
	4/8/86	92.3	--	1820	8	8.2	1100.00	-- <	-- <	
	7/28/87	93.7	--	--	7.56	8	1100.00	-- <	-- <	
	7/11/88	93	--	--	8.08	8.3	1300.00	-- <	-- <	
	7/19/89	95	--	--	7.8	8.3	1100.00	--	--	
	7/18/90	95.5	--	--	8.11	8.4	1000.00	-- <	--	
	4/16/92	81	--	1830	7.6	8.1	1100.00	--	--	
374010118465301	04-10-86	56.6	--	1810	6.6	6.9	470.00	18	15	
	8/29/87	58.4	0.075	--	6.78	7.2	86.00	17	15	
	7/14/88	57.6	0.06	--	6.95	7.6	380.00	18	16	
	1/12/89	57.4	0.05	--	7	7.3	470.00	16	15	
	7/17/89	57.5	0.057	--	6.7	7.3	200.00	18	15	
	1/10/90	57.1	0.1	--	6.96	7.4	150.00	19	16	

STATION	DATE	TEMP	CFS	COND	pH FIEL	pH LAB	AS	CU	PB	
		-10	-61	-95	-400	-403	-1000.00			
374125118502501	08-19-83	82.2	--	2830	6.7	6.8	600.00	--	--	
	1/17/84	80	--	2810	6.7	7	580.00	3	20	
	5/9/84	81.2	--	2730	6.8	7	590.00	4	20	
	9/3/84	82.7	0.08	--	6.8	7	620.00	3	21	
	11/12/84	82.6	--	--	6.8	8.9	450.00	10.000 4	10.000 20	
	4/10/86	82.4	--	2010	6.53	6.9	720.00	4	20	
	8/29/87	82.8	0.12	--	6.6	7.3	<650.00	4	21	
	7/14/88	82.8	0.12	--	6.95	8.9	590.00	3	21	
	1/13/89	82.6	0.12	--	6.8	7	850.00	3	20	
	7/17/89	82.5	0.133	--	6.7	7.5	300.00	3	20	
	1/9/90	82.7	0.12	2100	7.11	7.4	700.00	3	21	
	7/18/90	82.8	0.12	--	7	7.2	610.00	1	21	
	1/18/91	82.6	0.123	1990	6.9	7.2	700.00	3	20	
	7/24/91	82.8	--	2030	7.63	7.8	710.00	3	19	
	1/15/92	82.7	0.119	1920	8	8.1	710.00	3	20	
	4/16/92	82.6	--	1980	7.6	7.8	710.00	2	20	
	7/8/92	82.7	--	1920	7.7	7.7	690.00	5	20	
	1/26/93	82.8	0.13	1900	7.12	7.1	780.00	3	21	
	7/15/93	82.7	0.13	1910	7.82	8.2	650.00	3	20	
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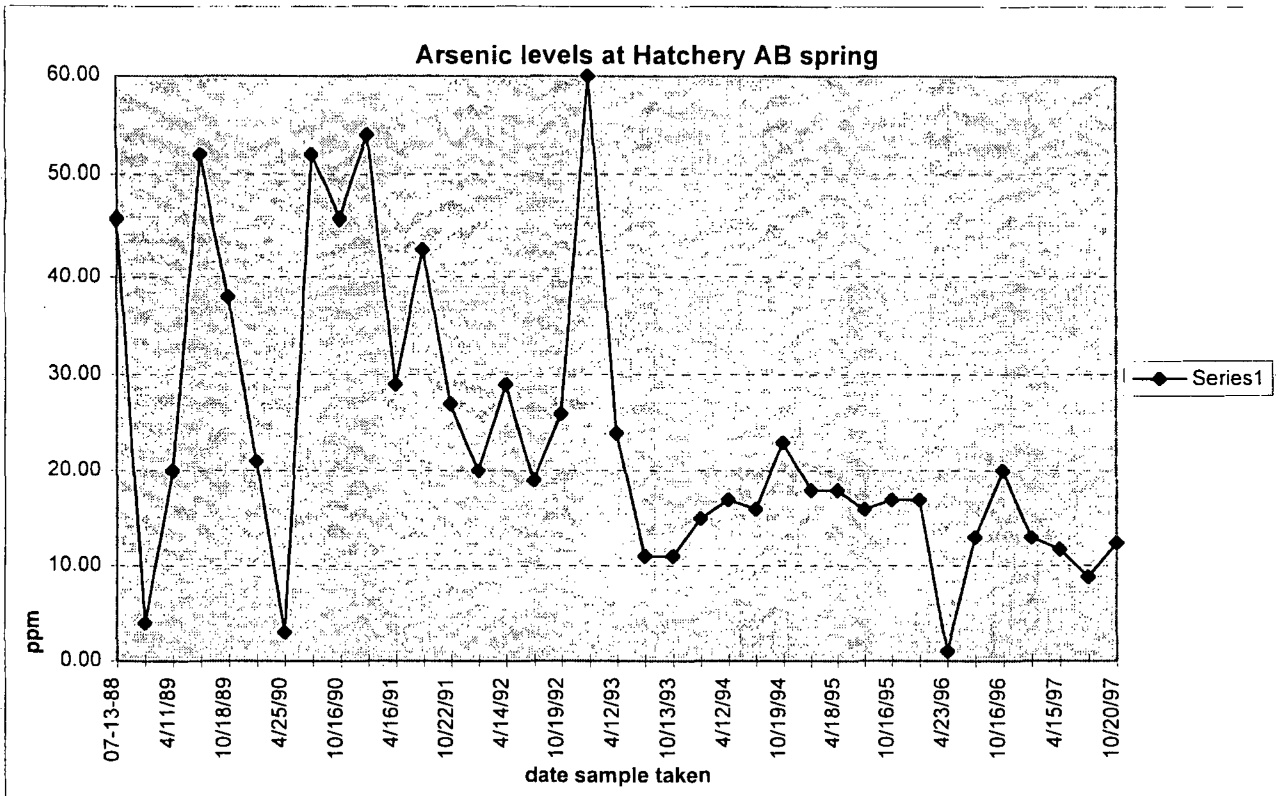
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30.00
20.00
10.00
0.00
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10/18/89
4/25/90
10/16/90
4/16/91
10/22/91
4/14/92
10/19/92
4/12/93
10/13/93
4/12/94
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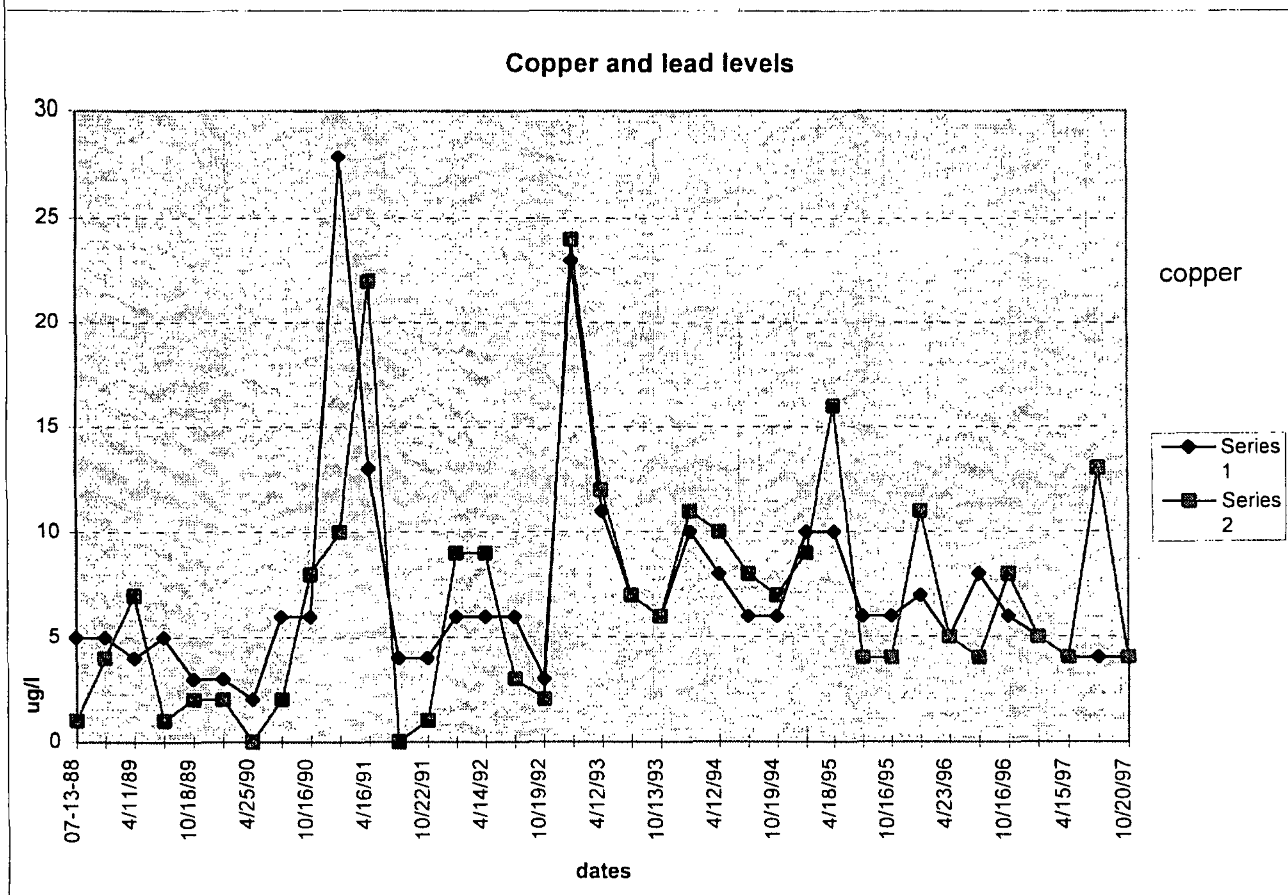
10/16/95
4/23/96
10/16/96
4/15/97
10/20/97
date sample taken
Series1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10
5
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4/16/91
10/22/91
4/14/92
10/19/92
4/12/93
10/13/93
4/12/94
10/19/94
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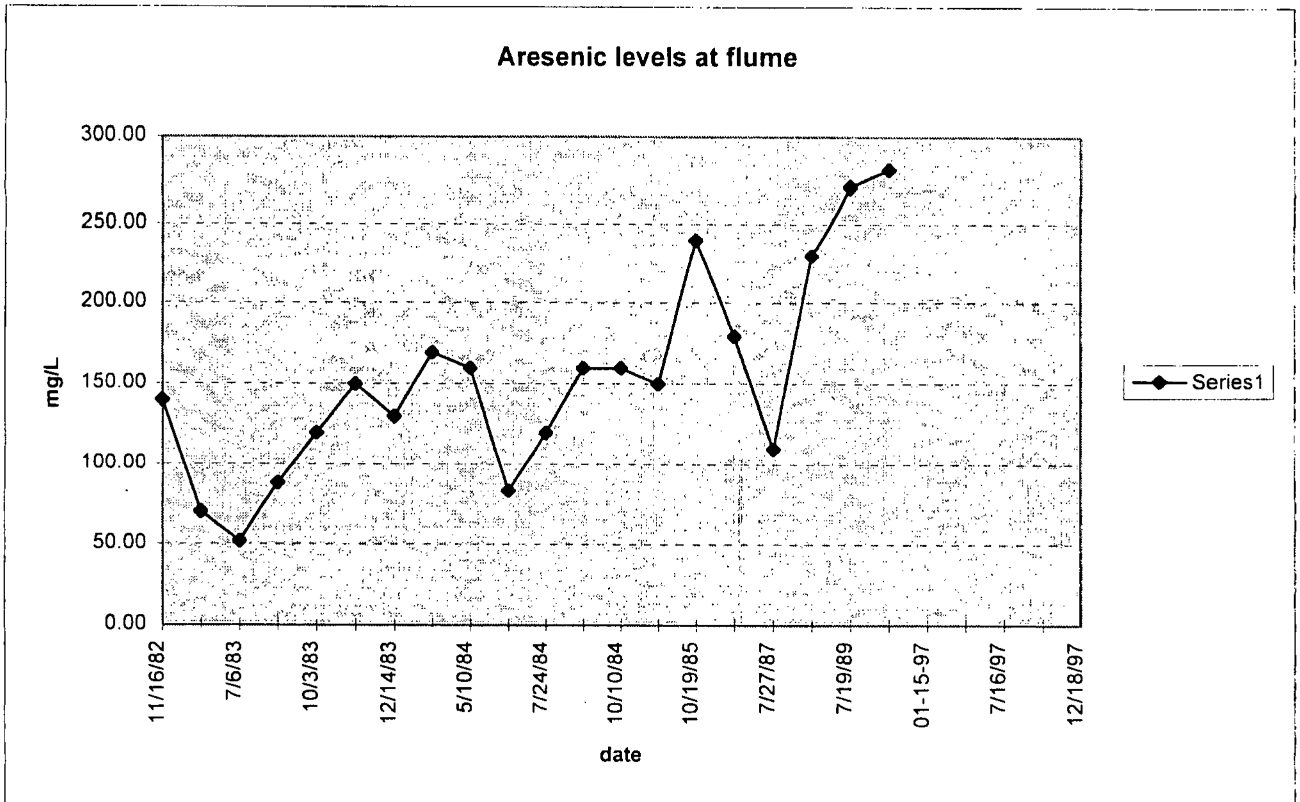
10/20/97
dates
copper
Series 1
Series 2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10/3/83
12/14/83
5/10/84
7/24/84
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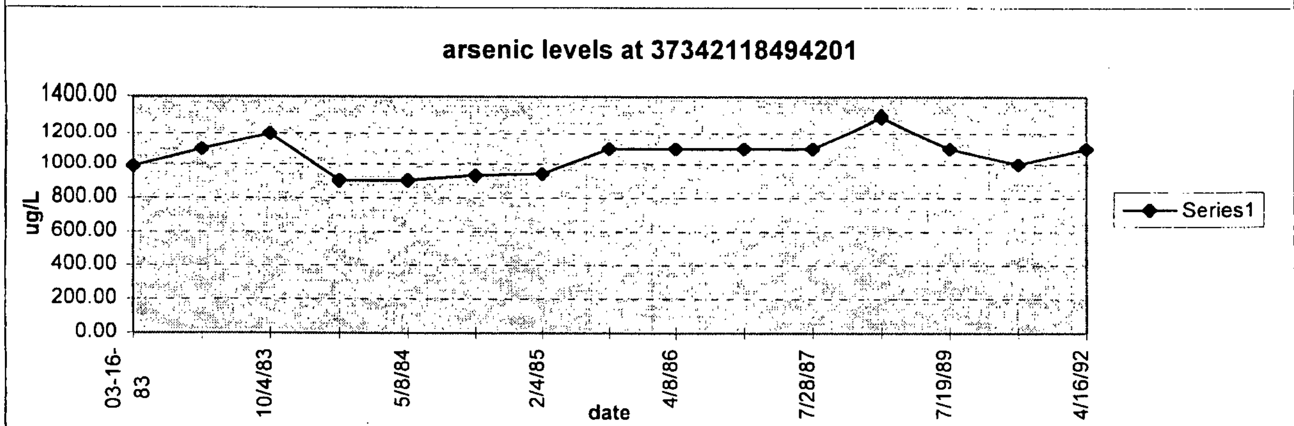
7/19/89
01-15-97
7/16/97
12/18/97
date
Series1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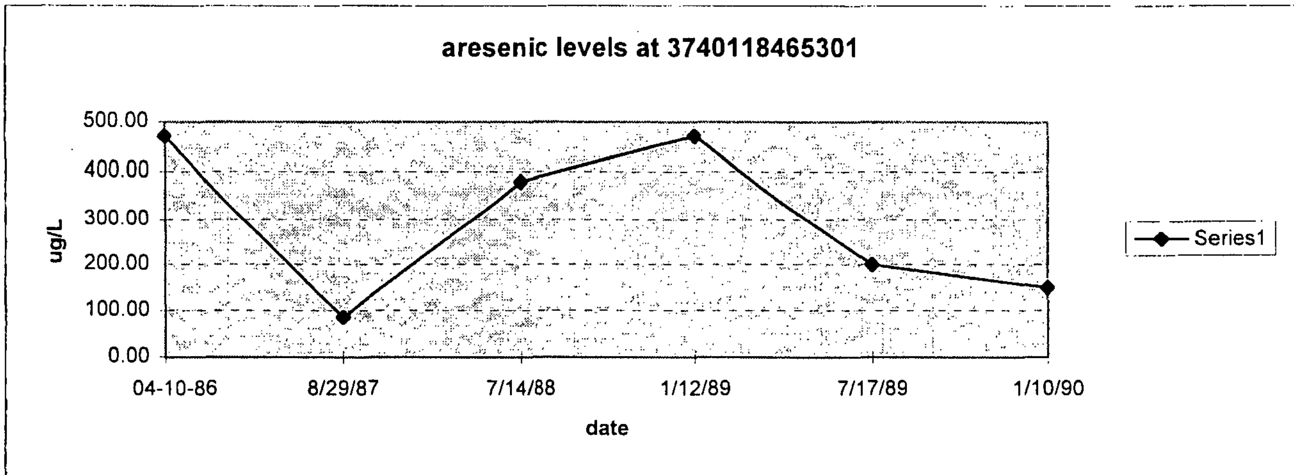
date
Series1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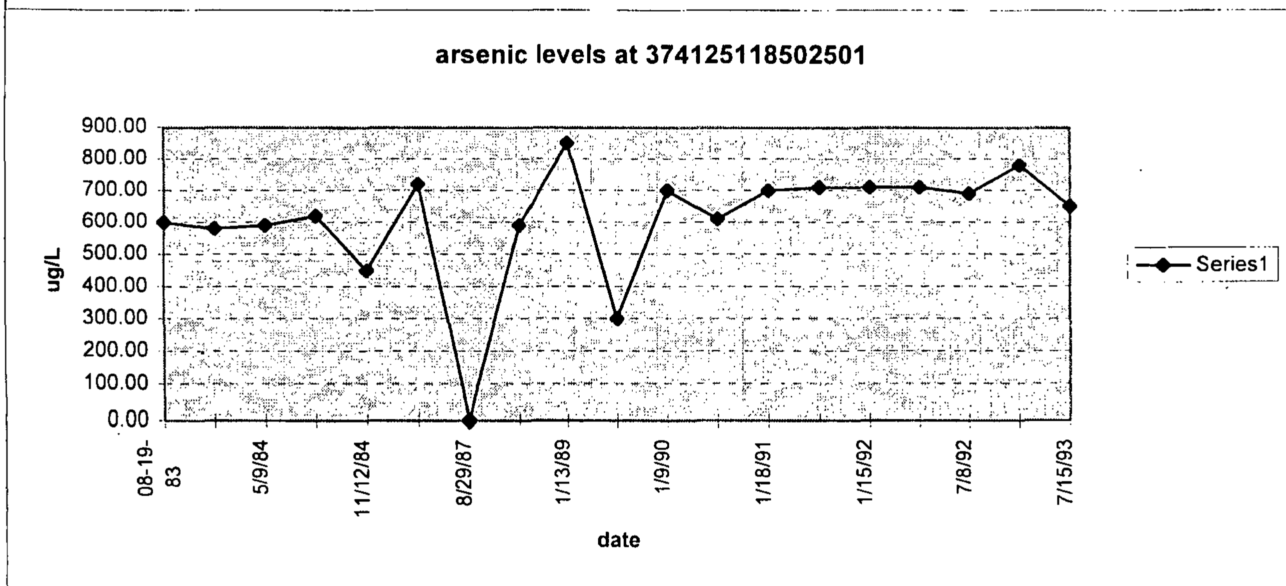
date
Series1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ug/L
08-19-83
5/9/84
11/12/84
8/29/87
1/13/89
1/9/90
1/18/91
1/15/92
7/8/92
7/15/93
date
Series1

Hot Creek (long Hydrologic area) has been classified as a perennial stream and is designated for the following uses under the Basin Plan:

AGR
Cattle grazing is under permit from the LADWP.

AQUA
The Hot Creek Fish Hatchery raises trout for stocking purposes. The stock provides a state wide commercial sport fishing industry.

BIOL
This is not a current designated beneficial use. However, the proposed Hot Creek Conservation Area makes this a possibility.

COLD
The Hot Creek Fish Hatchery is a state run cold water fishery, using water from four groups of springs. The creek provides year round habitat to the Owens tui chub.

COMM
The Hot Creek ranch advertises "great" fly fishing on their webpage, and provides its guests with access to the creek. Catch and Release fly fishing is permitted along the creek.

GWR
Maintaining quality and amount of groundwater in this area is important since the Casa Diablo plant draws on geothermal waters to create energy. Also, groundwater levels can affect flow rates of the springs feeding Hot Creek. A drastic change could alter the quality and amount of water flowing into the hatchery.

IND
Casa Diablo is upstream of the considered area. An arsenic treatment plant may be considered under this use.

MIGR
Trout migrate within the Hot Creek watershed.

MUN
Hot Creek is not a direct source of drinking water for any municipality,. though it remains open to these possibilities. It flows into the Owens river which is received by Lake Crowley, a source of water for the Los Angeles Aqueduct. The water is treated before entering the city's municipal water system.

RARE

The Owens Valley sucker, Long Valley speckled dace (*Rhinichthys osculus*) and the hydrobieddae springsnail (*tryonia protea*) are not federally listed endangered species, but they are species of concern limited to this habitat.

REC-1

Many bathers visit the Hot Creek Gorge. Signs have been placed to warn bathers of the possibility of extreme water temperatures and unusual chemical contents. There is also access to fly fishing.

REC-2

There is a visitor's site which presents a short interpretive trail and possibilities for other hikes into the gorge.

SPWN

Trout use the habitat for spawning.

WILD

Native fish in the Upper Owens basin are Owens tui chub and Owens sucker. Three introduced species have been noted in the same area: brown trout, rainbow trout, and threespine stickleback. Rainbow trout have been observed in the Hot Creek headwaters.

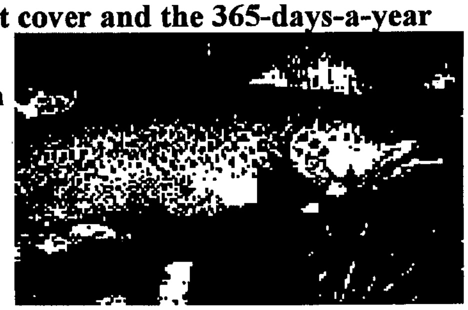
Hot Creek Ranch

Traditional Dry-Fly Chalkstream Fly Fishing

Hot Creek is born in a gush of thermal water bubbling from a fissure and dies at its confluence with the Owens River eight or ten miles later. The Hot Creek Ranch property begins just a mile or so downstream from the source.

The resource is a triumph of Mother Nature.

Nearby springs maintain a perfect balance in terms of mineral content and temperature.The abundant weeds give trout excellent cover and the 365-days-a-year aquatic insect hatch provides the food. Gravel provides the spawning beds for both the resident fish and massive swarms of brood trout that make the excursion from the Owens River and Lake Crowley.



It adds up to great fishing.

The valley was homesteaded by a family as a cattle ranch in the middle-late 1800s: a small log cabin (re-roofed and used today as a tool shed) still stands not far from the river bank where it was built some 110 years ago.

Before it was homesteaded, Hot Creek was a favorite campsite of the native Paiute Indians. The men used the abundant obsidian rock for their points while women wove wild grasses and willows into baskets and food containers. Believe it or not, arrowheads and other points are still occasionally found along the stream bank and trails.

In the early 1950s, at the suggestion of a fishery biologist with the California Department of Fish & Game, the two miles of private water that comprise Hot Creek Ranch were made dry fly only. The result is one of the most spectacular fly-fisheries in the United States if not the world.Browns and rainbows in excess of 20-inches are not uncommon; 16- to 18-inchers are the rule rather than the exception; and 13- to

15-inch trout are standard.

The Ranch offers nine superbly-maintained and fully-equipped all-electric housekeeping cabins. We also offer expert guide service with advance booking.

Hot Creek Ranch offers something else: The serenity of the Eastern Sierra with a clear view of Mammoth Mountain (el. 11,053') and the Minarets (el. 13,000'+) in the distance, deer and jackrabbits in the meadow, eagles and other raptors above and the gurgle of a crystal-clear stream at your feet.

Riverkeeper Cabins Location Rates
Email
The Mammoth Web
Eastern Sierra Overview
Mammoth Visitor Center

Hot Creek Ranch.

Come fish with us.

Hot Creek Ranch
Route 1, Box 206
Mammoth Lakes, CA 93546
Phone (760) 924-5637

Mammoth WebPage Mammoth WebPage Mammoth

Hot Tubbing

Sitting around in hot water with a bunch of strangers is an age old tradition in the Mammoth area. People talk of wild things down at Hot Creek in the 60's and 70's. Well, Hot Creek has cleaned up it's act, with the help of the Forest Service, and now it is a great place to take the kids or just go and relax after doing too much of some physical activity. There are also a number of other natural and man-assisted hot tubs in the valley below Mammoth. Some are well know and some aren't. We will tell you about the well known ones and let you find out about the others on your own. Most are small, so when 50 people show up it isn't as much fun. Hint...almost all of the tubs are described in a guide book, so they aren't really hidden or secret. But we like to maintain that illusion.

We ought to mention one thing, first -- you can hot tub in rocks, or in redwood. If a freshly cleaned redwood tub filled with hot mineral water sounds nice -- an affordable luxury -- check out the hot tubs at the Old House at Benton, outside Bishop.

Hot tub etiquette
Yes you can get a ticket for tubbing naked. But most of the hot tubs are isolated and private, so most people don't wear anything while bathing. Some of the tubs, like Hilltop, are popular, and considered open whether occupied or not. Some are considered private spots and if occupied you might want to wait your turn. Usually your intuition will guide you properly. If you don't feel comfortable taking it off in front of others, don't. If you do, and it feels okay, do. Just be nice, considerate, and circumspect. There is nothing better for the soul than to lie naked by yourself in a natural hot tub surrounded by the aura of nature. Unless it is to lie naked in a tub with 6 naked German guy or girl tourists. Please take care of the tubs, don't be a putz, and take your trash out with you. There are several anonymous locals who spend a lot of time keeping the tubs clean and functioning for all of us. Help them out.

Hot Creek
The grand daddy of them all. In the 60's this was really a party place during the nighttime. You will meet a lot of people in Mammoth who can tell stories about happenings. Well, all *good* things end. Now Hot Creek is managed by the Forest Service to provide a safe family type experience. But it is still one of the best places to go. Two large pools sitting in the middle of Hot Creek creek are fed hot water by subsurface magma three miles below the surface. There are bathrooms and changing facilities here, along with a paved parking lot. Only open during the daylight hours these days, you can get a ticket for going naked here, and most people wear suits. This is a great X-Country ski trip during the winter when there is enough snow on the ground. Take HWY south about 2 miles to the left turn exit marked Hot Creek/Airport. Follow the signs. About 2 miles of the road is gravel graded suitable for passenger cars. Look for the paved parking area on the left.

Hilltop Tub
This is probably the best known, most popular tub site. Accessible in the winter by walking 300 yards, in the summer you can drive almost right up to the tub. This tub isn't private. If you are in it, expect company. The tub is about seven feet in diameter and about two feet deep, manmade fed by a nearby hot water source. Probably the best view in the valley, you sit on a small hilltop with a 360 degree view of THE WORLD. You will run into a lot of locals and a lot of tourists here. Take HWY 395 south to Benton Crossing Road. Turn left at the green church and go about 2.5 miles, past two cattle guard crossings. Just past the second cattle guard you will go down a moderate hill, at the bottom of the hill turn left onto a dirt road and follow it, staying to the right, for about 300 yards to a well marked dirt parking area. The tub is just about 100 feet on top of the small hill in front of you.

Wild Willy's
Another popular well known site. This one has two manmade sitting areas on different branches of a natural creek, so if one is occupied and you are shy, use the other. The views aren't as nice as Hilltop, but so what. To get there drive towards Hilltop as noted above, but just past the second cattle guard turn right on the dirt road. Follow it for about a mile, staying to the left until you reach a well marked parking area. Then on foot follow the obvious trail for about 200 yards to the tubs. This also is not regarded as private, and you may have company at times.

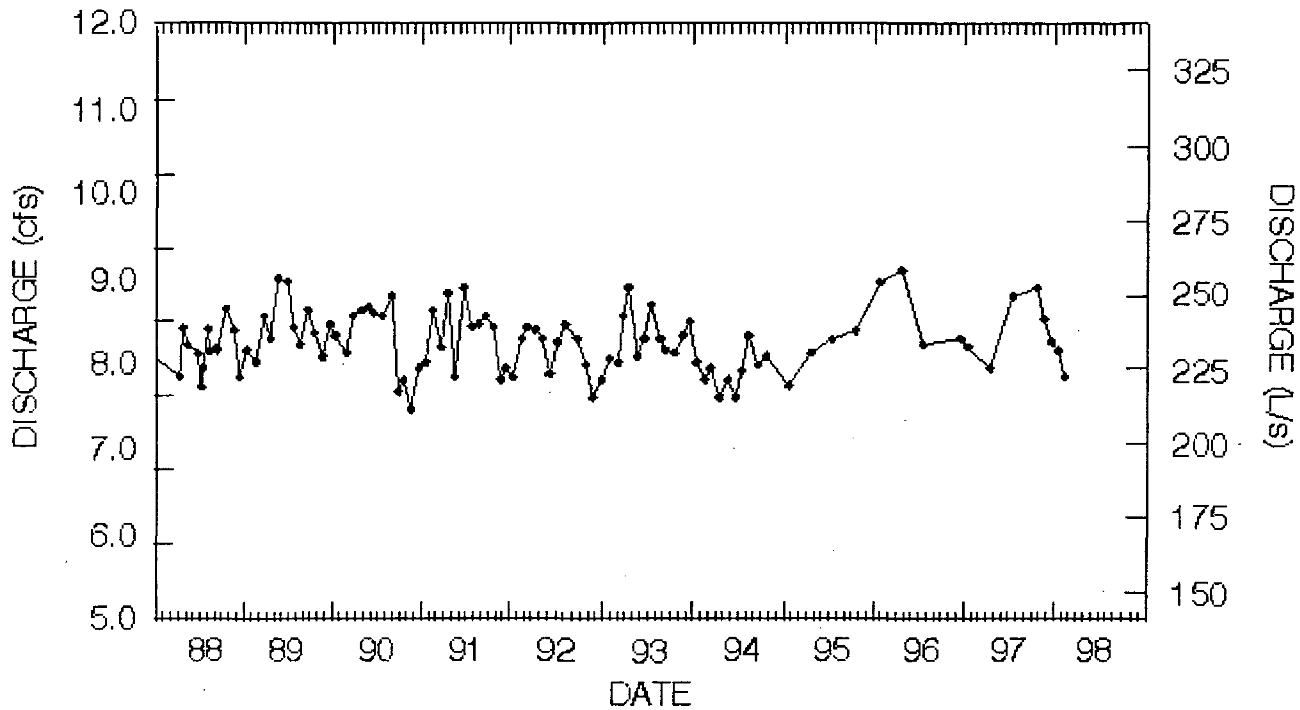
Crab Cooker
This is called the crab cooker because it sometimes is hot enough to do just that. This is more of a private tub, most people won't approach when they see it occupied. Smaller and shallow, and sometimes not working well, but nice place when it is. You will need a map to find it, so get the guide book. Take Benton Crossing Road again but turn left at the wide dirt road just past the baseball fields, follow that dirt road for about a mile. The tubs are along one of the dirt roads off the right side, follow one or the other until you find it. There are actually several in this area, some good and most not. You have found the Crab Cooker when you find one at the END of a dirt road in a small valley.

BACK to the VISITORS GUIDE

U.S GEOLOGICAL SURVEY
VOLCANO HAZARDS PROGRAM

U.S. Geological Survey
Earth Science in the Public Service

Hot Creek Gorge Hot Springs



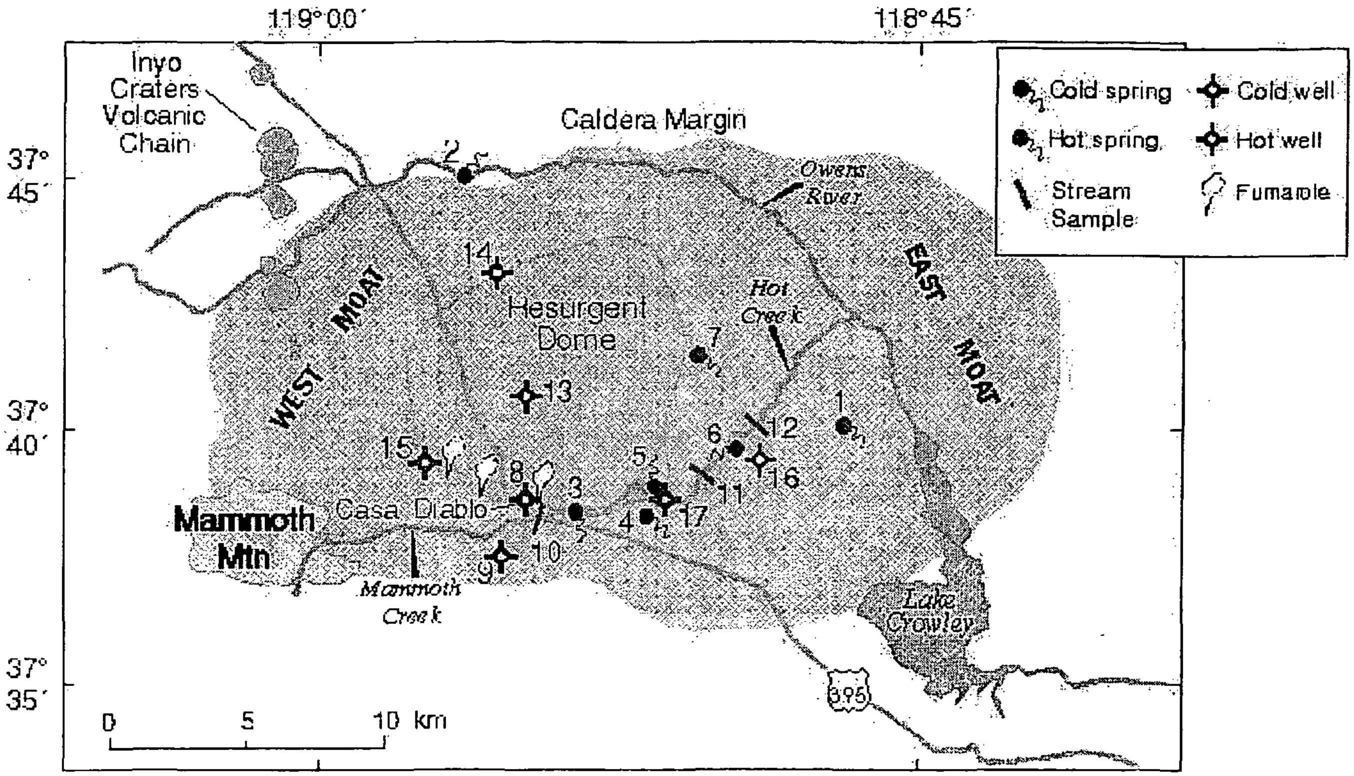
The total thermal-water discharge in Hot Creek gorge (feature #6) is calculated using periodic measurements of stream discharge and the average concentrations of chloride and boron at sites upstream (HCA - feature #11) and downstream (HCF - feature #12) from the area where the hot springs discharge into the creek. The streamflow and chemical concentrations are multiplied together to produce values for chemical flux at both the upstream and downstream sites. The difference in flux between sites, divided by the concentration of Cl and B in the hot spring waters (220 mg/L and 10 mg/L, respectively) yields estimates of total thermal-water input.

Most of the short-term variability in the hot-spring discharge data results from the level of precision (+/- 10%) in measurements of streamflow, integrated sampling, and chemical analysis. Given this uncertainty, it is difficult to discern any actual changes in total thermal-water dicharge from 1988-1997. This is also true for the recent period of unrest in 1997. Visual observations did, however, show significant changes in flow of some hot-spring vents associated with seismic events in the south moat during the fall of 1997.

Return to Long Valley Caldera homepage
USGS Home Page
USGS Water Resources Headquarters

Last modified: March 4, 1998

Selected Hydrologic Features in Long Valley caldera



Map of Long Valley caldera showing locations of selected USGS hydrologic monitoring sites, the geothermal well field at Casa Diablo, and various geologic features referred to in the text. Numbered sites are described in the table below, which lists the maximum temperature in wells or the vent temperature in springs. The geologic features include Mammoth Mountain (the site of anomalous gas discharge that is killing trees), the Resurgent Dome (a highland region formed by repeated volcanic eruptions and magmatic uplift following the initial formation of the caldera 760,000 years ago), and the Inyo Craters Volcanic Chain consisting of numerous volcanic domes and phreatic craters that have erupted repeatedly over the past 10,000 years or so.

Number on map	Site Name	Site Description	Temperature (Celsius)
1	**Big Alkali Spring**	Hot Spring near Big Alkali Lake	57
2	**Big Springs**	Cold springs along Owens River	11
3	**Colton Spring**	Hot spring activated by earthquakes in the 1980's, but ceasing to flow in 1991 as a result of pressure declines from geothermal development	93
4	**Fish Hatchery Springs**	Four groups of spring vents; water used for fish rearing operations	11-18
5	**Hot Bubbling Pool**	Hot pool with no surface discharge; fed by hot springs at temperatures of 93 C	~70
6	**Hot Creek gorge Springs**	Numerous hot springs in and adjacent to a ~1 km long reach of Hot Creek	93
7	**Little Hot Creek Springs**	Numerous hot springs that feed into Little Hot Creek	~80
8	**Well MBP-3**	Geothermal production well at Casa Diablo	161
9	**Wells SC-1, SC-2**	Wells near Sherwin Creek Campground	17
10	**Mammoth Creek at Hwy 395**	Site for chemical sampling and discharge measurements	17
11	**Hot Creek above gorge**	Site for chemical sampling and discharge measurements	~15
12	**Hot Creek at Flume**	Site for chemical sampling and discharge measurements	~35
13	**LVEW**	Site of Long Valley Exploration Well and adjacent water-supply well (SF) used for continuous pressure monitoring	100
14	**LKT Well**	Well near Lookout Mountain used for continuous pressure monitoring	--
15	**RDO-8**	Well near Shady Rest Campground used for continuous pressure monitoring	202
16	**CH10-B Well**	Well near Hot Creek Gorge used for continuous pressure monitoring	95
17	**CW-3**	Chance Well #3 near Hot Bubbling Pool	120

Return to Hydrologic Studies page
Return to Long Valley Caldera home page

Last modified: Feb 12, 1998

Dams Within Jurisdiction of the State of California

Department of Water Resources
Bulletin 17
June 1993

DWR Bulletin 17 provides information about 1395 dams within the jurisdiction of the State of California. The bulk of the printed bulletin is a single multi-page table with one three-line entry for each dam. The information from this table was extracted using document image decoders that were specialized for the actual character shapes in the scanned document images. No attempt was made to correct the OCR errors; thus, for example, several obvious errors appear in the list of county names below. Primary access to the on-line table is via a database query interface. In addition, a number of simple groupings are provided below, such as by county or the first letter of the dam name.

- Click *here* to access a database query form.
- Click on one of the groups below to access an alphabetical listing of dams within that group.
- Click on particular page:

Comments and suggestions are welcome at www@elib.cs.berkeley.edu

---

Dams Grouped by First Letter of Name

1 3 4 A B C D E F G H I J K L M N O P Q R S T U V W Y

Dams Grouped by County

- ALAMEDA
- ALPINE
- AMADOR
- BUTTE
- CALAVERAS
- COLUSA
- CONTRA COSTA

- EL DORADO
- FRESNO
- GLENN
- HUMBOLDT
- IMPERIAL
- INYO
- KERN
- KINGS
- LAKE
- LASSEN
- LOS ANGELES
- MADERA
- MARIN
- MARIPOSA
- MEHDOCINO
- MENDOCINO
- MERCED
- MODOC
- MONO
- MONTEREY
- NAPA
- NEVADA
- ORANGE
- PLACER
- PLUMAS
- RIVERSIDE
- SACRAMENTO
- SAH DIEGO
- SAHTA CLARA
- SAN BENITO
- SAN BERNARDINO
- SAN DIEGO
- SAN FRANCISCO
- SAN JOAQUIN
- SAN LUIS OBISPO
- SAN MATEO
- SANTA BARBARA
- SANTA CLARA
- SANTA CRUZ
- SHASTA
- SIERRA
- SISKIYOU
- SOLANO
- SONOMA
- STANISLAUS
- SUTTER
- TEHAMA
- TRINITY
- TULARE
- TUOLUMNE

- VENTURA
- YOLO
- YUBA

Last modified 02/02/1996 10:25:02

Tinemaha

Page 70 OCR 70 Inyo Cty 'T' dams Photo? Bulletin 17

General Information

Name	DWR Number	National ID	Owner	Year Completed
TINEMAHA	6-026	CA00084	CITY OF LOS ANGELES	1928

Location Information

County	Latitude	Longitude	Crest Elevation	Stream
INYO	37 d, 3.5 m	118 d, 13.5 m	3882.0 ft 1183.2 m	OWENS RIVER
Baseline / Meridian MD	**Section** 25	**Township** 10S	**Range** 34E	

Dam Characteristics

Dam Type	Parapet Type	Crest Length	Total Freeboard	Height
ERTH	none	5800 ft 1768 m	9.5 ft 2.9 m	32 ft 10 m
Material Volume 495900 cu yd 379140 cu m	**Parapet Height** ? ?	**Crest Width** 43 ft 13 m	**Operating Freeboard** ? ?	

Reservoir Characteristics

Storage Capacity	Drainage Area	Reservoir Area
16405 acre-ft 20235 sq dm	1915.0 sq mi 4959.85 sq km	2098 acre 849 hect

Hydrologic Data for Long Valley Caldera, Mono County, California, 1987-93

U.S. Geological Survey
Open-File Report 96-382

James F. Howle
Christopher D. Farrar

Sacramento, 1996

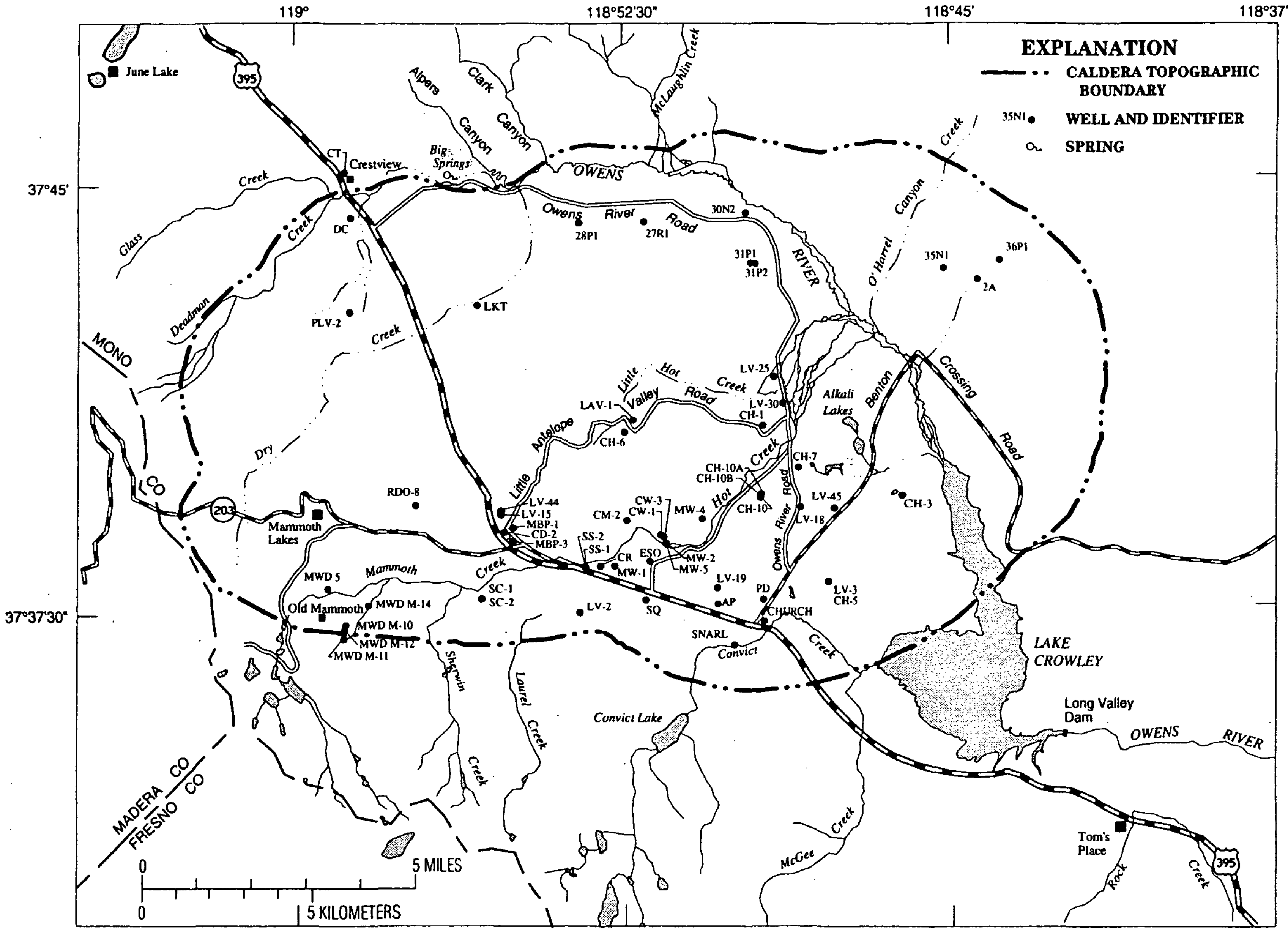


Figure 3. Locations of wells, Long Valley Caldera, Mono County, California.

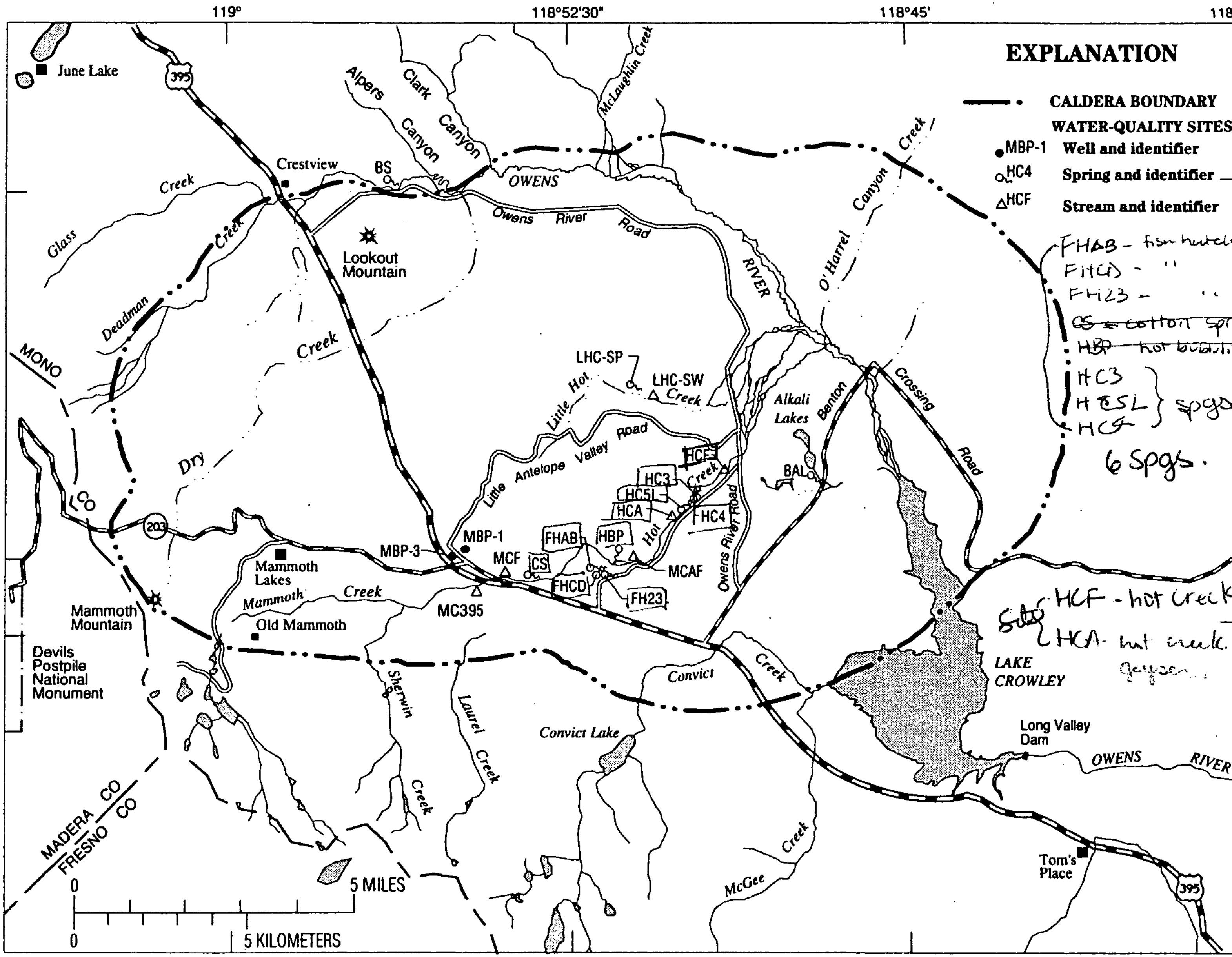


Figure 52. Locations of water-quality sampling sites, Long Valley Caldera, Mono County, California.

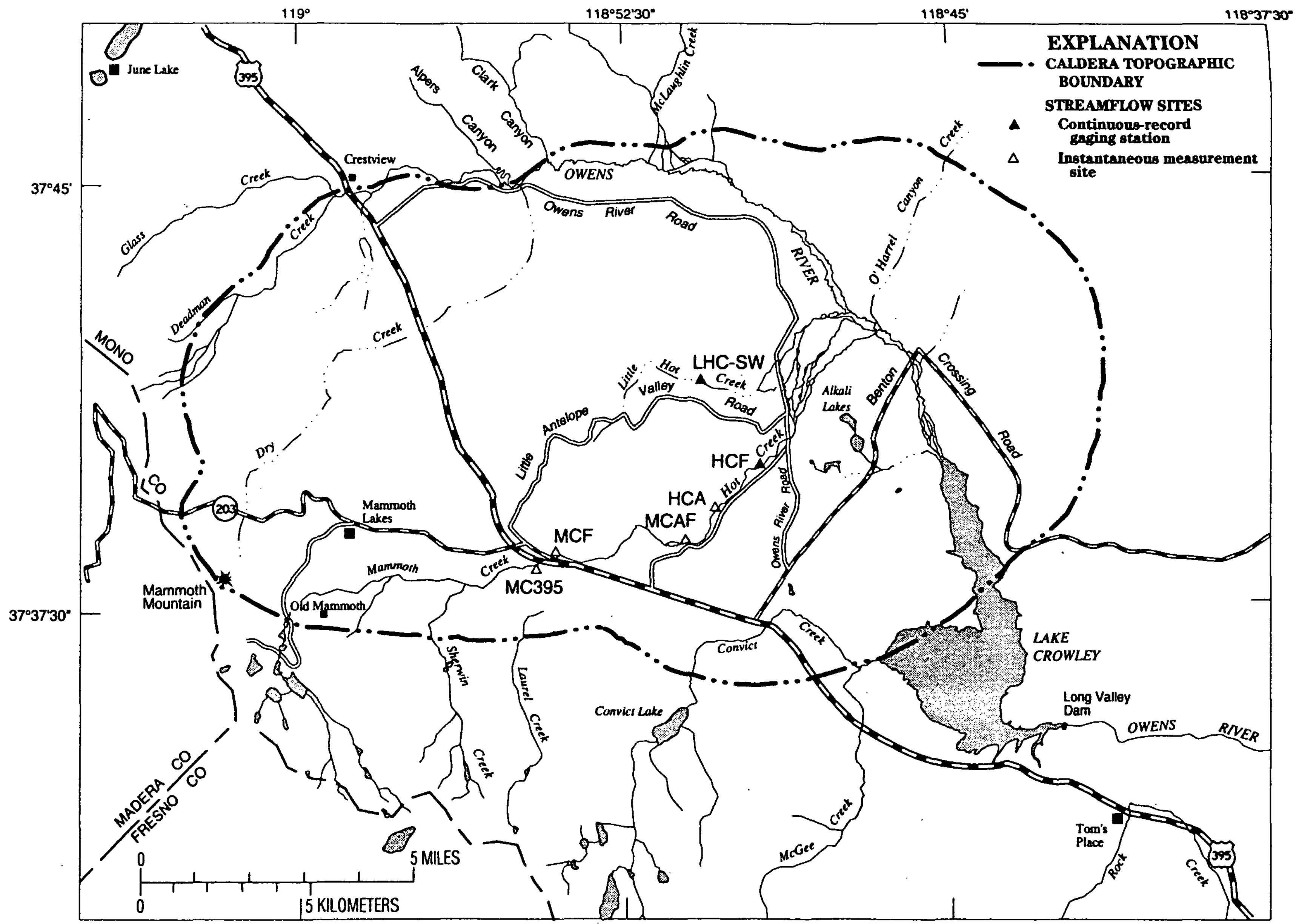


Figure 39. Locations of streamflow sites, Long Valley Caldera, Mono County, California.

P1

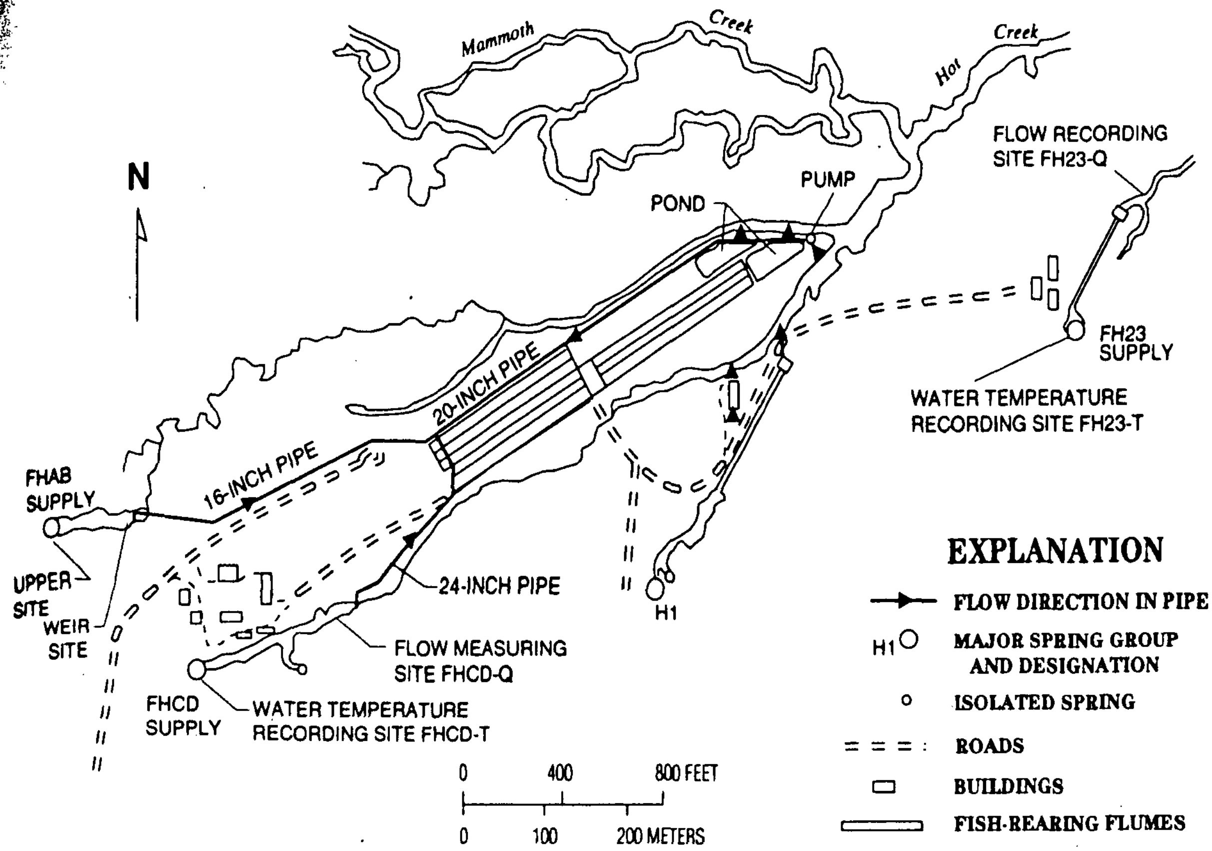


Figure 23. Locations of data-collection sites at Hot Creek Fish Hatchery, Long Valley Caldera, Mono County, California.

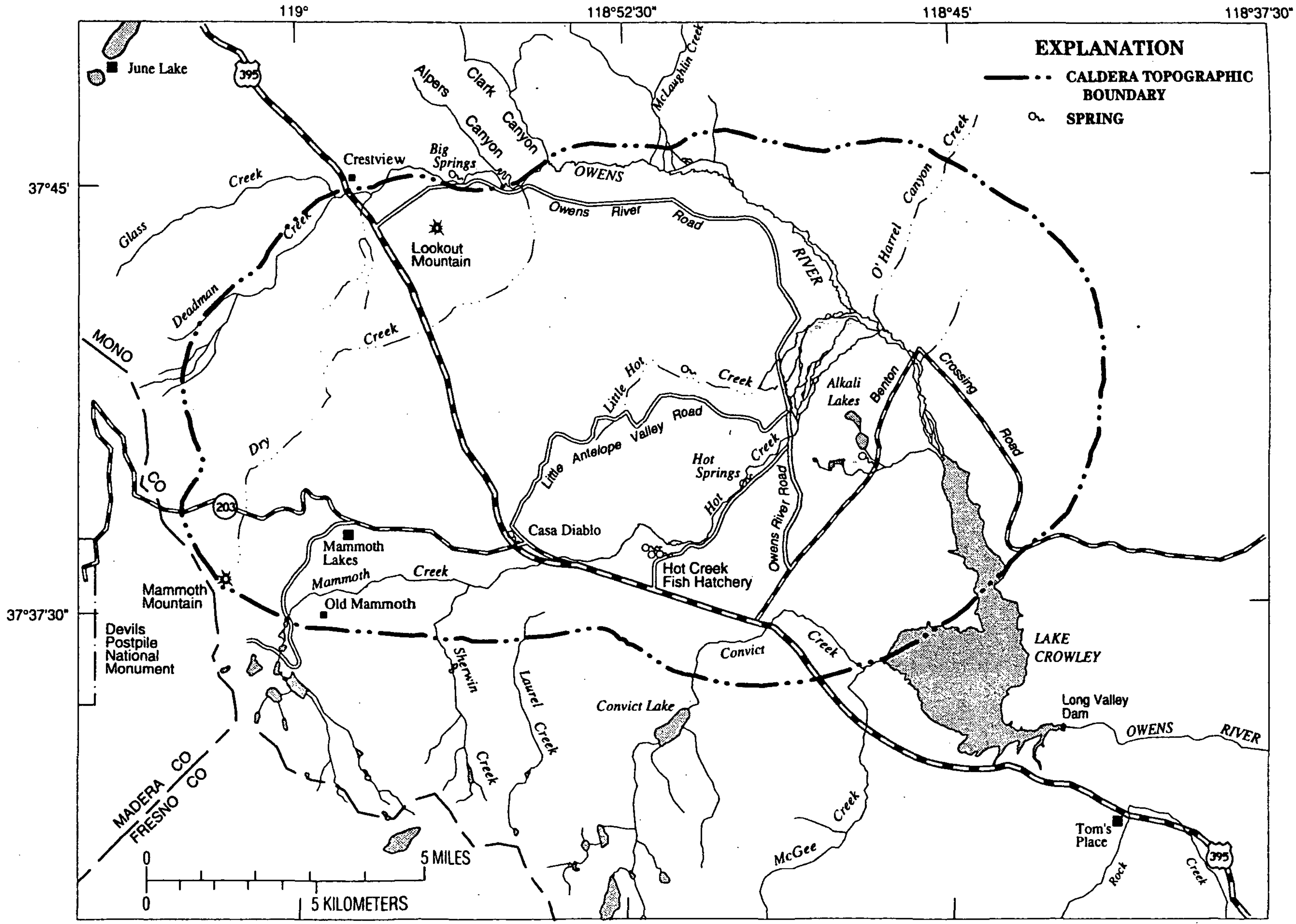


Figure 2. Key geographic features of Long Valley Caldera, Mono County, California.

TABLES

Hydrologic Data for Long Valley Caldera, Mono County, California, 1987–93

By James F. Howle *and* Christopher D. Farrar

Abstract

Hydrologic data were collected during 1987–93 as part of the U.S. Geological Survey's long-term Volcanic Hazards Monitoring Program of the Long Valley Caldera, Mono County, California. The data are presented in graphs or tables. Data collected for the Long Valley Hydrologic Advisory Committee monitoring program also are presented. Hydrologic data collected include continuous record of ground-water levels in 6 wells, instantaneous measurement of ground-water levels in 55 wells, continuous record of discharge at 2 streams and 5 springs, instantaneous discharge measurements at 4 streams and 2 springs, ground-water temperature profiles of 3 thermal wells, continuous record of water temperature in 1 stream and 5 springs, vent gas temperatures at 2 fumaroles, and chemical and isotopic analyses of water samples collected at 13 ground-water and 6 surface-water sites. Precipitation amounts at three sites also are included. A diskette of data tables is provided.

INTRODUCTION

Long Valley Caldera (fig. 1) is a site of geologically recent volcanism (Bailey, 1989). The high rates of seismicity and crustal deformation recorded in Long Valley Caldera since 1980 probably are related to magmatic intrusions (Rundle and Hill, 1988). The volcanic history and recent crustal unrest have been the motivation for the U.S. Geological Survey and other agencies to monitor a number of geologic and geophysical parameters to assess the potential of volcanic eruption in the near term (Hill and others, 1991).

The volcanic activity has provided heat for a hydrothermal system that underlies the western, southern, and eastern parts of Long Valley Caldera. Ground-water temperatures greater than 200 °C have been measured in the western part of the caldera. Flow in the hydrothermal system is from west to east along the hydraulic gradient (Sorey and others, 1991). Thermal springs located in the southern and eastern parts of the caldera are natural discharge points for the hydrothermal system.

The thermal springs provide unique environments for wildlife and plants and are used for recreational bathing by thousands of tourists each year. The largest direct use of geothermal resources in the study area is at the Hot Creek Fish Hatchery (fig. 2), operated by the State of California since 1932. The hatchery uses between 15 and 25 ft^3/s of water from low-temperature (15–20 °C) thermal springs for raising trout. Use of geothermal resources for electric power generation began in 1985. By 1992, power production totaled about 40 megawatts from three plants located at Casa Diablo (fig. 2).

Purpose and Scope

This report provides a compilation of hydrologic data collected in Long Valley Caldera by the U.S. Geological Survey during 1987–93. Data collected for both the volcanic hazards monitoring program and the LVHAC are presented in this report. The data include ground-water levels; discharge measurements; water temperatures in wells, streams, and springs; vent gas temperatures; precipitation amounts; and chemical and isotopic analyses of water samples collected at selected sites. Hydrologic records for most of the monitoring sites span a few years and in some cases span the entire 7-year period. In many cases, these multi-year records indicate annual cycles and long-term trends.

Although no interpretations of the data are provided in this report, the data will be useful to researchers who may want to relate hydrologic changes to geodetic and geophysical measurements collected during the study of volcanic and seismic processes active during recent years. The report also provides a summary of hydrologic data relevant to some of the environmental concerns of local, State, and Federal agencies, as well as individuals.

Previous Reports

Hydrologic data from the volcanic hazards monitoring program for years prior to 1987 have been published in reports by Farrar and others (1985; 1987; 1989). Other significant data compilations include: California Department of Water Resources (1967; 1973), Lewis (1974), Willey and others (1974), Mariner and Willey (1976), and Setmire (1984). In addition, the U.S. Forest Service has published annual reports containing hydrologic data for 1980 through 1985.

Report Format

The data tables and figures in this report are grouped by site type (wells, springs, streams, fumaroles, and precipitation gages) and are further subdivided into nonthermal or thermal within the groups for wells and springs. Individual maps show the locations of sites by site type.

The presentation of data differs according to site type and the level of variability of the data over the collection period. In general, each graph is followed by the table of data used to construct the graph. For sites with several years of record and where the variability of data is great, graphs for individual years are provided in addition to the multi-year graphs.

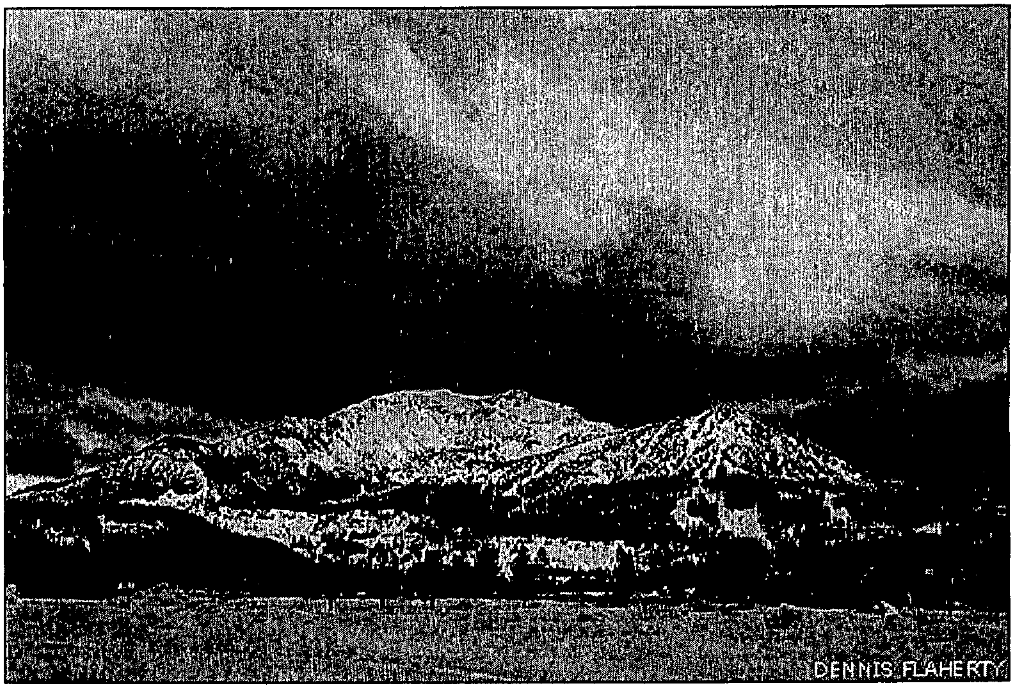
Each site has been assigned a short alpha or alphanumeric identifier that is used in figures and tables. Table 1 lists all sites, grouped by site type, and provides the U.S. Geological Survey station identifier, station number, latitude, longitude, altitude, and information about the data presented in this report.

A high density, 1.4 Megabyte, 3-1/2-in. diskette containing ASCII files of the data tables is included at the back of the report. The files on the diskette are labeled to match the table numbers in the report.

Acknowledgments

The cooperation of many well owners and landowners in allowing access to collect data is greatly appreciated. Thom Heller, U.S. Forest Service, provided the precipitation data for the Mammoth Ranger Station gage. Gary Sisson was especially helpful in providing information and access to some of the Mammoth Community Water District wells. Donald Barnett, Intermountain Water Consultants, provided water-level data for well CW-3 for 1988–91. Chris Boone and Dennis Redfern, California Department of Fish and Game, cooperated in many ways that assisted data collection at Hot Creek Fish Hatchery.

MAMMOTH'S PERILOUS MAGMA - NO SHORT ANSWERS TO EARTH-SHAKING QUESTIONS AT LONG VALLEY CALDERA



Towering 11,000 feet at the summit, Mammoth Mountain dominates the southwest corner of Long Valley Caldera. Eruptions formed this volcano between 200,000 and 50,000 years ago, but it could erupt again. In the meantime, earthquakes frequently rattle the region.

Eleven years ago, Horseshoe Lake in the eastern Sierra Nevada was a splendid place to camp. Families staked tents under the shady boughs of lodgepole pine, mountain hemlock, and red fir. Swimmers splashed in the sparkling blue water and sunbathed on the pumice beach, soft as sand. Children tossed peanuts to squirrels. At night, smoke from campfires curled up to the stars.

Today, Horseshoe Lake is a quiet place. Its trees are dead. Its Forest Service campground is closed. "Danger" signs warn children and dogs to stay away. The lake, still a sparkling blue, is considered hazardous for swimmers. No deer nibble here, no squirrels scamper, no birds chirp. The most common sound at Horseshoe Lake is an occasional wind whistling through spindly branches.

When I visited Horseshoe Lake one August weekend, it seemed at first that a small forest fire had swept through. Or a beetle infestation. Or maybe a drought. But as I walked among the dead conifers, I noticed that their hunched profiles told a different story. Their weathered silhouettes all slumped downslope, branches pointing to the earth, as though accusing their assassin.

Indeed, the earth at Horseshoe Lake is saturated with so much carbon dioxide (CO_2) that a couple of whiffs in a hole there could make a person dizzy - and a few more could kill. In early 1990, U.S. Forest Service ranger Fred Richter almost died when he entered a ski hut at Horseshoe Lake to escape a snowstorm. He had rested in the same hut only two months earlier without any problem. But in March, as he climbed down into the snow-buried hut from a ladder on the ceiling, he became dizzy and would have lost consciousness if he hadnt managed to climb back out.

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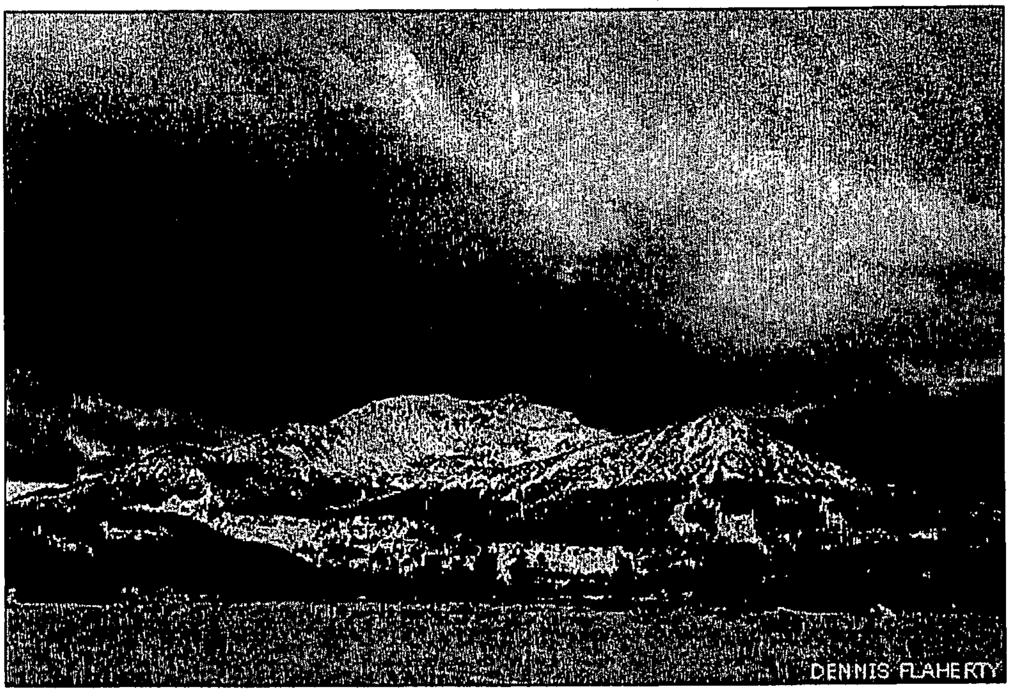

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"Thats how we know when the CO_2 reached the surface," said Mike Sorey, a hydrologist with the U.S. Geological Survey (usgs). "The difference in the huts air between January and March."

At the time of Richters visit, Horseshoe Lakes trees were still green. No one thought the lake had a problem, and Richters near-suffocation went unnoticed. It was only after the conifers started dying over the next few years - and drought and beetle infestations were ruled out - that the usgs started testing the ground for emissions. In 1994, a soil sample taken at Horseshoe Lake confirmed that lethal doses of CO_2 were seeping from an underground source. Heavier than air, the odorless, colorless gas was concentrating near the ground, becoming trapped under snowbanks as well as in buildings like the ski hut. Even in the open forest in summer, the gas was concentrated enough to asphyxiate the conifers by interrupting their roots ability to take in oxygen and nutrients from the soil. Sorey and his co-workers determined that if a tree sank its roots deeper than two feet, it encountered lethal levels of CO_2 - about 30 percent or higher.

Nothing like this had happened at Horseshoe Lake before - at least for a couple of centuries, given that some of the dying trees were 250 years old. In the next few years, several trees crashed to the ground, and birds and rodents were found asphyxiated in tree wells. Gas samples taken from shallow depressions dug into the ground contained almost 90 percent CO_2.

Carbon dioxide escaping from trapped underground magma killed 170 acres of trees at Horseshoe Lake on the south side of Mammoth Mountain. Most of the trees that have died from this degassing fringe the mountain's flanks, indicating that a mammoth reservoir of potentially lethal gas underlies the volcano.

After identifying the poisonous gas, it didnt take usgs scientists long to solve the mystery of its source: magma.

During 1989, less than a year before Richters near-asphyxiation, Horseshoe Lake and nearby Mammoth Mountain were shaken for six months by swarms of small earthquakes - a sign of moving magma. The molten basalt, rich in CO_2, rose into Mammoth Mountain to roughly one mile below the surface.

"When the magma was injected, it probably opened cracks which allowed the CO_2 to escape to the surface," according to Sorey. By 1995, the magmas gas had killed roughly 100 acres of trees at Horseshoe Lake as well as at five other sites on the mountain. Chemically the same at all sites, the gas was also discovered in effervescent cold springs and steaming fumaroles on the 11,053-foot volcano.

Sorey believes that "the fact that the same kind of gas has been emitted all over Mammoth Mountain for a decade means there is a very large reservoir underneath the volcano." Although it first appeared that the 1989 magma was the sole source, Sorey and other usgs researchers now speculate that the gas must be from a larger, older, and deeper source. The gas reservoir

- located roughly one mile below Mammoths surface - could be from a previous intrusion of magma whose CO_2 was trapped for centuries and is now being replenished from new magma still degassing.

Carbon dioxide emissions from magma have been observed on the flanks of other volcanoes such as Vulcano and Etna in Italy. What is strange at Mammoth is the prodigious quantity of gas without any accompanying eruption. The widespread tree kill is also unusual and has been seen in only a few places around the world.

Although the emissions have decreased slightly from their peak in the early 1990s, Mammoth Mountain still fumes daily with 300 tons of CO_2. Sorey anticipates that the gas will continue to seep, probably for many more years. Having monitored Mammoth Mountain for the last decade, he often peppers his statements with adverbs like "probably." He knows only too well that the dormant volcano is tucked into a sprawling volcanic complex known as Long Valley - where, geologically speaking, there are no short answers.

Signs on the shore of Horseshoe Lake warn visitors of an invisible danger at a once-popular campsite. The gas first bubbled to the surface in 1990, discovered when a forest ranger nearly passed out after taking shelter in a ski hut.

As I discovered during my weekend there, Long Valley Caldera is aptly named. Calderas are craters formed by the collapse of volcanoes. This one is 20 miles long and ten miles wide. Its topographical contours are astounding, with spectacular 10,000-foot Sierran peaks along its western rim and a low, sagebrush-dotted plateau on its floor. It was created 760,000 years ago when a gigantic eruption blew ash as far east as Nebraska and caused the earth to collapse a mile deep. The eruption, which sent magma gushing over the Sierra Nevada and down the San Joaquin River, is believed to have been one of the largest ever in North America.

More impressive yet, the caldera lies in the middle of an even greater volcanic region, known as the Long Valley/Mono-Inyo Volcanic Field. In his book *Fire Mountains of the West*, author Stephen Harris calls the region "Californias potentially most dangerous volcanic field." Bordered by the eastern slope of the Sierra, this volcanically restless area begins at Mono Lake and spreads 25 miles south past the town of Mammoth Lakes. Its eruptive landmarks include the Long Valley Caldera, framed by Glass Mountain on the northeast, and a 400,000-year-old volcanic chain called the Mono-Inyo Craters. Beginning as islands in the alkaline waters of Mono Lake, the Mono-Inyo chain ends at Mammoth Mountain, which has erupted frequently for 40,000 years and whose most recent eruption was 600 years ago.

The Long Valley region exhibits all the classic symptoms of geologic unrest: pent-up magma, earthquakes, and gas. In addition to magma-rich Mammoth Mountain, the Inyo Craters - known for explosive blasts - have magma bodies beneath them. These craters have erupted regularly every 200 to 700 years for millennia, and their last eruption was 600 years ago. The

Long Valley Caldera itself is swelling ominously as magma rises beneath its floor. The 100-square-mile-wide uplift was first noticed in 1980 when the caldera was rocked by four magnitude 6.0 earthquakes from May 25 to 27. Since then, Long Valleys "resurgent dome" - as it is scientifically termed - has risen almost three feet and continues to rise about an inch a year.

For someone like me, who lived through the May 18, 1980 eruption of Mount St. Helens, there are so many signs of restless earth at Long Valley that its hard not to wonder when the next eruption is going to blast everything to smithereens. Gas emissions, ground swelling, and earthquakes all preceded Mount St. Helenss eruption. Back then, no one but a few wary geologists thought the mountain was going to blow.

From icy and clear water near Horseshoe Lake, Mammoth Creek merges with sulfurous hot springs to form Hot Creek, a gorge full of boiling pools and baked boulders.

But Long Valley is not a small, young Cascade volcano with a predictable eruptive profile. It is an old, huge, and volcanically complicated region that has been active for four million years. In her 1902 work, *The Land of Little Rain*, Mary Austin described Long Valley as a "mysterious country" where "a hidden force works mischief, mole-like, under the crust of the earth." Even then, a century ago, it was obvious to Austin and her contemporaries that the ground was moving in elusive and monumental ways. She writes:

Whatever agency is at work in that neighborhood, and it is popularly supposed to be the devil, it changes means and direction without time or season. It creeps up whole hillsides with insidious heat, unguessed at until one notes the pine woods dying at the top, and having scorched out a good block of timber returns to steam and spout in caked, forgotten crevices of years before.

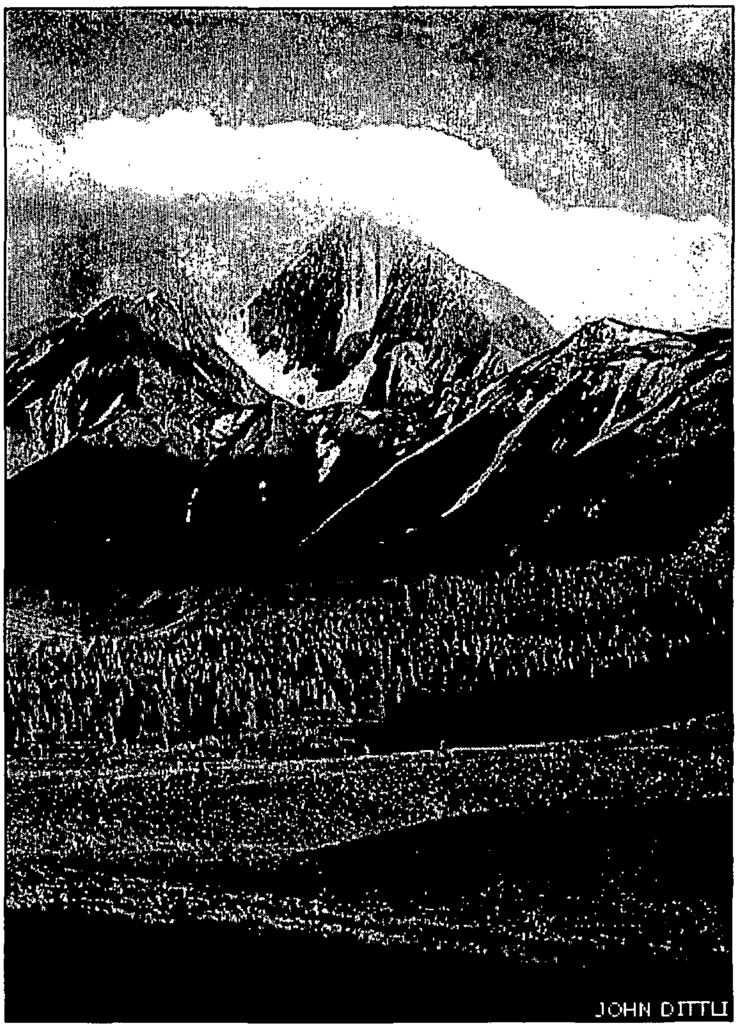
Austins passage sounds eerily prescient about Horseshoe Lakes dead trees. But she was describing another aptly named place in Long Valley: Hot Creek.

After horseshoe lake i headed to Hot Creek. I descended north and east out of the shady, steep Sierra and found myself on an open, unpaved road winding gently through sagebrush, manzanita, and juniper. Great expanses of sky engulfed the car, and the desert heat made me rifle around for a water bottle. Puffy cumuli peppered the caldera floor with fleeting shadows. I parked on a pumice-sprinkled cliff overlooking a small gorge. Down below, steaming and bubbling around rocks and algal mats, flowed Hot Creek.

A long-time favorite among hot-springs enthusiasts, Hot Creek gurgles and geysers its way straight through the caldera. The creek begins near Horseshoe Lake as Mammoth Creek, where it runs icy and clear. Then, as it flows northeast it merges with hot springs to form a sulfurous, gassy gorge full of milky-blue pools and baked boulders. Not far from its banks lies the Casa Diablo geothermal plant, which transforms Long Valleys heat into electricity. At Casa Diablo, acres of conifers have also died, due to acid poisoning and heat.

The afternoon I visited Hot Creek, swimmers lounged in pools just beyond the "Danger Keep Out" signs. Since 1968, more than a dozen people and four dogs have drowned here or been scalded to death. Like Horseshoe Lake, Hot Creek lies inside the Inyo National Forest and is managed by the Forest Service. Both sites are posted but not policed. As with Horseshoe Lake - where a crosscountry skier died in 1998 possibly from CO_2 asphyxiation - Hot Creek is both scenic and sinister, natural and unnatural. Mountain bikers cruise along fire roads near Horseshoe Lake, and bathers soak in Hot Creek - both lured to Long Valley not for volcanisms sake, as at Mount St. Helens or Hawaii, but for the recreation volcanism has created. I didnt envy the Forest Service its job.

I bent down and stuck my hand in the creek. The currents swirled around it - sometimes burning hot, sometimes icy cold. The erratic temperatures seemed to sum up precisely the regions volcanism. Maybe Hot Creek will scald another swimmer to death tomorrow. Or maybe not. Maybe Long Valleys resurgent dome will explode with billions of gallons of magma next month. Or maybe not. Maybe a magnitude 7.5 earthquake will rip through the earth next year, and a heavy wave of carbon dioxide gas will surge out of the ground to strangle the 5,000 residents of Mammoth Lakes. Or maybe not.



A forest of Jeffery pines marks part of the resurgent dome of magma that rises from the center of Long Valley Caldera. The dome reaches some 1,500 feet above the caldera floor and extends more than five miles in diameter. Between the swelling dome and quaking Mammoth Mountain lies the booming town of Mammoth Lakes.

Cold, hot, cold, hot. I withdrew my hand and started back up the paved walkway to escape the nauseating odor of rotten-egg sulfur rising from scoured pits along the bank. As I topped the canyon, I passed a man on his way down with a T-shirt that read "faultline." I asked him if he thought there would be an eruption at Long Valley any time soon.

"Nah," he said, rolling his eyes. "I wish. Then it wouldnt be so crowded."

But talk to usgs seismologist David Hill and you might hear a different response. As scientist-in-charge at Long Valley, Hill shares the generally accepted view among geologists that Long Valley marks an area of crustal stretching - where the Earths crust is spreading. The stretching is occurring as the Sierra Nevada Range tilts up and westward about an inch a year, as it has been doing for millions of years. "As the crust stretches, it sucks up magma," according to Hill. In this process, eruptions are inevitable.

Nonetheless, Hill chooses his words carefully when he talks about future eruptions at Long Valley. Having overseen the monitoring of the region since 1982, Hill can still remember when geologists were *personae non gratae* in the early 1980s due to a usgs hazard alert that angered residents of Mammoth Lakes, which depends heavily on tourists. It took county and city officials several years - and a few earthquakes - to understand the precarious position in which the Survey stood. Either it could do nothing and risk criticism, or issue an alert and risk criticism.

Eventually, residents recognized that they were living on top of a swelling caldera. In 1983, after another earthquake swarm, an escape route was built out of Mammoth Lakes when officials realized that the town had only one road connecting it to Highway 395. But then the seismicity decreased, and the escape route was signposted as the "Mammoth Scenic Loop." There is nothing particularly scenic about the six-mile-long road, except perhaps the Jeffrey pines that shade it.

But the euphemism used for the evacuation route attests to the power of tourism at Mammoth Lakes, where the winter population swells to 40,000 skiers, mostly from southern California. Snowy, sunny, and scenic, Mammoth Lakes is enjoying a tourism boom that is expected to intensify over the next decade. As one real-estate brochure claims, "Mammoth Real Estate is *HOT*." Vacant lots in Mammoth Lakes have doubled in price in the last year, according to Mike Vance of the Mammoth Lakes Visitors Bureau. The local airport and college are expanding. And Mammoth Mountain - a major ski resort - is being aggressively developed and marketed by Intrawest, a multinational corporation that plans to invest $700 million there over the next decade. Vacation homes are sprouting around Mammoth Mountain as fast as summer wildflowers. New lodges are being erected even as CO_2 emissions have crept into some ski areas on the mountains slopes.

Amidst the real-estate buzz, Hill and a team of usgs scientists keep a close watch on each of Long Valleys puffs, swells, and quivers. On Mammoth Mountain, Sorey and others constantly monitor the volcanos emissions with high-tech gear installed at some sites as well as with hundreds of one-time measurements throughout the tree-kill areas. Data from the decade-long monitoring show that Mammoths CO_2 emissions peaked in 1991 and have leveled off since 1995.

The caldera, too, is wired like a heart-surgery patient. Even the slightest geologic sneeze is caught on seismographs, and the resurgent dome is surveyed regularly for new deformation. The Survey has even drilled a 9,833-foot well into the domes center. Partially funded by state and other federal agencies, the well was completed in September 1998. Its core samples have helped scientists map the domes layers of rock, and the Survey also hopes to measure earthquakes, uplift, tension, pressure, and heat through special underground sensing devices in the future.

Despite the threat of sudden scalding, Hot Creek lures swimmers and soakers to its milky-blue pools.

Dying trees, shaky ground, scalding water, deadly gas. Mammoth real estate is indeed hot. And yet, as I discovered traveling around Long Valley, few residents consider themselves in any danger. After a sunny day spent at Horseshoe Lake and Hot Creek, I talked to a desk clerk at a lodge built in 1924 on the shores of Twin Lakes, hardly a mile from Horseshoe Lake. Having worked at a 1920s lodge that was destroyed by a volcano, I was curious to know whether the clerk was worried about a future eruption.

"No," he replied confidently.

"And do you ever feel earthquakes?" I wondered, having felt one myself at Mount St. Helens the summer before it erupted. I remember how the old lodges walls had shaken and its kitchen cabinets had rattled.

He smiled and nodded.

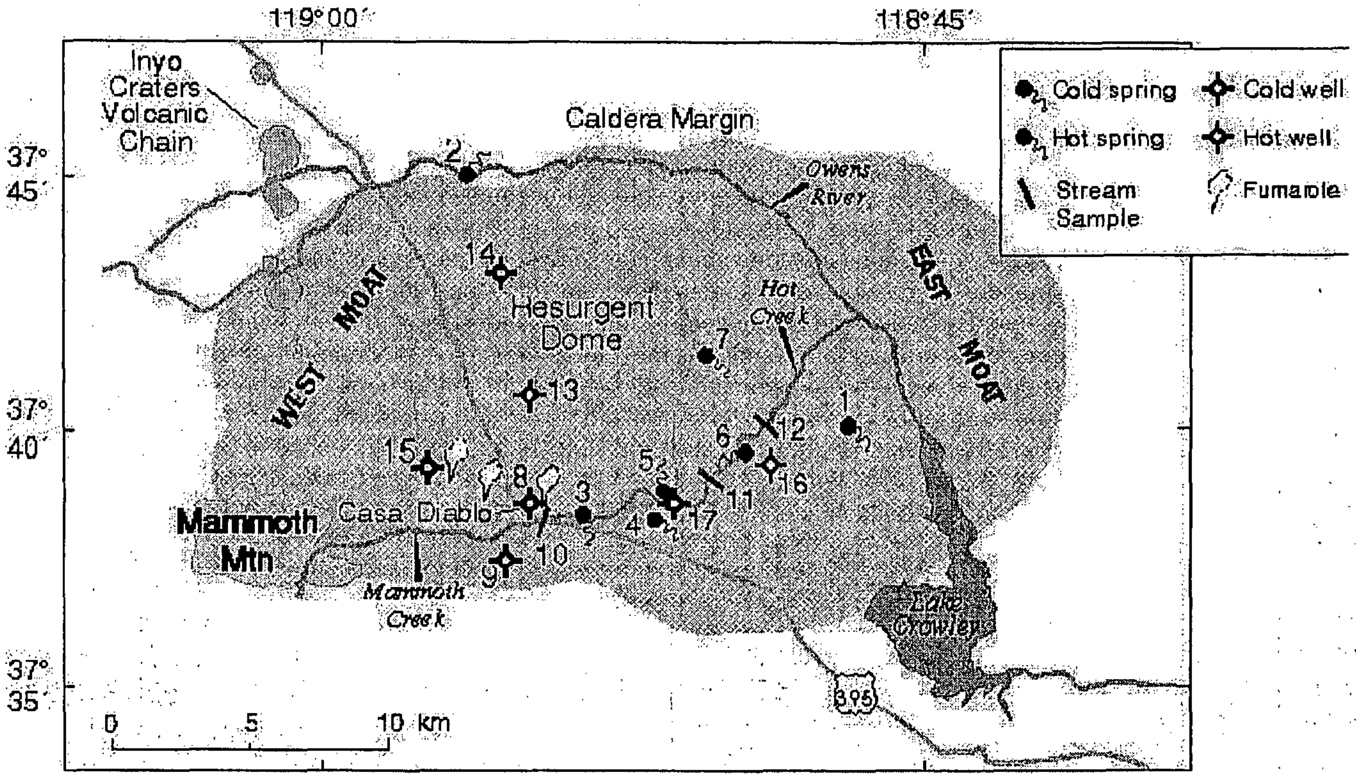
"All the time," he said.

Christine Colasurdo *is the author of* Return to Spirit Lake, *a natural history memoir of Mount St. Helens. She lives in San Francisco, where the usgs estimates the same statistical odds for an 8.0 earthquake along the San Andreas fault as a Long Valley eruption.*

Table of Contents

USGS

Selected Hydrologic Features in Long Valley caldera



Map of Long Valley caldera showing locations of selected USGS hydrologic monitoring sites, the geothermal well field at Casa Diablo, and various geologic features referred to in the text. Numbered sites are described in the table below, which lists the maximum temperature in wells or the vent temperature in springs. The geologic features include Mammoth Mountain (the site of anomalous gas discharge that is killing trees), the Resurgent Dome (a highland region formed by repeated volcanic eruptions and magmatic uplift following the initial formation of the caldera 760,000 years ago), and the Inyo Craters Volcanic Chain consisting of numerous volcanic domes and phreatic craters that have erupted repeatedly over the past 10,000 years or so.

Number on map	Site Name	Site Description	Temperature (Celsius)
1	**Big Alkali Spring**	Hot Spring near Big Alkali Lake	57
2	**Big Springs**	Cold springs along Owens River	11
3	**Colton Spring**	Hot spring activated by earthquakes in the 1980's, but ceasing to flow in 1991 as a result of pressure declines from geothermal development	93
4	**Fish Hatchery Springs**	Four groups of spring vents; water used for fish rearing operations	11-18

5	**Hot Bubbling Pool**	Hot pool with no surface discharge; fed by hot springs at temperatures of 93 °C	~70
6	**Hot Creek gorge Springs**	Numerous hot springs in and adjacent to an approximately 1-km long reach of Hot Creek	93
7	**Little Hot Creek Springs**	Numerous hot springs that feed into Little Hot Creek	~80
8	**Well MBP-3**	Geothermal production well at Casa Diablo	161
9	**Wells SC-1, SC-2**	Wells near Sherwin Creek Campground	17
10	**Mammoth Creek at Hwy 395**	Site for chemical sampling and discharge measurements	17
11	**Hot Creek above gorge**	Site for chemical sampling and discharge measurements	~15
12	**Hot Creek at Flume**	Site for chemical sampling and discharge measurements	~35
13	**LVEW**	Site of Long Valley Exploration Well and adjacent water-supply well (SF) used for continuous pressure monitoring	100
14	**LKT Well**	Well near Lookout Mountain used for continuous pressure monitoring	--
15	**RDO-8**	Well near Shady Rest Campground used for continuous pressure monitoring	202
16	**CH10-B Well**	Well near Hot Creek Gorge used for continuous pressure monitoring	95
17	**CW-3**	Chance Well #3 near Hot Bubbling Pool	120

| Main Page | Hydrothermal System | Hydrologic Monitoring Data | Geothermal Development |

URL of this page: http://quake.wr.usgs.gov/VOLCANOES/LongValley/CalderaMap.html

Maintained by: Carolyn Donlin
Last modified: 6-12-98 (cad)

USGS

U.S. Geological Survey Volcano Hazards Program
Long Valley Observatory

Carbon Dioxide and Helium Discharge from Mammoth Mountain

CURRENT STATUS: Measurements of the total discharge of carbon dioxide (CO2) gas at the Horseshoe Lake tree kill area range from 50-150 tons per day. Variations are primarily caused by changes in barometric pressure. There is no obvious trend of either increasing or decreasing gas flux at this area; we conclude that the total gas flux coming to the surface at Horseshoe Lake has remained at these relatively high levels since 1996. We do not have enough data from any other gas discharge areas around the mountain to draw conclusions about changes over time at those locations.

CURRENT HAZARDS: Inhaling high concentrations of carbon dioxide gas can cause dizziness, unconsciousness, and death. It is hazardous to dig holes in and around areas where the trees have been killed by carbon dioxide gas. Natural collapse pits that develop on the northwestern shore of Horseshoe Lake as the lake level declines contain high CO2 concentrations - extreme care should be taken to prevent children and dogs from entering these pits or digging up loose soil that has been placed in the pits. Care should also be taken to avoid a crack 1-2 feet wide that extends from the lake onto the west shore. Do not lie face down on the ground anywhere near Horseshoe Lake or the tree-kill area.

As snow levels accumulate in the winter, toxic levels of CO2 can develop in tree wells, around buildings, and immediately below the snow surface in areas of high CO2 emissions. Pay serious attention to signs warning of CO2 hazards.

Horseshoe Lake treekill (©John Rogie)

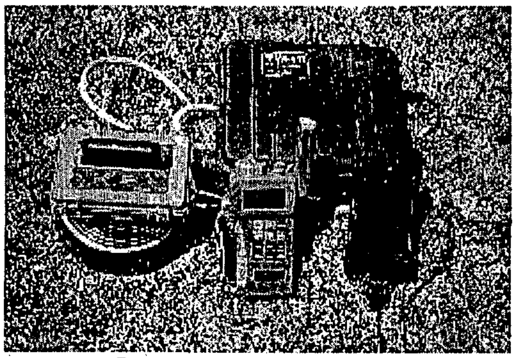
Aerial view of Horseshoe Lake and Mammoth Mountain. A large area of trees killed by carbon dioxide emissions is visible near the northern (top) shore of the lake. See **tree-kill map** for a map showing the locations of the carbon dioxide emission sites around Mammoth Mountain.

High concentrations of carbon dioxide (CO2) in soil gas are killing trees on the flanks of Mammoth Mountain at the southwestern edge of Long Valley Caldera. First noted in 1990, the areas of tree kill now total about 170 acres in six general areas, including the most visually impressive tree-kill area adjacent to Horseshoe Lake on the south side of Mammoth Mountain. The soil gas in the tree-kill areas is composed of 20 to 90 percent CO2; there is less than 1 percent CO2 in soils outside the tree-kill areas.

Carbon Dioxide Monitoring

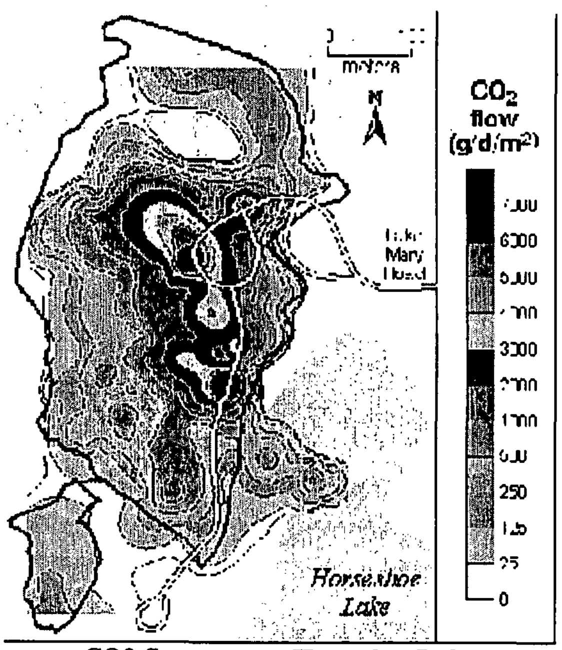
The concentration of carbon dioxide in soil gas at Mammoth Mountain is currently being monitored on a continuous, year-round basis at four sites - three at Horseshoe Lake and one near the base of Chair 19 at the ski area. Evaluations of anomalous changes in concentration are made by researchers at the USGS Cascades Volcano Observatory (*McGee and others, 1998*).

Carbon dioxide flux (the rate at which CO2 gas comes out of the ground) is monitored periodically at each tree kill area:



Portable CO2 flowmeter

Sampling grids have been set up at the Horseshoe Lake tree kill and at other tree-kill areas on Mammoth Mountain so repeat measurements can be made of gas flow rates. A portable flowmeter is used to make measurements of gas flow at approximately 50-100 sites on the grid within a single day.



CO2 flow rates at Horseshoe Lake

CO2 flow is measured in units of grams/day/square meter (g/d/m2). The natural background rate of CO2 flux in this area is up to 25 g/d/m2. In this CO2 flow map made at the Horseshoe Lake tree kill on January 5, 1999 (when the lake was frozen), the area of dead trees is outlined in red. The pattern shows several small areas of very high flow (red patches) surrounded by a broader region of lower gas flow rates. Note the arm of high flow extending toward the lake - this is the area where collapse pits containing high CO2 concentrations develop each fall. The measured flux at this time was 108 tons/day.

Twenty-one separate CO2 flux (*flow x area*) determinations made at Horseshoe Lake over the 1996-1999 period average 110 ±24 metric tons per day. For comparison, 110 metric tons of CO2 gas would fill approximately one million bottles of champagne. The observed variability in flux is most likely caused by changes in atmospheric conditions (e.g. barometric pressure and wind speed), rather than increasing or decreasing flow from the deep gas reservoir.


Continuous Flow Instrument (CFI)

In a joint project between the USGS and Penn State University, two Continuous Flow Instruments (CFI's) were placed at several different locations on Mammoth Mountain during the 1998 and 1999 field seasons. CFI's measure the CO2 flow every 30-60 minutes, along with barometric pressure, wind speed and direction, temperature, and other environmental conditions. Data collected thus far indicates that at some sites gas flow rates can vary quite a bit over days or even hours. Interpretations are still in progress, but changes in gas flow appear to be positively correlated with the longer-term changes in barometric pressure.

The most likely sources of the CO2 are degassing of intruded magma and gas release from limestone-rich metasedimentary rocks that are heated by magmatic intrusions. The remarkable uniformity in chemical and isotopic composition of the CO2 and accompanying gases at different locations around Mammoth Mountain indicates that there may actually be a large reservoir of gas deep below the mountain from which gas escapes along faults to the surface. See Helium Discharge at the Mammoth Mountain Fumarole for information on helium gas measurements.

The CO2 is released as a cool, diffuse gas from broad areas of soil. Although it quickly dissipates when it leaves the ground, CO2 is heavier than air and can collect in depressions in the land surface, in unvented buildings, and in other confined spaces. Carbon dioxide displaces oxygen and can cause unconsciousness or asphyxiation very quickly at concentrations above 30 percent. The National Institute for Occupational Safety and Health recommends a ceiling limit of 3 percent CO2 for up to 10 minutes for occupational exposure. Summer-time exposure to high levels of CO2 in the Horseshoe Lake area may result from lying directly on the ground or digging pits in the ground. Walking through the area in the summertime is safe for children and dogs, as long as their heads stay above ground level. During the winter, CO2 levels can build up beneath the snowpack and the CO2 gas will preferentially escape around buildings, through tree wells, and through depressions around large rocks. Such areas should obviously be avoided, as should snow camping within tree-kill areas.

Selected sources of additional information:

- Invisible CO2 Gas Killing Trees at Mammoth Mountain, California, USGS Fact Sheet 172-96.
- U.S. Forest Service - Mammoth Visitor's Center.
- USGS information on volcanic gas.
- McGee and others, 1998, *Annual cycle of magmatic CO2 in a tree-kill soil at Mammoth Mountain, California; implications for soil acidification*, Geology, vol. 26, no. 5, p. 463-466.
- Sorey and others, 1999, *Magmatic gas emissions from Mammoth Mountain*, California Geology, September/October, p. 4-16.

| Home | Current Condition | Monitoring Data | Volcano Hazards |
| Photo Gallery | Area Maps | Geologic History | Response Plan |

U.S. Department of the Interior, U.S. Geological Survey, ***Menlo Park, California****, USA*
URL ***http://lvo.wr.usgs.gov/CO2.html***
Contact: **Long Valley Web Team**
Last modification: 30 November 1999 (EMC)

A FISHERIES MANAGEMENT PLAN FOR

CROWLEY LAKE AND TRIBUTARIES

MONO COUNTY, CALIFORNIA

1997

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF FISH AND GAME

State of California
The Resource Agency
DEPARTMENT OF FISH AND GAME

A FISHERIES MANAGEMENT PLAN FOR CROWLEY LAKE AND TRIBUTARIES, MONO COUNTY, CALIFORNIA, 1997

by

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SPORT FISH RESTORATION

Under the Supervision of

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

PREFACE

"Of the many fishable waters in the Inyo-Mono area of eastern California, Crowley Lake is the largest and perhaps the most used" (Pister, 1960). This statement, made over three decades ago, remains true with anglers seeking sustained high catch rates of quality put-and-grow rainbow trout; fast action and trophy Sacramento perch angling; and trophy catch-and-release trout angling. High angler satisfaction, even under heavy angling pressure, has become the Crowley trademark. Yet, these fishery resources remain dependent on weather cycles and human intervention.

A decline in Crowley Lake angling success, beginning in 1987 and persisting through several seasons, roused much public concern. Angling groups, including a newly-formed "Committee to Save Crowley Lake", requested action from the California Department of Fish and Game (Department). A study to evaluate the Department's management of put-and-grow hatchery stocks and to better understand wild trout fisheries was initiated in 1989. In June, 1991, a meeting held at the Department's Bishop office provided a forum for participation by concerned organizations and agencies to develop a management plan for Crowley Lake and its tributary waters. Issues identified by the group are addressed in this management plan.

The Department emphasizes management of fish and wildlife resources on an ecosystem or watershed basis using strategic planning and management concepts. These "units" represent specific geographical areas requiring coordinated resource management. Programs need to be developed and implemented which "manage diverse fish, wildlife, and plant resources, including the habitats upon which they depend, for their ecological values and their use and enjoyment by the public" (Department Mission Statement). The "unit" covered by this plan includes Crowley Lake and tributary waters which are linked to Crowley Lake fisheries, along with the lands associated with these resources. This plan does not include the upper reaches of some tributary waters.

This plan incorporates certain recommendations from *A FISHERIES MANAGEMENT PLAN FOR THE MAMMOTH LAKES BASIN AND CERTAIN ADJACENT WATERS, MONO AND MADERA COUNTIES, CALIFORNIA* (von Geldern, 1989). Two issues regarding Crowley Lake and tributary waters that were discussed in the Mammoth Lakes Basin management plan have been, or are being, remedied. These are "Damage by grazing cattle on public portions of the Owens River and other tributaries", and

"Over-domestication of trout used to stock Crowley". An issue previously brought up in the 1989 plan that remains a part of this plan's focus is: "Trout losses to irrigation diversions on public portions of the Owens River and other tributaries of Crowley Lake". The following items are discussed in this plan, but no actions, other than further study, are proposed: presence of Sacramento perch in Crowley Lake, loss of stream channel in the Owens River above Crowley Lake, and increased abundance of American White Pelicans, Cormorants, and other fish eating birds in the vicinity of Crowley Lake.

RESOURCE STATUS

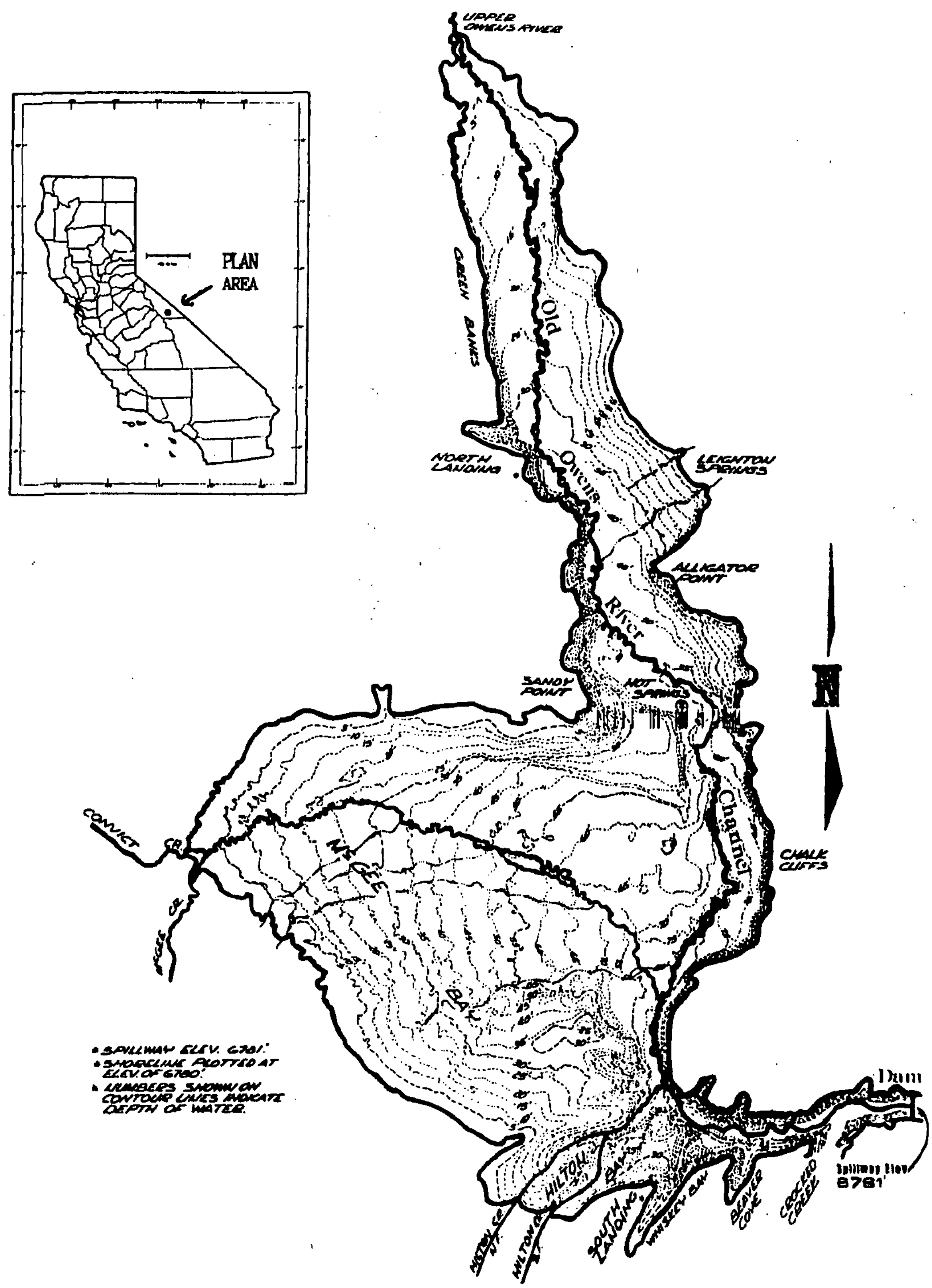
General Setting

Crowley Lake (Long Valley Reservoir) is located in southern Mono County on the eastern slope of the Sierra Nevada at an elevation of 6,781 feet (Figure 1). The lake was created in April 1941, when Long Valley Dam was put into operation by the Los Angeles Department of Water and Power (DWP) to impound water imported from the Mono Basin and the Owens River drainage.

Tributaries draining directly into Crowley Lake are the upper Owens River, Leighton Springs, and McGee, Hilton, Whiskey, and Crooked creeks. Tributaries to the upper Owens River are Hot Creek, Mammoth Creek (tributary to Hot Creek), Deadman Creek and Glass Creek. Convict Creek joins McGee Creek between Highway 395 and Crowley Lake. These waters provide diverse angling opportunities for thousands of anglers.

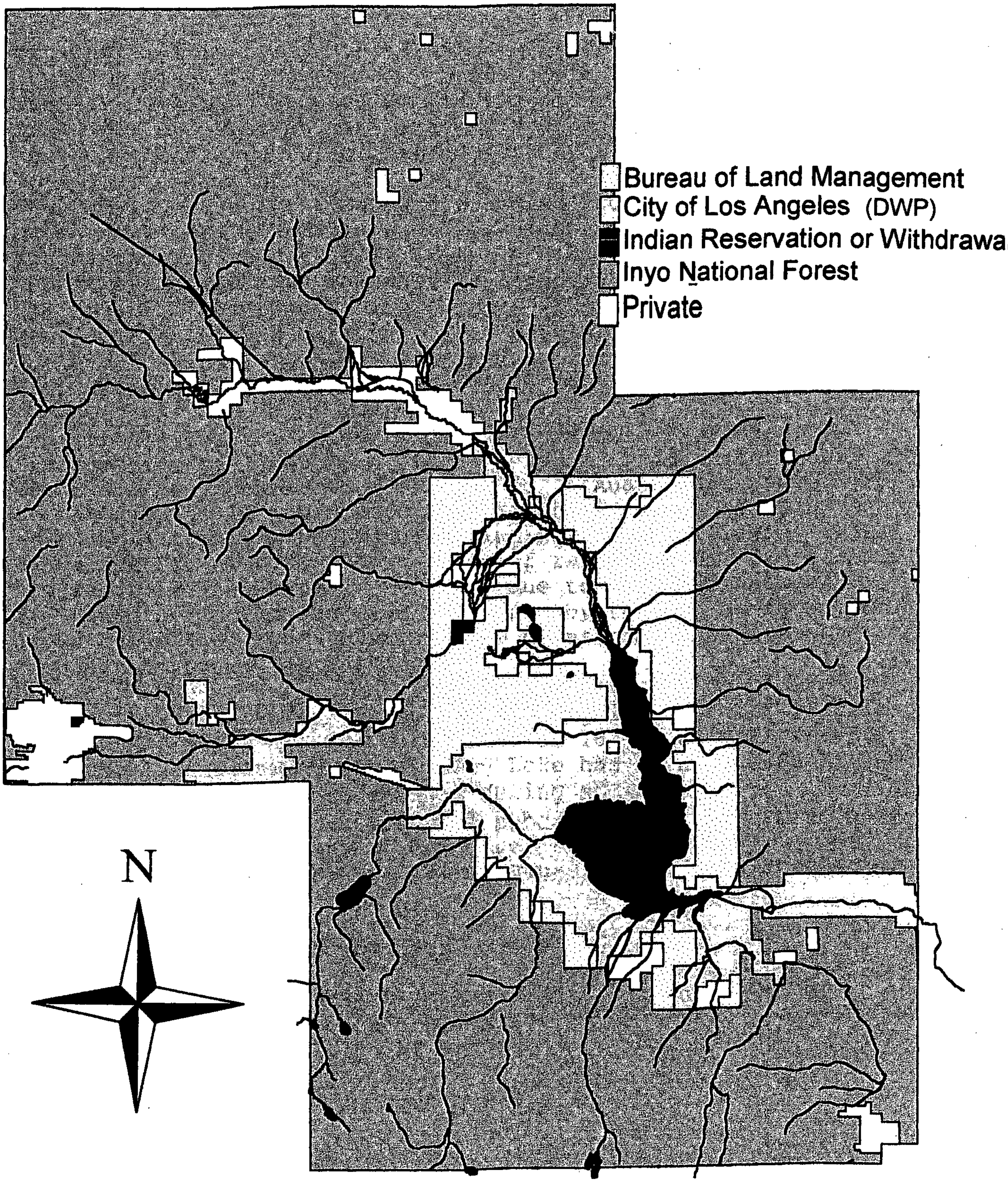
The region is largely publicly-owned with private lands located primarily along the upper reaches of the upper Owens River and parts of Hot Creek. The DWP is the major owner of lands adjoining Crowley Lake and its lower elevation tributary waters. While DWP lands are publicly used as referenced in this and previous fishery planning documents, they are technically private since they are subjected to local taxation. The Inyo National Forest (INF) and the Bureau of Land Management (BLM) administer the remaining public lands in Long Valley (Figure 2).

Figure 1. Crowley Lake Site Location and Lake Bathymetry



Originally Prepared by Larry Bell.

Figure 2. Land Ownership Around Crowley Lake.



THE CROWLEY LAKE FISHERY

Crowley Lake is by far the dominant fishery in the eastern Sierra in terms of angler use and fish production. An attractive trout fishery developed almost immediately after the reservoir filled in 1945. By 1961, an estimated 19,000 anglers harvested over 40 tons of trout on opening weekend (Pister 1965).

The Crowley fishery is managed for wild trout and "put and grow" hatchery trout. Department policy encourages the use of fingerling and subcatchable trout in hatchery stocking programs when the smaller fish maintain satisfactory angling. Because of the lake's high productivity, stocked trout gain from 3 to 40 times their stocked weight before harvest and are of exceptional quality. A complete history of the Department's Crowley Lake trout stocking from 1941 through 1996 is presented in Appendix 1.

The size of trout stocked into Crowley varies by strain. A minimum size of 12 fish/lb. is necessary for adequate stock survival. Rainbow trout (RT) stocked in August and September, averaging 6 to 12/lb., reach approximately one pound and average 13 inches total length by the beginning of the following season (late April). The Kamloops strain of rainbow trout are usually stocked at a larger size (2-5/lb.) due to a longer hatchery residence period and average 14 inches by the following season. Brown trout (BN) subcatchables have occasionally been stocked to supplement natural recruitment.

Trout are stocked after August 1 when regulations that restrict harvest and set a minimum size limit of 18 inches take effect. The stocking allotment for Crowley Lake has been 350,000 RT, with 15,000 to 50,000 BN also stocked during some years. In 1996, the allotment increased to 400,000 RT subcatchables to take advantage of the high productivity of the lake. BN of the newly established Crowley and Whitney strains will also be stocked in 1996 and evaluated.

The 1996 stocking allotment for Crowley Lake is:

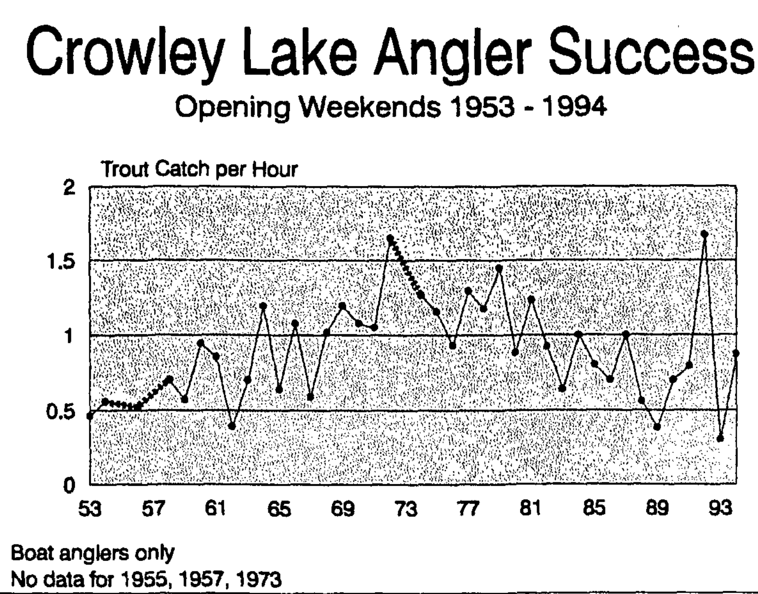
150,000 Coleman RT (RT-C)
150,000 Eagle Lake RT (ELT)
100,000 Kamloops RT (RT-K)
25,000 Crowley strain BN (BN-C)
25,000 Whitney strain BN (BN-W)

Hatchery allotments are "goals", and production shortfalls may occur in some years. Actual numbers stocked are affected by the availability of strains, Department hatchery budgets, and the need to stock unallotted trout (trout that are excess to hatchery production goals). Crowley Lake has often been stocked with large numbers of unallotted fingerling and subcatchable trout. Most of the fingerlings, averaging only 1 to 2 inches long, increased the forage base for larger piscivorous trout and birds, but probably added little to angler catch rates. It is unlikely that large numbers of unallotted subcatchable trout will routinely be stocked due to diminished budgets. The practice of stocking unallotted trout in Crowley Lake was discontinued in 1990 to facilitate the study of allotted hatchery strains and wild trout, and because the lake's surface elevation and volume averaged well below historic levels. When adequate trout habitat exists, unallotted hatchery stockings will resume after completion of the study.

Under current regulations, the angling season at Crowley is from the last Saturday in April through October. The first three months, referred to as the "harvest season", are governed by Sierra District general trout regulations (5 fish per day, 10 in possession, with no special gear or size restrictions). August through October, known as the "second season", is managed as a trophy fishery with a two trout limit and a minimum size of 18 inches total length. Artificial lures and flies with barbless hooks are required for all angling.

The Department has monitored opening weekend angler success since 1953 to determine fishery trends (Figure 3). Catch rates have fluctuated greatly, mostly due to weather conditions. Catch rate

Figure 3.



declines in 1988 and 1989 followed by reportedly poor season-long angling prompted the Department to commence the recent study at Crowley. The objectives were to determine the relative performance of stocked RT and BN strains and the contribution of wild trout to the fishery.

Fisheries Research and Discussion

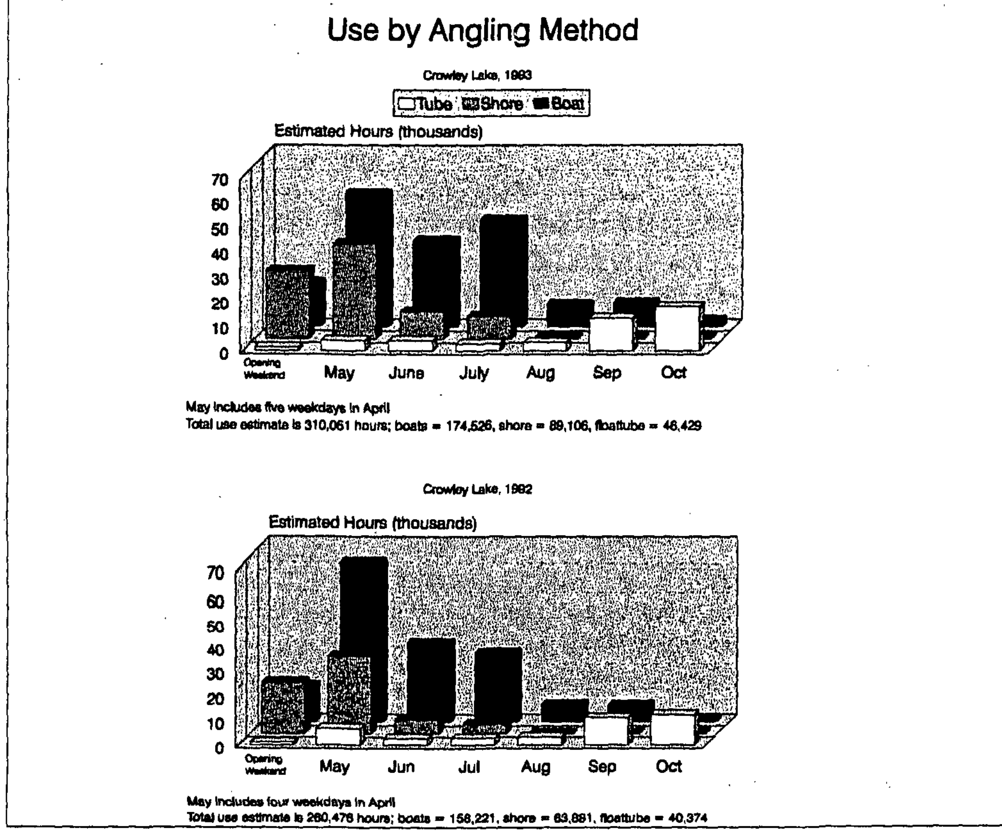
Angler Use, Catch and Harvest

To identify stocked RT strains and differentiate hatchery and wild trout, a hatchery trout marking program was initiated in 1989. Over 200 volunteers, supervised by California Trout and Department employees, fin-clipped 923,000 trout over a four-year period (Appendix 1). Season-long angler surveys were conducted in 1991 by volunteers and in 1992 and 1993 by Department employees. Six half-day periods and three full-length days were surveyed each week during the 1992 and 1993 seasons, respectively. Angler catch and trout growth data were recorded for three angling methods: boat, shore, and float tube. To estimate angling effort by method, angler counts were conducted every two hours in 1993, and one to four times per six hour survey in 1992. Boat anglers were contacted as they returned to the South Landing launch facility (Figure 1), while shore and float tube anglers were contacted by boat.

A total of 22,026 angler interviews were made, representing approximately 70,000 hours of angling effort. Estimates of angler use for 1992 and 1993 show similar trends (Figure 4). Angling effort increased in 1993 by 19% over 1992 despite a severe wind storm that dismantled the boat docks and closed the lake for seven days in May, the busiest month of the season. Crowley Lake Fish Camp, the lake's recreation concessionaire, reported that angling effort continued to increase in 1994, based upon use figures and gross receipts.

Angler use patterns are influenced by the regulation changes on August 1, the beginning of the second season at Crowley. Boat and shore angler effort drops concurrent with the more restrictive regulation period. Conversely, float tube angler effort increases, peaking in October at the end of the season. However, improved catch rates for Sacramento perch (SP) in 1993 attracted boat anglers to the lake after the August 1 regulation change. There was a 38% increase in boat angler use during the second season between 1992 and 1993, with most anglers targeting SP. In 1993, SP catch success was highest in August (averaging 6 fish per hour, 20 fish per trip), and good perch catch rates were maintained through September.

Figure 4.



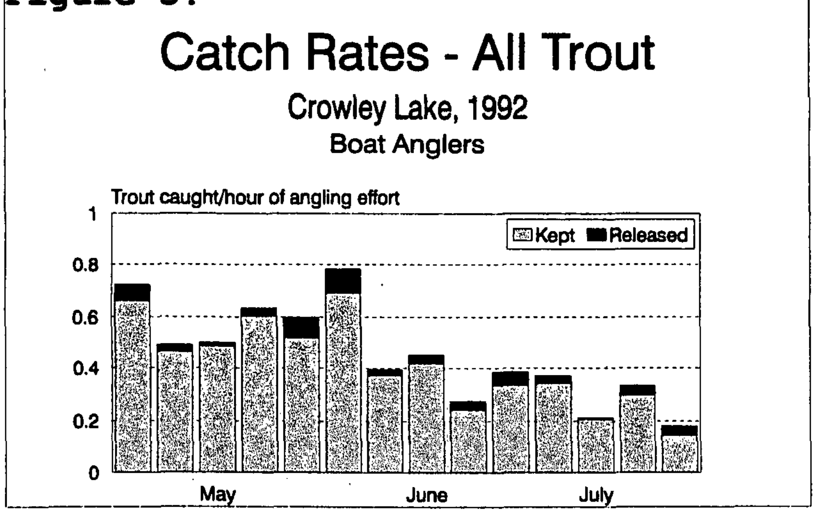
In 1993, June shoreline angling effort was 29% of May, and August was only 3% of May. These declines occurred even though trout catch rates were higher after May. Similar patterns have been observed in other years indicating a preference by shore anglers to participate in the early season fishery. The decline in shore angler use after August may be due to the mid-season regulation change and to the formation of weedbeds along the shore of the lake.

Shoreline angling becomes difficult as weedbeds increase through the season. The condition is exacerbated when a lowering lake level consolidates weedbeds, as occurred in 1992. Shore angler use increased by 59% between the 1992 and 1993 second seasons. This may reflect improved angling conditions in 1993 that were associated with a more stable reservoir level, though it is uncertain whether shore anglers were targeting perch or trout.

Float tube angling has continued to increase in popularity since 1985, when the current regulations were implemented. Prior to 1985, Crowley Lake was open to trout anglers from the last Saturday in April through July 31. Although the trout season closed on August 1, some shore and float tube anglers enjoyed a catch-and-release trout fishery by claiming to be angling for SP. Adopting the second season catch-and-release regulations allowed and promoted angler use after July 31, while protecting annual hatchery trout stockings. Boat anglers were not allowed on the lake during the second season until 1991, when the current lake concessionaire acquired the lease. Boat angler use remains second to float tube angling during the last two months of the season.

Opening weekend and seasonal catch rates can vary greatly from year to year. Pister (1965) noted a correlation coefficient of 0.92 for the relationship between number of RT subcatchables stocked during the previous year and mean catch per angler hour over the opening weekend of the following season. This correlation has not held up in recent years. The highest opening weekend catch rate ever recorded was in 1992; a year supported with relatively low numbers of hatchery trout. Angling remained above average for several weeks into the season (Figure 5). Twenty nine percent more trout of the same strains and approximately of the same size were stocked in 1992 than in 1991, yet season-long angling success in 1993 was below average. Clearly, there are more factors related to angler success and over-winter trout survival than the stocking of trout. Weather, water quality, reservoir water management, watershed land and water management, angler use, bird migration patterns, occurrence of SP, and the availability of domestic trout strains are probably the major variables which annually influence the Crowley Lake fishery.

Figure 5.



Increases in trout catch rates during June were observed during the study. This is coincidental with RT returning to Crowley Lake after spawning, and to near optimal water quality condition for trout. By June, spring spawning RT that are typically abundant in tributaries through May, have returned to the lake fishery. An increase in June catch rates for fall spawning Coleman RT appears to be less than that observed for spring spawners, and may be related to improved water quality and feeding conditions. The fishery in June can provide higher catc rates for larger trout with lower angling pressure than found during May.

The greatest increase in trout catch rates occurs in August and September after the stocking of approximately 1/3 million six to ten inch trout (Figures 6,7,8). Some anglers express

Figure 6.

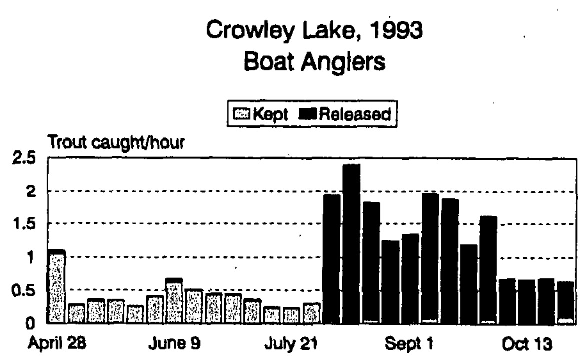


Figure 7.

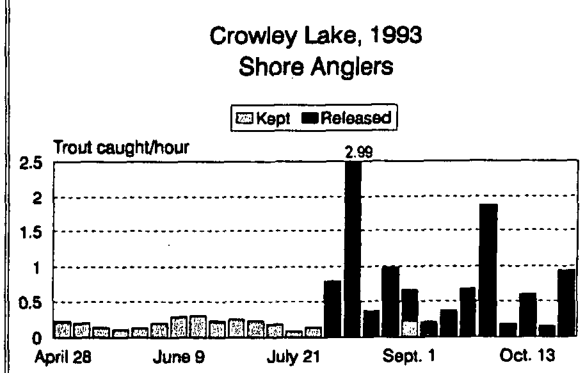
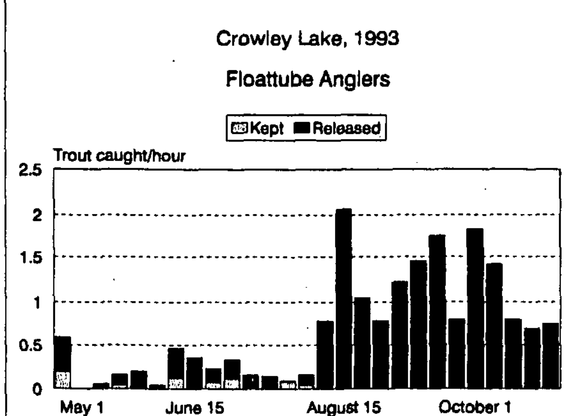


Figure 8.

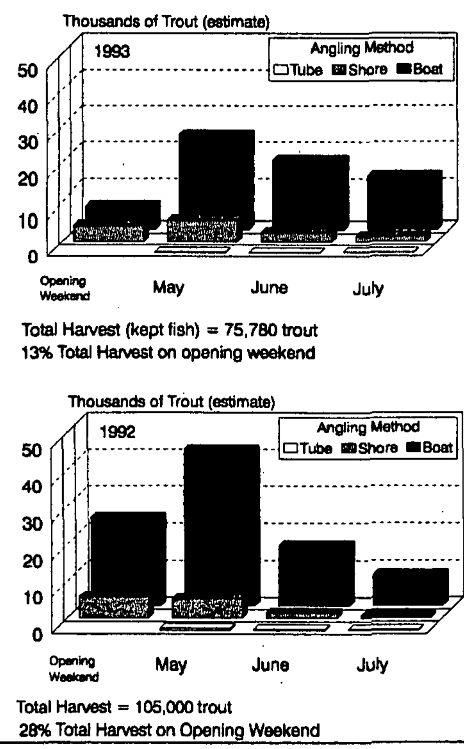


dissatisfaction when small fish are repeatedly hooked to the exclusion of larger fish. However, by the end of the second season, stocked trout are generally of a size large enough to satisfy anglers in pursuit of trophy-class hookups. Boat anglers in 1993 were typically more successful than shore or floattube anglers. However, the pattern of angler success (catch rates over time) remained similar for all methods.

During the first three months of the 1992 and 1993 angling seasons, approximately 105,000 and 76,000 trout were harvested, respectively (Figure 9). This difference is due to opening weekend success, and the timing of good catch rates with peak angling effort. Angler success and effort during the beginning of the 1993 season were impacted by persistent winter-like conditions with Crowley Lake remaining frozen until the Wednesday prior to opening weekend. Opening weekend success in 1993 was estimated to be among the poorest recorded; harvest amounted to approximately 13% of the season's total. This contrasts with an estimated 1992 opening weekend harvest of 28% of the season's total. Harvest was further reduced in 1993 when high winds forced limited boat use during May, the busiest month of the season.

Figure 9.

Crowley Lake Trout Harvest
Under District General Regulations



Comparison of Survey Box and Angler Interview Data

A comparison was made of two measures of angling success at Crowley Lake: angler survey box data (1990 through 1994) (John Deinstadt pers. comm.) and angler interview data (1992 through 1994) (Table 1). Both methods rely on accurate reporting of catch statistics from float tube and shore anglers, since almost all fish caught are released and are not observed by Department interviewers. However, interviewers occasionally met anglers with trout that were kept, providing the opportunity to collect strain-specific data. The interview data includes catch statistics from anglers who may not have filled out a voluntary survey form located near two popular access points. Anglers were interviewed three days per week, whereas the survey boxes were always available for data collection. Yet, the survey boxes provided a yearly average of only 16.3% of the catch data collected during interviews. The survey box data represents completed trip statistics, including an estimate of the mean number of trout per angler per trip; whereas interviews were conducted while anglers were still fishing.

Both survey methods resulted in similar catch estimates of the percentage of RT 18 inches or greater total length (legal-sized trout). This statistic is important for monitoring the future success of the Crowley Lake trophy trout fishery. Trout catch rates and the percentage of legal-sized trout that were caught and kept were usually lower from the interview data than from the survey box data. Apparently, anglers with poor catch success do not volunteer information as frequently. Nonetheless, the trend of angler catch success appears to be adequately monitored by either method. The major benefit of the survey box method is the low cost to the Department for data that appears to track important fishery statistics.

Table 1. Angling Success at Crowley Lake. A Comparison between Angler Survey Box Data (years 1990 through 1994) and Angler Interview Data (years 1992 through 1994) During the Second Season (kept trout must be equal to or greater than 18 inches total length). RT = rainbow trout; BN = brown trout.

Survey Box Data

	1990	1991	1992	1993	1994
Surveys received	118	177	233	173	98
Hours fished	572	873	1075	872	425
Total RT caught	927	848	1150	1168	446
Percent RT ≥ 18 inches	11.7	10.7	9.9	8.0	6.9
RT ≥ 18 inches kept	22	14	44	14	2
Percent RT ≥ 18 inches kept	20.3	15.4	38.6	15.0	6.5
Total BN caught	29	54	25	30	8
BN kept	4	3	4	3	1
Catch/hr RT	1.62	0.97	1.07	1.35	1.05
Catch/hr BN	0.05	0.06	0.02	0.02	0.02
Overall catch/hour	1.67	1.03	1.09	1.37	1.07
Mean number trout/angler	8.1	5.1	5.0	6.9	4.6

Interview Data

	1992	1993	1994
Number of anglers surveyed	2,876	3,251	1,077
Hours fished	5,704	6,738	2,060
Total RT caught	5,195	8,557	1,738
Percent RT ≥ 18 inches	9.2	8.2	7.5
RT ≥ 18 inches kept	51	70	21
Percent RT ≥ 18 inches kept	10.7	10.0	16.1
Total BN caught	75	106	10
Percent BN ≥ 18 inches caught	42.7	60.4	50.0
BN ≥ 18 in. kept	4	5	0
Percent BN ≥ 18 inches kept	12.5	7.8	0
Catch/hour RT	0.91	1.27	0.84
Catch/hour BN	0.01	0.02	0.01
Overall catch/hour	0.92	1.29	0.85

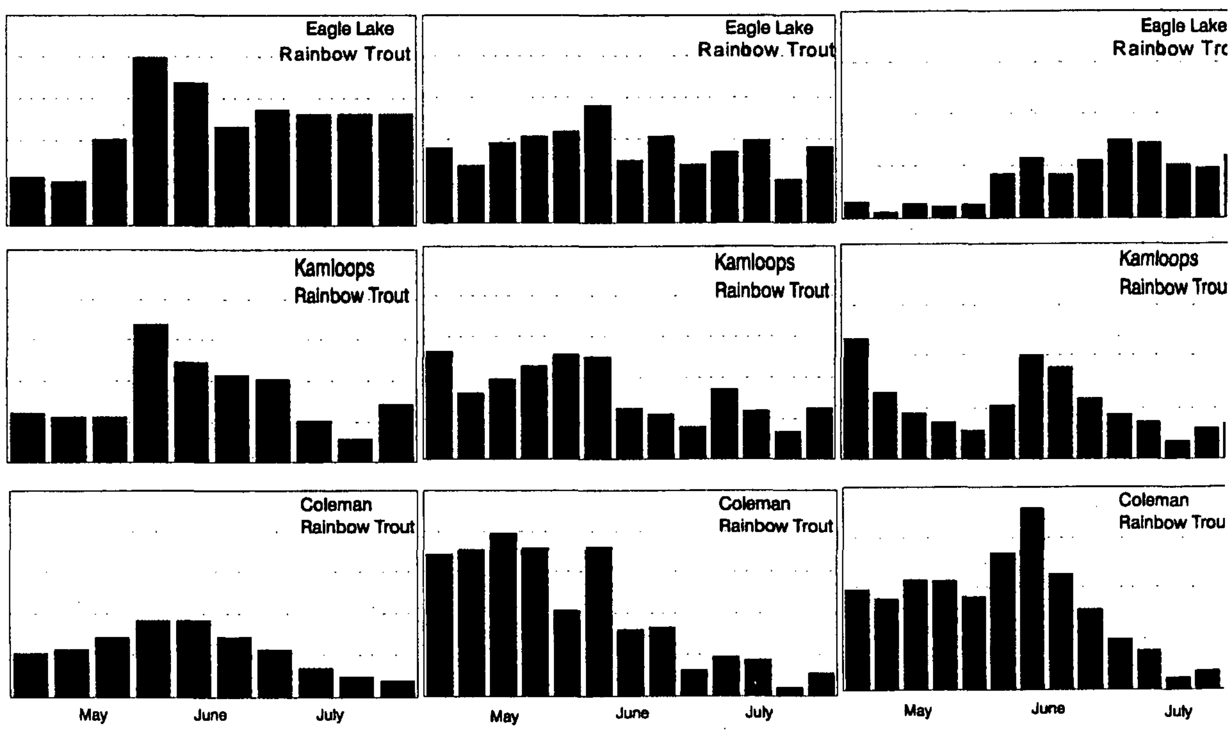
Hatchery Rainbow Trout Strain Analysis

Determining the benefit to the angler for each hatchery trout strain was one of the primary objectives of the study, and was accomplished through a marking program. In 1989, 22% of the hatchery trout stocked into Crowley were fin clipped for identification by volunteers (Appendix 1). The percent of trout marked increased each year until 1992, when 100% of the stocked trout were fin clipped. Coleman and Kamloops RT were also marke with a supplemental clip during even years to distinguish year class. Eagle Lake Trout year classes were determined by length frequency analysis.

Estimates of catch rates for each of the three strains of stocke RT for the 1992 and 1993 harvest seasons are presented in Appendix 2. To compare the relative performance of the three trout strains, the data were standardized to eliminate differences in the number of fish marked and stocked. Numbers caught were divided by the percent marked and percent stocked fo each strain. Standardized catch rates are presented for first and second (carryover) harvest seasons (Figures 10-14), and are the basis for the following discussion.

Standardized Angler Catch Rates of Three Strains of Rainbow Trou Their First Season after Planting (Figures 10-12). Y-axes represent hypothetical catch per hour.

Figure 10. Crowley Lake, 1991 Season | Figure 11. Crowley Lake, 1992 Season | Figure 12. Crowley Lake, 1993 Seasc



Standardized Angler Catch Rates of Three Strains of Rainbow Trout Their Second Season after Planting (Figures 13 and 14). Y-axes represent hypothetical catch per hour.

Figure 13. Crowley Lake, 1992 Season

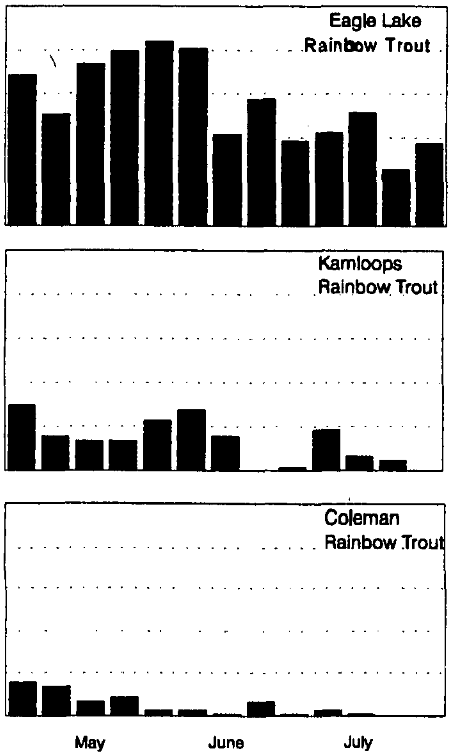
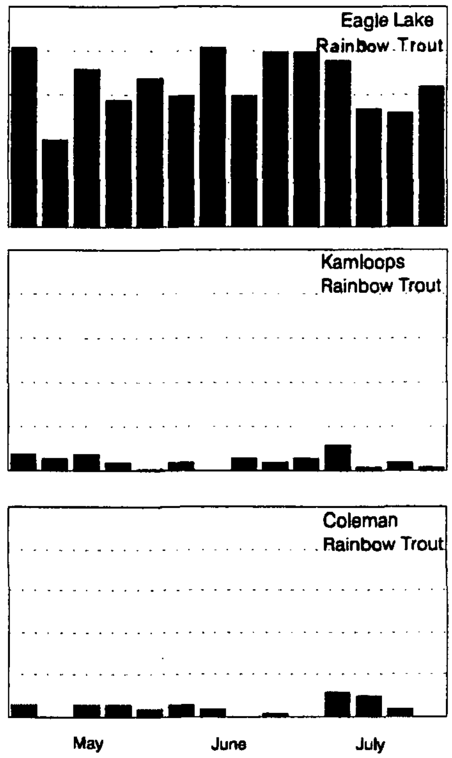


Figure 14. Crowley Lake, 1993 Season



Coleman Rainbow Trout

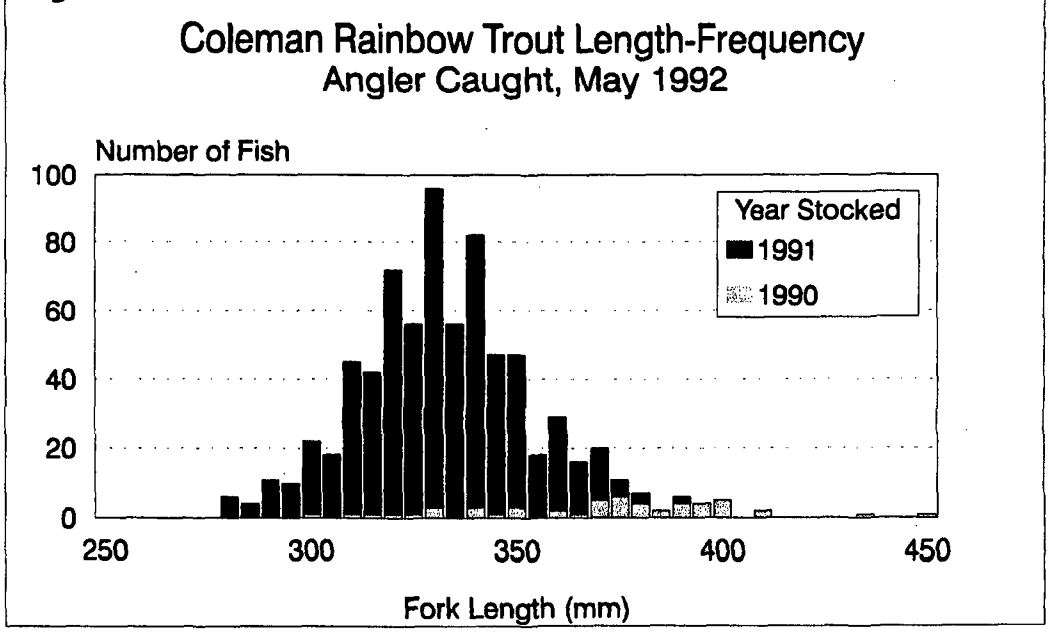
Prior to 1990, Coleman RT (RT-C) and Coleman/Hot Creek crosses dominated the hatchery program. The RT-C allotment of 250,000 was reduced to 100,000 subcatchables per year in 1990 when Eagle Lake trout were added to the program. The RT-C allotment was increased to 150,000 in 1994 because of their high return rates during May and June, the period of highest angler use.

Unlike most other RT strains, RT-C spawn during the fall/winter period. This characteristic sustains the catch rates in the reservoir during May when large numbers of spring spawning trout are in the tributaries and not available to lake anglers. RT-C were caught in greater abundance than the other two hatchery strains during the first two months of the harvest season in 1992 and 1993.

Following the initial plateau in catch rates, RT-C are gradually depleted in numbers until few are caught by the end of the harvest season. Very few RT-C have been observed in Department fall fish surveys or in angler catches during the second season. RT-C do not contribute much to the trophy fishery (only 4 % of the total RT-C catch in May 1992 were carryovers), as few individuals survive until the second year. RT-C were not observed in the upper Owens River during spawning studies, indicating that very few survive to maturity or contribute to the wild trout population.

This highly domestic strain performs well during their hatchery residence. Eggs are taken in the late fall, and subcatchable fish are stocked the following August, eight months later. Average size at stocking has varied from 6 to 12 per pound. These fish return to the angler 9 months later averaging 330 mm (13 inches) fork length (Figure 15) and nearly one pound each. RT-C are associated with open water rather than shallows or shoreline areas and are frequently caught by boat anglers while trolling.

Figure 15.



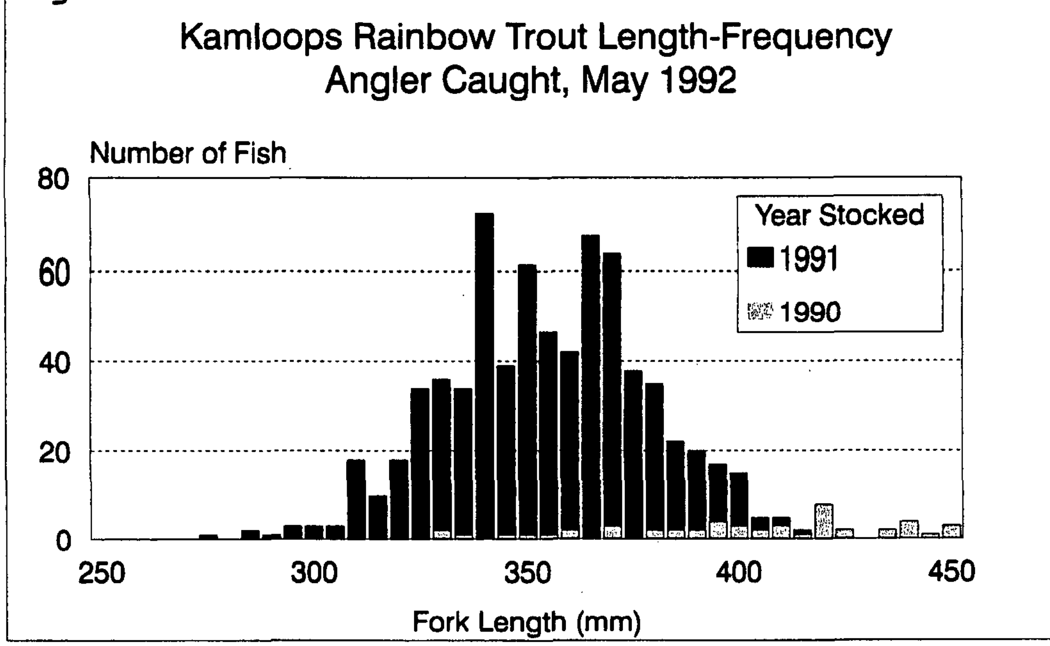
Kamloops Rainbow Trout

The Kamloops RT (KJ or RT-KJ) allotment is 100,000. These fish provide good returns to shore and other shallow water anglers and are renowned for surface breaking action. KJ broodstock reside at Junction Reservoir, Mono County. Eggs are taken at the reservoir each spring and reared at Hot Creek Hatchery with most stocked as fingerlings into back country lakes. The Crowley KJ allotment is stocked in August of the following year, approximately 16 months later. Though they are slower growing than other RT strains, they are the largest trout at stocking due to the long hatchery residence, averaging 2 to 5 fish per pound. They average 355 mm (14 inches) fork length and just over one pound by the beginning of the following season (Figure 16).

Hot Creek Hatchery has had difficulties raising the full allotment of KJ due to reduced water flow from hatchery springs, cutbacks in hatchery operation budgets, and the occasional inability to collect eggs. As a result, Crowley Lake has not received a full allotment of KJ since 1988, when 101,620 KJ were stocked. During years when the KJ allotment is not met, another RT strain is usually substituted. In 1995, approximately 116,000 Whitney x KJ crossed trout were stocked to augment the KJ allotment.

Stocked KJ are two years old by their first harvest season, and many migrate into tributaries to spawn. High early season catch rates in the lake decline sharply indicating initial harvest quickly depletes the KJ population remaining in the lake. However, catch rates rebound by early summer after spawning KJ return to the lake. As the season continues, KJ catch rates steadily decline. KJ carryovers contribute to angler catches slightly better than Colemans, making up 5 to 10% of the total KJ catch.

Figure 16.



Eagle Lake Trout

Eagle Lake Trout (RT-ELT) are imported from Mt. Shasta Hatchery as eggs taken from the offspring of wild trout caught in Eagle Lake, Lassen County. These fish are only one generation removed from the wild population, and desirable traits are maintained. They are only seven months old when stocked in September, one month later than KJ or RT-C. They average between 8 to 12 fish per pound at stocking. The RT-ELT allotment for Crowley Lake is 150,000.

RT-ELT contribute less to early season angler harvests than other strains, but increase in angler catches after June, a period when angling success traditionally waned. They are the only strain to show increasing catch rates through the harvest season and contribute significantly as carryovers the following season. RT-ELT have improved the trophy aspect of the Crowley trout fishery.

Opening weekend catches of all strains of carryover RT (> 15" on opening weekend) in 1993 and 1994 were 10% and 10.6% of the total catch of trout, respectively. These figures are up considerably from the long term average of 3%. Of the carryover trout caught on opening weekend in 1993, over 50% were RT-ELT. This figure jumped to 72% RT-ELT in 1994. These carryover fish average 2.5 pounds and 17 inches total length at the beginning of the season

An estimated 31% (Figure 17) of the total catch of RT-ELT during the first month of the 1992 season were carryovers, whereas RT-C and KJ carryovers were 4 and 10%, respectively for the same period. In 1993, carryovers comprised 52% of the total RT-ELT catch in May and 28% of the total RT-ELT catch for the harvest season.

During the 1995 opening weekend, an estimated 9.4% of the total RT carryover catch were RT-ELT that had survived into a third angling season (stocked in 1992). This statistic highlights the longevity of this RT strain in a fishery that has traditionally sustained very few stocked trout beyond a second year.

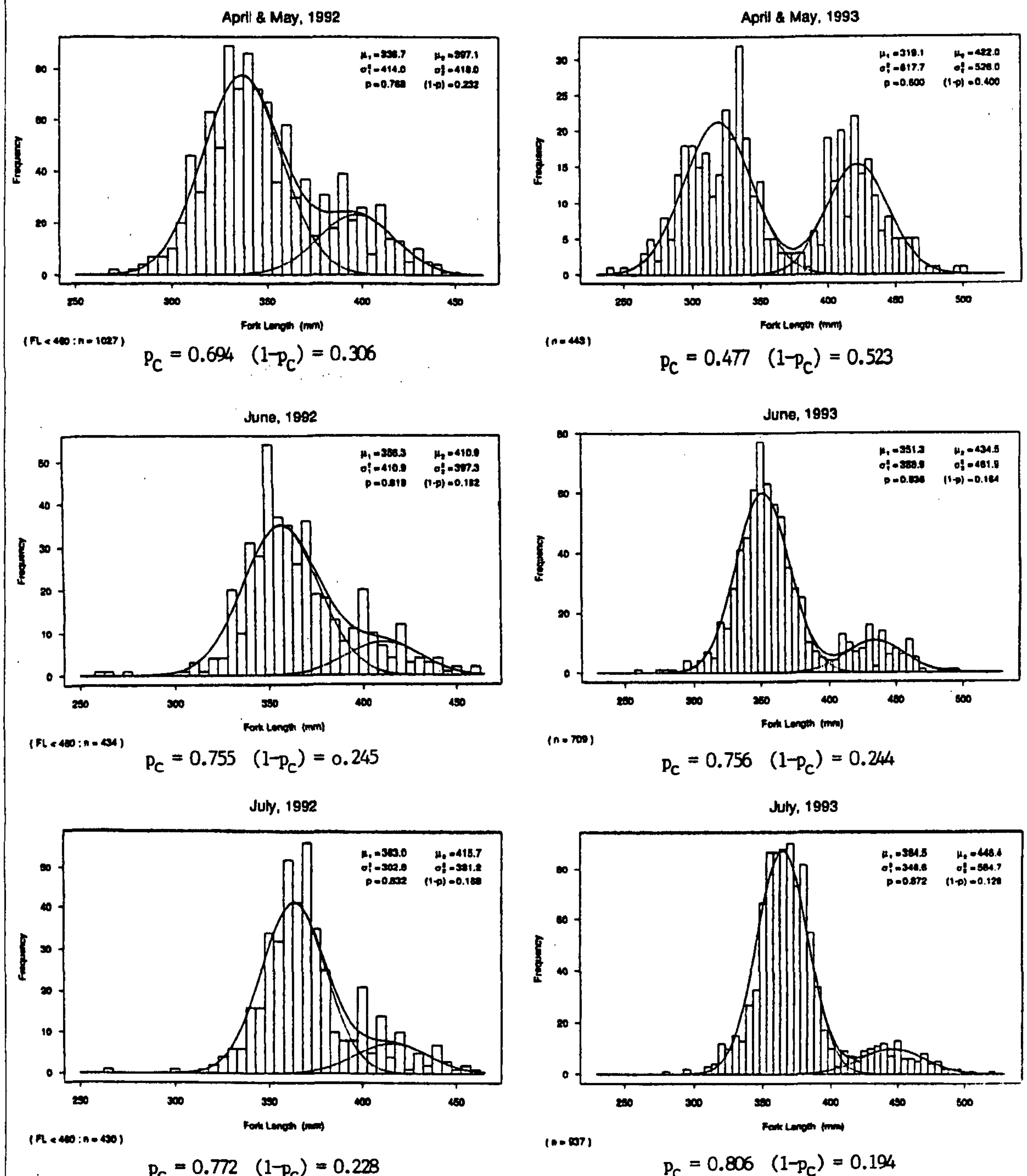
RT-ELT are usually below the average size observed on opening weekend. However, these fish exhibit fast growth rates, and surpass KJ and RT-C by the end of their second year.

Estimating RT-ELT second season catch rates is difficult since almost all trout, regardless of size, are returned to the lake. However, results of Department electrofishing surveys indicate RT-ELT and wild trout constitute most of the large trout available to anglers.

Figure 17. Length-Frequency of Angler Caught Eagle Lake Trout, 1992-93

1992 - 1993

p_c = proportion of Eagle Lake Trout planted the previous year to the total catch of Eagle Lake Trout, corrected for the number of marked fish planted each year



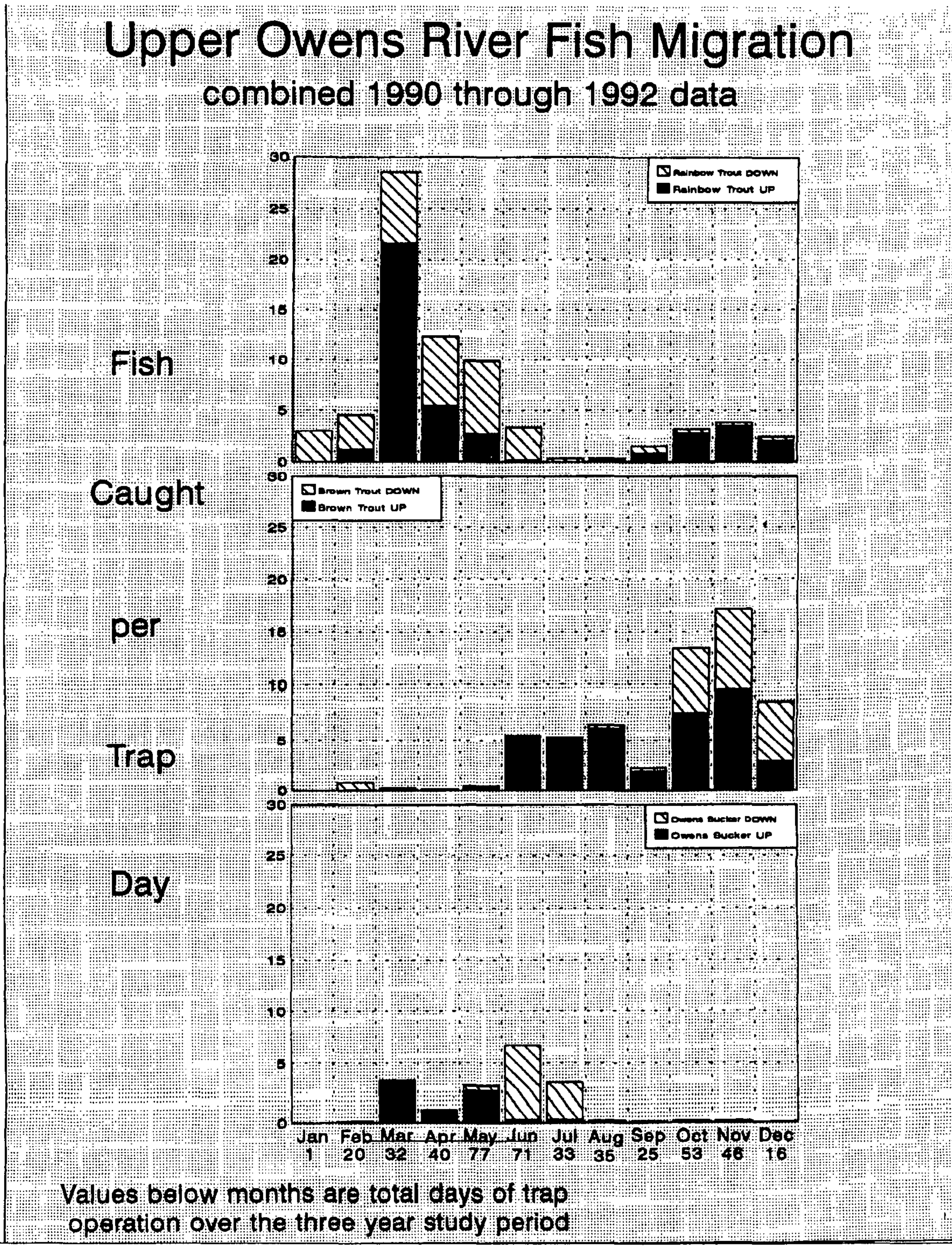
Wild Trout

Many strains of RT and BN have been stocked into Crowley Lake tributaries. Aside from annual allotments, Crowley has also received trout of various strains that were surplus to the hatchery program. Some of these trout successfully spawned in the waters tributary to Crowley, and their progeny are collectively known as "wild trout". The term "wild trout" sho not be confused with "native trout", which refers to trout tha existed prior to human intervention. All waters in Inyo Count and in Mono County south of the Walker Drainage, including Crowley Lake, have no native trout.

A fish weir with upstream and downstream fish traps was instal in the upper Owens River near Benton Bridge road crossing in t spring of 1990. The weir was in use through 1992, though operations were usually interrupted by storm and icing periods Fish greater than approximately 300 mm (12 inches) were captur while attempting to move past the weir in either upstream or downstream direction (Figure 18). The purpose of the weir was monitor the movement of adult trout and native Owens suckers between the upper Owens River and Crowley Lake.

All BN and RT caught in the fall at the fish weir were wild, as evidenced by their general appearance and a complete lack of finclips. In contrast, spring RT migrants were a mixture of hatchery and wild trout. Fish movement can be triggered by increases in river flow, which often times resulted in weir failure. Although the magnitude of fish movement is underestimated due to this sampling limitation, estimates of th duration of a run and peak run times for each species appear valid.

Figure 18.



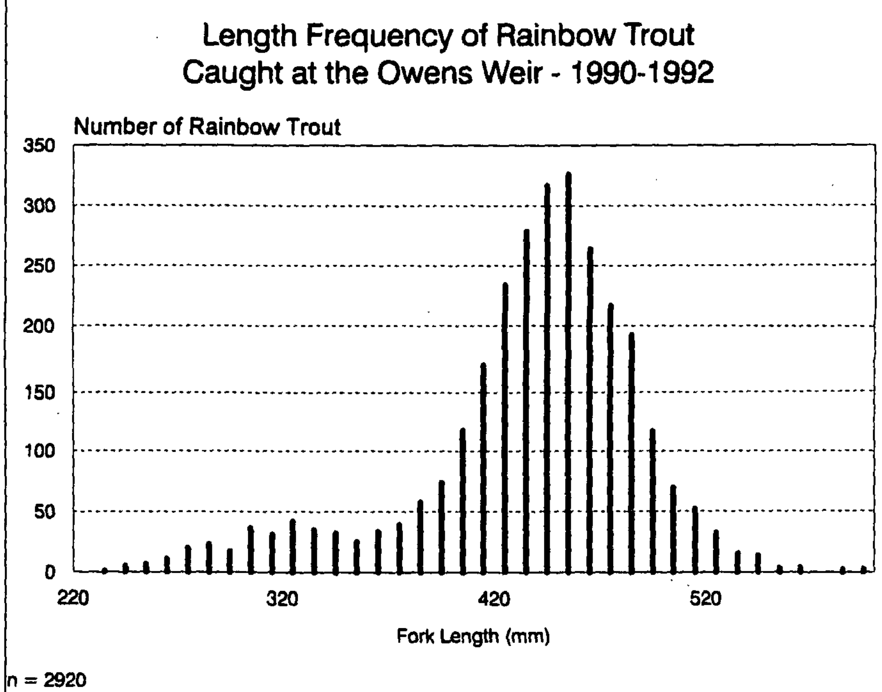
Upper Owens River Fish Migration
combined 1990 through 1992 data
Fish Caught per Trap Day
Rainbow Trout DOWN
Rainbow Trout UP
Brown Trout DOWN
Brown Trout UP
Owens Sucker DOWN
Owens Sucker UP
0
5
10
15
20
25
30
Jan 1
Feb 20
Mar 32
Apr 40
May 77
Jun 71
Jul 33
Aug 35
Sep 25
Oct 53
Nov 46
Dec 16
Values below months are total days of trap operation over the three year study period

Rainbow Trout

RT movement into the upper Owens River was concentrated during two periods: in the spring peaking in March, and in the fall peaking in November. The much larger spring run was comprised hatchery and wild individuals.

Smaller RT captured at the weir were mostly catchable hatchery trout stocked near the Benton Bridge, while larger fish were spawning RT from Crowley Lake. The median size spawning RT was approximately 455 mm fork length, or approximately 19 inches total length (Figure 19).

Figure 19.



On opening weekend in 1993, the catch of wild RT greater than 15 inches was estimated to be 25% of the total carryover trout catch. During the next three months, wild RT comprised an estimated 8.6% of the total catch of trout by boat anglers. Their contribution during the second season is difficult to monitor since almost all trout are released. However, wild RT and RT-ELT have dominated Department fall electrofishing samples of trophy-sized trout, indicating their importance during the second season. These findings depict the status of wild trout under drought-impacted conditions. Wild trout presumably contribute more to angler catches during periods when conditions for wild trout production are improved.

The density of wild trout in several sample stream reaches on Convict and McGee creeks was estimated in 1994 to be greater than 1,000 fish (mostly young-of-the-year) per 100 meters of stream (R. Knapp, unpublished data). The abundance of wild trout indicates their potential to greatly contribute to stream and lake fisheries. Further investigations of the contributions of wild trout to Crowley Lake and tributary fisheries are needed.

Brown Trout

BN have never contributed more than a minor component to the total catch of trout at Crowley. However, they are highly regarded as a sport fish, being long-lived and reaching a large size. BN up to 12 pounds were captured in the Owens weir, and since 1987, Department personnel have documented specimens weighing over 15 pounds in the reservoir. In recent years the numbers of BN in the catch have declined from an average of approximately 10% of the opening weekend catch to less than 2%. A decline in BN catch has been observed during the second season, with very few trophy-class specimens being reported. The following may have contributed to these declines: persistent (1988-1993) drought impacts to spawning and nursery habitats, reductions in forage fish abundance, reductions in productive lake habitats associated with higher water storage, and the failure of hatchery BN stocks to augment the fishery. The loss of wild trout juveniles to irrigation diversions has, and continues to be, a concern to the Department.

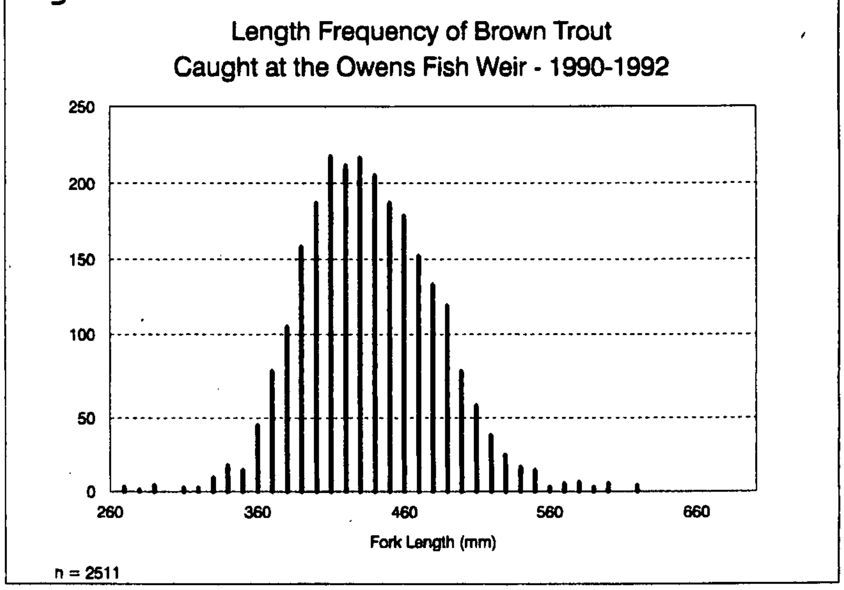
Capture rate of BN at the Owens weir peaked in November. However, with good water quality, BN migrate upstream as early as June. An estimated 48 percent of the total upstream migration of BN during the weir study occurred during the months of June through September, with the remainder of the run going from October through December. Almost all downstream BN movement occurred after September. The median sized BN was approximately 435 mm fork length, or approximately 18 inches total length (Figure 20).

The strain of BN stocked into Crowley Lake prior to 1985 was known as the Whitney BN (BN-W) and was maintained at Mt. Whitney Fish Hatchery, Inyo County. From 1975 to 1984 approximately 879,000 subcatchable or larger BN-W were stocked into Crowley. In 1984, it was discovered that the BN-W were infected with whirling disease and the broodstock was destroyed in an effort to eliminate the infection. An attempt to reestablish the BN-W strain in 1987 with fish from the Owens River Wild Trout Area near Bishop, CA was unsuccessful. Several strains of BN were imported from other state and federal hatcheries and stocked int Crowley Lake. Since 1985, 224,360 BN subcatchables or larger have been stocked. Of the 41,500 adipose-marked BN stocked during the course of the study, only five were observed in the catch during the three years of Department angler surveys. Moreover, none of the 2,511 BN caught at the Owens weir were marked. The hatchery BN stocked at Crowley during the study wer ineffective in supplementing the wild stocks, so the allotment was canceled in 1993.

The development of a Crowley strain of hatchery BN is currently underway. Eggs have been collected from wild Crowley BN during the fall of 1993 and 1994 to develop a new strain, BN-C (BN-Crowley strain). A second strain, BN-W, also is being developed from eggs taken from BN in Oak Creek, Inyo County. The progeny of these two broodstock will be available in 1996 for use at Crowley Lake to augment natural recruitment. An experimental allotment of 25,000 BN-C and 25,000 BN-W subcatchables for Crowley Lake is set for 1996.

Augmenting the numbers of BN in the Crowley system through tributary spawning and rearing habitat improvement, reducing losses of wild BN juveniles from irrigation ditches, and by stocking BN strains developed from local stocks should improve B catch rates and increase the numbers of unusually large trout.

Figure 20.



Growth of Trout

Growth rates of Crowley Lake RT and BN are among the highest ever recorded for resident trout populations in an alpine or semi-alpine setting (von Geldern 1989). Pister (1965) calculated length at ages I, II, and III, at 10.1, 15.8, and 19.9 inches and 9.4, 14.6, and 18.7 inches for RT and BN, respectively.

Average lengths of age I and II trout that were stocked as subcatchables in 1991 and 1992 and caught by anglers in 1993 remain close to those reported by Pister. However, the use of different hatchery strains with different hatchery resident times makes exact comparisons impossible (Figures 21 and 22). There is no indication that the growth of hatchery trout is different from historic rates.

Figure 21.

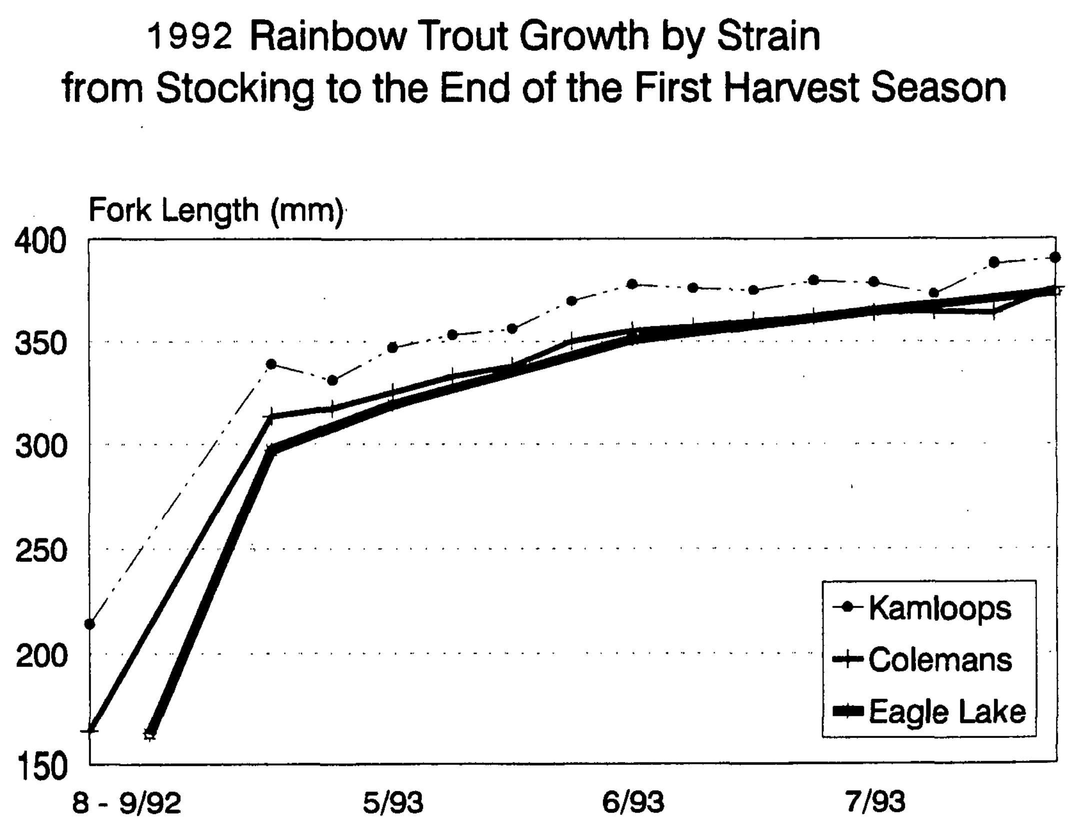
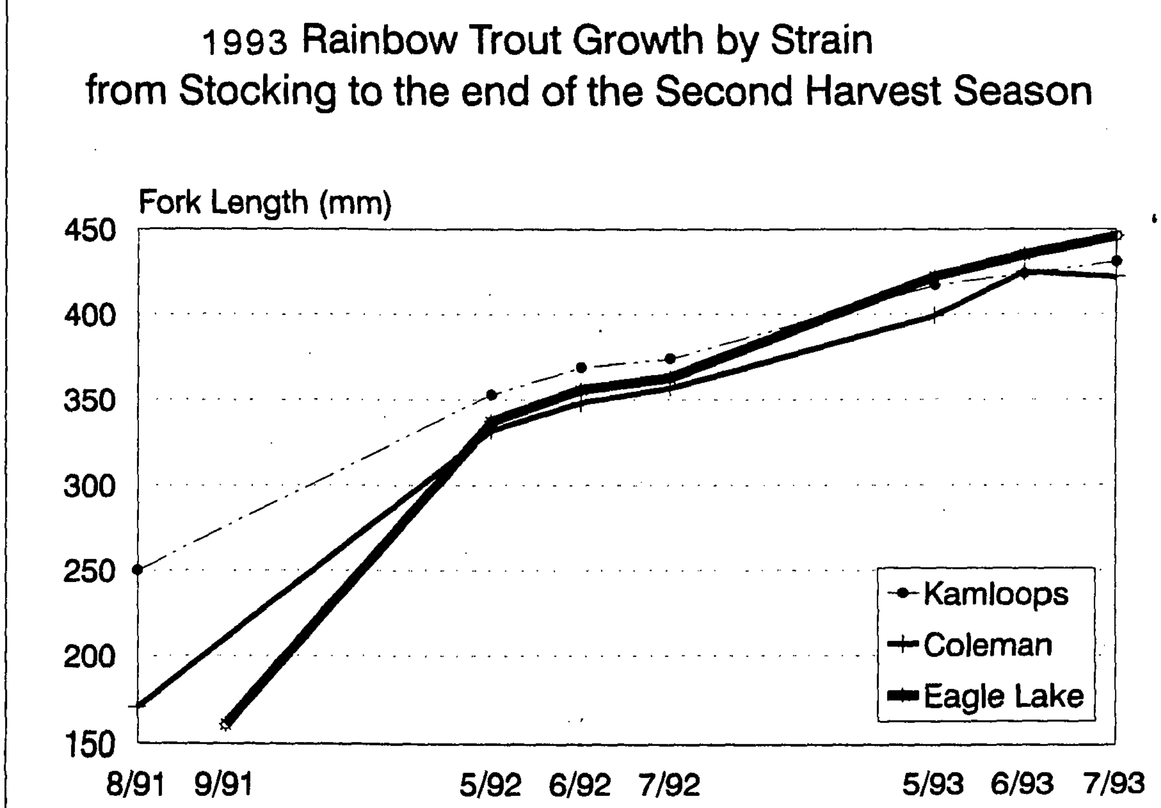


Figure 22.



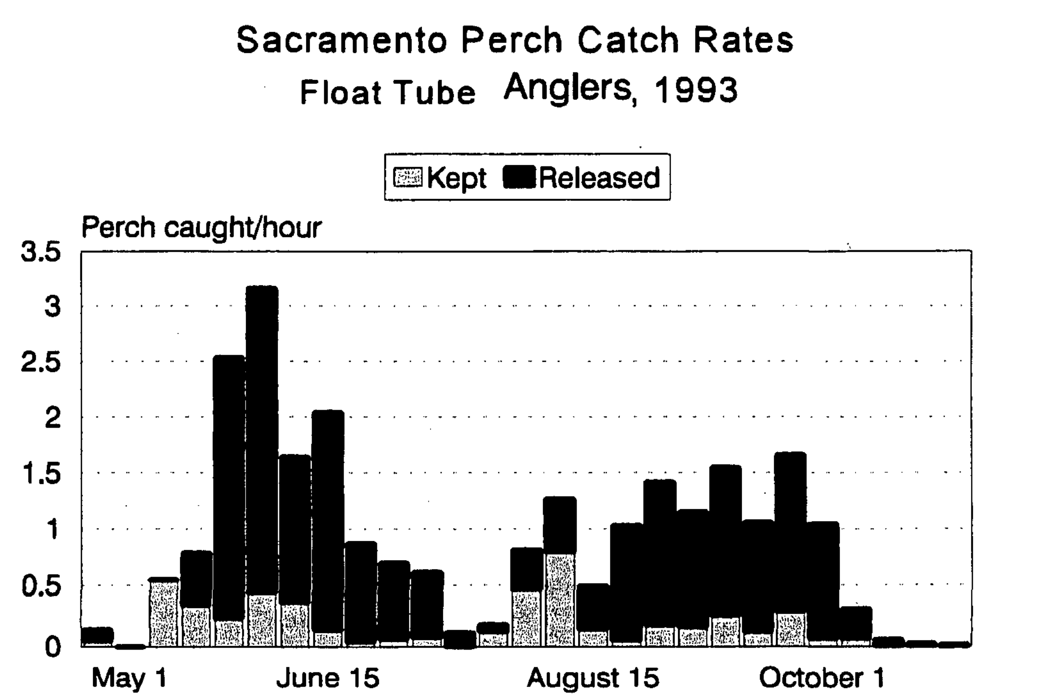
Sacramento Perch

On September 23, 1965 Sacramento Perch (SP) were discovered in Crowley during Department surveys. They were probably illegally introduced several years prior. Their numbers increased until they began to appear in the catch in 1968. Subsequently, they were found in the DWP penstock and are established in Pleasant Valley Reservoir.

Early concerns that the species would become so numerous as to stunt, as well as compete for food with trout did not manifest themselves; Crowley produced the current state record SP in 1987 at 3 pounds 10 ounces. Trout growth appears unaffected by the introduction of SP. Though SP consume the same food items as trout, they contribute to the forage base for trout, attract large trout into shallow water, and are themselves the subject of a fast action fishery. SP in Crowley supplement angling opportunities and are highly regarded for their eating quality.

Float tube anglers, who generally release legal-sized trout, often keep SP (Figure 23).

Figure 23.

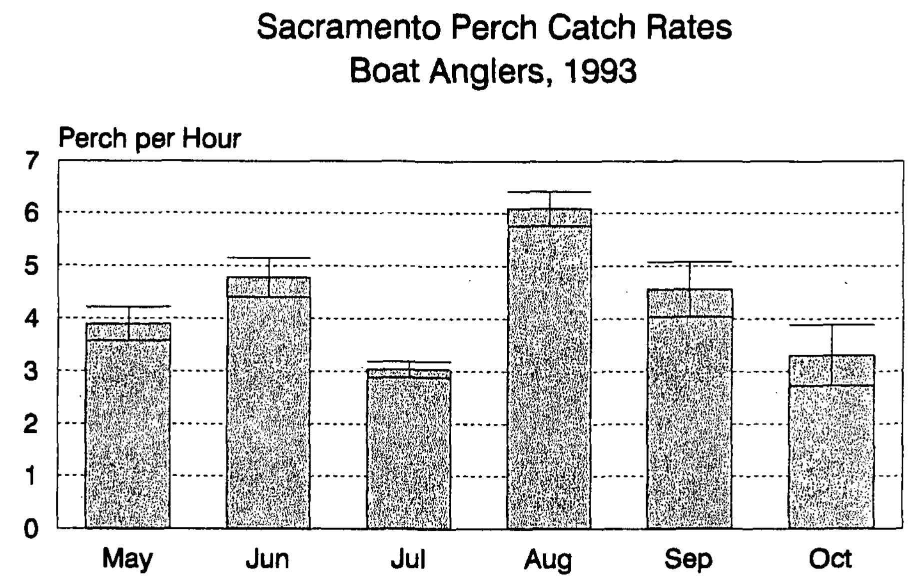


By 1992 the SP fishery at Crowley appeared to have recovered from a population crash in 1989. Prior to August 1992, few SP were observed in the catch. From August 1 through October 31, surveyed boat anglers had kept 5,803 SP and an additional 967 were released. These fish were caught in 2,757 hours, or 2.5 SP per hour of fishing effort (caught and kept combined). The average length of SP kept (n=169) was 23.6 cm (9.3 inches). The average weight (n=138) was 322 g (0.71 lb).

In 1993, SP angling continued to improve and by August boat anglers targeting perch averaged over six fish per hour, and over 20 perch per trip (Figures 24 and 25). The weight/length relationship of 516 SP caught in Crowley Lake in 1993 is presented in Figure 26.

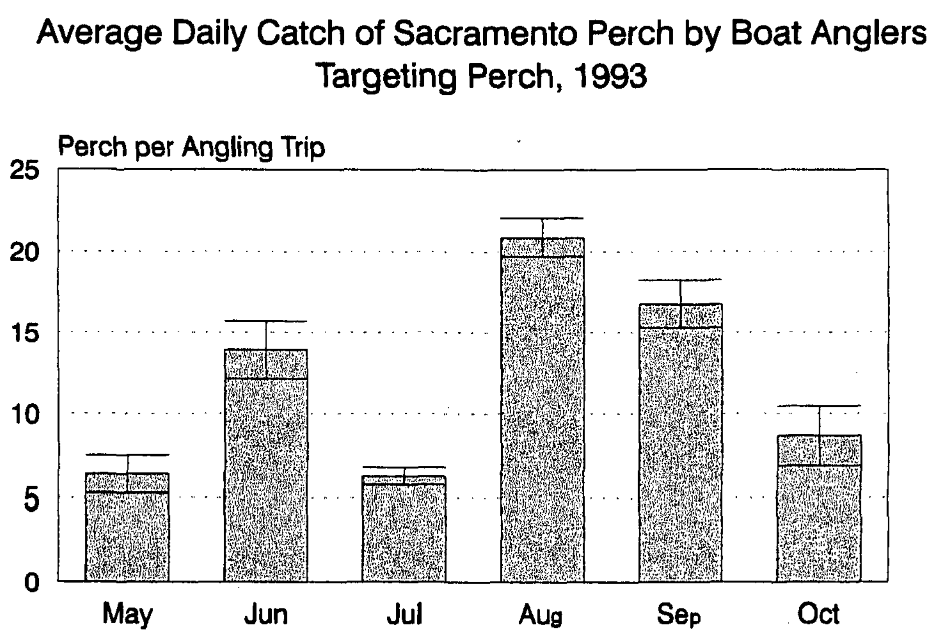
Monitoring SP growth and catch rates should provide adequate information for management of this popular fishery. Although it is common to observe catches exceeding 50 SP per angler during the peak of the season, restrictions on SP harvest do not appear warranted at this time.

Figure 24.



Catch rates are monthly averages of individual angler catch success
Error Bars = +- one SE

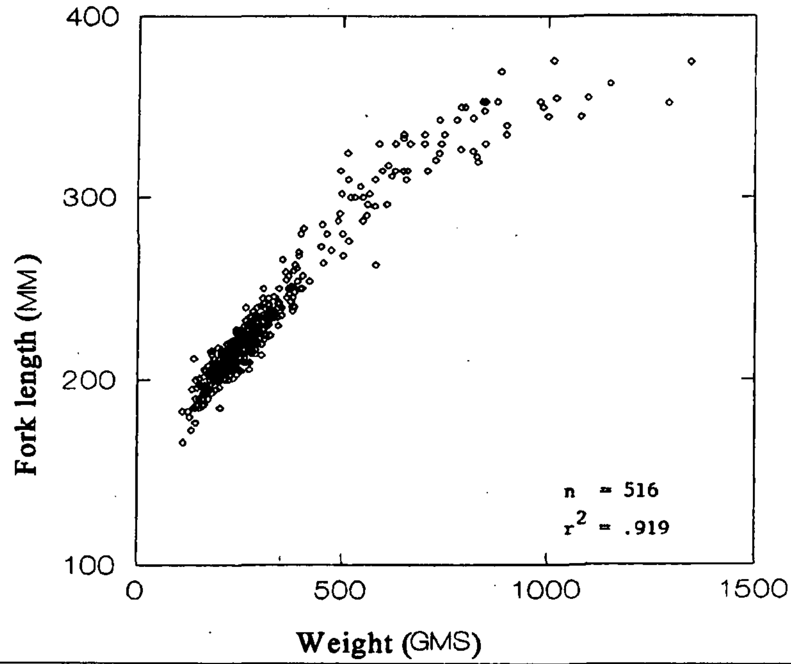
Figure 25.



Error Bars = +- one SE

Figure 26.

Sacramento Perch - Weight/Length Relationship
Crowley Lake - 1993



Food Habits - Trout and Perch

In 1958, Pister completed the first analysis on the diet of trout from Crowley. He noted that all RT stomachs examined during the early angling season contained chironomids, and that the pupal life stage comprised 89% of the total volume of natural food (some fish stomachs contained fish bait)(Pister, 1960). Zooplankton were present in 33% of the stomachs sampled, comprising approximately 10% of the total volume of organisms consumed (Appendix 3). Nine BN stomachs examined in 1958 contained approximately equal volumes of ramshorn snail (*Helisoma* sp.) and chironomid pupae.

A small number of stomach samples were taken during July 1982 to determine the relative importance of zooplankton as food for trout and SP, and what the effects would be on fish growth of chemically treating the lake with an algicide (Loudermilk, 1982). Results indicated that SP relied very heavily on larger cladocerans (*Daphnia* sp.) and trout consumed fish, chironomids, and cladocerans.

The food habits of trout and SP during the fall and winter months were studied in October 1993 and February 1994. Fish were collected in the fall by electrofishing. All trout (n=28) and five of the six SP, contained chironomid pupae, and most contained chironomid larvae in their stomachs. Cladocerans also were well represented in the samples with the highest total count of individual organisms, but a lower total volume than chironomids. Snails of the family Physidae were present in 53% of the stomachs sampled. Only one fish, a SP, had consumed another fish, also a SP (Appendix 3).

Winter samples were taken with gill nets at a time when the lake was partially ice-free. Cladocerans were the dominant food item, present in 94% of the stomachs sampled (n=16). This appears consistent with observations from fish sampled under the ice by biologists in the 1970's (Robert Toth, pers. comm.). The fact that only two chironomid pupae were found in all stomachs sampled is not surprising. Chironomid pupae generally remain in or near the bottom of lakes and do not become readily available for consumption by fish until their journey to the surface to emerge as adults. Emergence during the mid-winter period is not typical for this organism. The more active larval state is more vulnerable to predation and were present in 37.5% of the stomachs sampled.

Abundant populations of non-game fish and young SP have been assumed to be important food items for larger trout during the fall and winter periods. However, research has not documented the extent to which this is true. It is likely that trout do rely on small fish at certain times of the year; however, limited sampling has only documented the most common food items consumed during the periods sampled. Chironomid pupae and larvae appear to be the most important food items for trout growth based on the volumes consumed and their frequency of occurrence in the stomachs sampled.

Non-Game Fish

Native fishes in the Long Valley portion of the Owens River drainage are the Owens sucker, *Catostomus fumeiventris* (Miller); Owens tui chub, *Gila bicolor snyderi* (Miller); and speckled dace, *Rhinichthys osculus* (Hubbs, Miller, and Hubbs).

The type locality of the Owens sucker is Hilton Creek, tributary to Crowley Lake. Populations of this species are found throughout the Owens River system. Owens suckers spawn during late May through early July in the Owens River and Crowley Lake (Moyle 1976). Suckers up to 50.5 cm fork length (20 in) and over 1.5 kg (3.3 lb.) were trapped at the Owens weir from March through July. The mean fork length and weight of the 928 suckers trapped at the weir over the three year study was 36.7 cm (14.4 in) and 0.66 kg (1.45 lb).

Owens tui chub have been listed as an endangered species since 1974 by the State of California, and since 1985 under the Federal Endangered Species Act. Hybridization with other tui chub subspecies illegally introduced as bait fish has resulted in extensive losses of pure populations of Owens tui chub. Hybridized tui chub up to 300 mm (12 inches) reside in Crowley and are believed to be seasonally important food items for trout and birds.

Speckled dace have not been documented in Crowley Lake, but they reside in a small tributary to Hot Creek. It appears that dace do not coexist well with trout and have been extirpated from much of their former habitats in the drainage. The taxonomic status and potential future listing of Owens dace as a species of special concern is currently under review (Donald Sada, consulting biologist, pers. comm.).

Both the tui chub and the speckled dace are identified as target species in the draft Owens Watershed Multi-Species Recovery and Management Plan. This Plan is being developed by the U.S. Fish and Wildlife Service and is scheduled to be finalized in 1997.

CROWLEY LAKE TRIBUTARY FISHERIES[1]

Upper Owens River

The upper Owens River has been surveyed by Department Wild Trout Project personnel since the mid-1980's as a part of their statewide stream inventory to identify potential special regulation waters. The quality of the trout fishery has led to consideration of the upper Owens River for special wild trout management (David Lentz, 1993). In the Mammoth Lakes Basin fisheries management plan, von Geldern (1988) states "Private ranches between Big Springs and Benton Crossing control some of the finest trout fishing available in California today." The section on DWP land located downstream of private ranches meanders through a meadow which has been grazed intensively and supports little riparian vegetation capable of providing cover or

[1]See WATER RESOURCES section for tributary site descriptions.

aquatic habitat enhancement (D. Lentz, 1993). Anticipated fencing projects will control livestock distribution and furth improve fish habitat. As the largest tributary to Crowley Lak the Owens River provides spawning and rearing habitats for wil trout, and has a fishery of notable reputation. In addition, management of the land, flow regime and fisheries of the upper Owens River is intricately linked to the success of Crowley La fisheries.

The Department's Wild Trout Project has focused sampling effor on the DWP-owned section of upper Owens River. A study reach located at the upstream end of this section has been sampled i the fall four times since 1985 using backpack electrofishers. This reach supports high numbers of trout, usually greater tha 5,000 per mile, and has had standing crops in excess of 120 pounds per acre (Appendix 4). These values are high compared t other California wild trout streams.

Other reaches of the river that include deep pool habitats were sampled in 1989 and 1991 using a flat-bottomed, 12-foot electrofishing boat. Since fish were observed escaping the electric field in areas where the river channel is wide or deep mark-and-recapture estimates were made in 1991. Trout density estimates for the deeper pool sections were much lower than for the run/riffle-dominated reach sampled with backpack gear. Whether this was a result of the difference in the habitat type or a limitation of the sampling procedures was not determined.

Although estimated densities of trout in the deeper pool habita were lower than expected, trout size was noticeably larger. BN over 12 inches ranged from 11 to 24% of the total sampled in th deep pool reaches and 4 to 13% in the run/riffle reaches. Sinc all sampling was done from mid-September through mid-October, t presence of fall spawning BN and RT from Crowley was expected. The sample of BN and RT greater than 12 inches was comprised of both resident and migratory fish.

Looking at all the trout sampled from 1985 to 1991, RT were muc more abundant than BN (2,597 RT and 1,209 BN), but BN represent an average of 83% of the total trout biomass. Nearly 91% of th RT sampled were young-of-the-year (< 6 inches). Many of these juveniles will eventually migrate into Crowley Lake, though the proportion that move and the timing of migration is not known.

Even though BN spawn in the fall, trapping results from the Owe weir show that BN migration starts as early as June, at the end of the spring RT run. Fall spawning RT were intermixed with trapped BN, but were much less abundant, as reflected also in t electrofishing results. These findings support angling regulations that protect spawning BN and RT by restricting the take of large trout in the upper Owens River.

The catchable trout allotment on the upper Owens River is 2,100 RT stocked at Big Springs, and 28,800 RT stocked near Benton Bridge road crossing. The numbers of trout stocked may be modified under the new angling regulations.

McGee and Convict Creeks

In 1984, the Department surveyed 80 reaches within 29 streams in the Owens River drainage and estimated trout density and standing crop. Within Long Valley, two reaches on Convict Creek and one reach on McGee Creek were surveyed (Appendix 4). Although habitat degradation was noted to be severe, the numbers of young-of-the-year wild BN in one reach on Convict Creek ranked fifth out of the 80 reaches surveyed.

The catchable trout allotment is 9,200 RT for McGee Creek, and 15,400 RT for Convict Creek. Hatchery trout are stocked from Highway 395 upstream through the campground areas on McGee Creek, and above the U.C. study area on Convict Creek. To improve wild trout production, current angling regulations restrict trout harvest during periods of highest spawning activity.

Hilton and Whiskey Creeks

Hilton Creek empties into Crowley Lake at Hilton Bay and Whiskey Creek empties into Crowley Lake at South Landing Bay. Both these streams provide spawning and rearing habitats for Crowley Lake trout. Spawning habitat within these creeks may be enhanced by the addition of gravel, which is currently limited. A proposed gravel enhancement project may be developed in cooperation with University of California, Berkeley, researchers.

Current angling regulations on Hilton and Whiskey creeks are similar to Convict and McGee creeks. There is no trout stocking allotment for either creek.

Crooked Creek

Crooked Creek is the southernmost tributary to Crowley Lake. It is a small spring-fed creek that meanders through the meadows of Little Round Valley. The fish population is seasonally dominated by spawning Crowley Lake trout.

In most water years, available spawning habitat is inadequate tc support spawning escapement. Spawning habitat may be improved i good water years when sediment flushing and gravel exposure occur, as in 1995. The feasibility of augmenting Crooked Creek during low flow years with flow from existing Rock Creek diversions should be investigated.

Regulations on Crooked Creek encourage season-long angler use, while still providing protection for spawning trout through zero harvest. The creek is not stocked with hatchery fish.

Hot Creek

Trout from Crowley and the Owens River are limited in their use of Hot Creek due to high water temperature. During high runoff periods water temperatures can be low enough to attract spawning trout up to about the confluence of Little Hot Creek, although spawning success is believed to be low. The wild trout fishery in Hot Creek above several large thermal spring vents is the subject of another Department fisheries program, and is not included in this plan.

Recent Changes in Angling Regulations

In 1995, the Fish and Game Commission adopted the Department's angling regulation proposals for the upper Owens River, Convict, Hilton, Whiskey and Crooked creeks. These proposals were designed to improve wild trout fisheries and maintain quality anc diverse angling opportunities for the public. A complete listinc of angling regulations for waters included in this Plan is included in Appendix 5.

A 16-inch maximum size limit for the upper Owens River above Benton Bridge road crossing was adopted to protect spawning trout, allow harvest on stocked catchable trout, allow the oldest and largest trout to reproduce and remain in the system, and improve the Crowley Lake wild trout fishery. The 16-inch maximum size limit should increase the abundance of older and larger trout through conservation and genetic selection.

The concern that wild trout less than 16 inches would be over-harvested does not appear likely since most anglers attracted to catch-and-release waters will release almost all fish caught, including those of legal size. Additionally, data from Department electrofishing and trapping activities indicates that juvenile wild trout migrate to Crowley Lake prior to attaining an attractive harvestable size of 12 to 16 inches.

Regulating the entire upper Owens River for season-long catch-and-release would displace many anglers who prefer to harvest trout for food. To provide for a diversity of opportunity, the Department proposed the following: the reach of the upper Owens River above Benton Bridge road crossing will be managed as catch-and-release (two fish limit, 16-inch maximum size, artificial lures with barbless hooks), and the area downstream of Benton Bridge to a new fishing monument will be managed under Sierra District general regulations. The monument will be located approximately ¼ mile above the high water line of Crowley Lake, and will mark the regulated boundary between the lake and the river. The fishery below the monument will be regulated as in Crowley Lake. Since the lake is catch-and-release angling from August 1 through October 31, adult trout staging below the monument will receive greater protection than under previous regulations.

All trout moving through the reach from the monument to Benton Bridge will be available for harvest, raising public concern that an over-harvest of spawning trout may occur. Monitoring the catch and harvest of trout on the upper Owens River is a high Department priority, and will determine the validity of this concern. If needed, the Department will recommend modified regulations in the future.

WATER RESOURCES, MANAGEMENT AND ENVIRONMENTAL CONCERNS

Long Valley, a region of about 270 square miles, lies in the rain shadow of the Sierra Nevada. Average annual precipitation at Long Valley Dam is approximately 10 inches, in the form of both snow and rain. Average annual precipitation at higher elevations is greater (approximately 55 inches at Mammoth Pass) and falls mainly as snow, although summer thunderstorms are common. Runoff from high elevation snow melt generally peaks in June; however, an earlier flow increase in Long Valley streams usually occurs from in-valley snowmelt. This early increased stream flow may attract migrating spring-spawning trout from Crowley Lake.

Crowley Lake

Crowley Lake is approximately six miles long and three miles wide with a maximum surface area of 5,272 acres. At full pool, maximum depth is 114.5 feet and the mean depth is 34.85 feet. Volume at spill level is 183,743 acre feet (see Appendix 6 for Area and Capacity curves). Relatively high total dissolved solids, combined with a shallow mean depth, result in a highly productive system (Pister 1960).

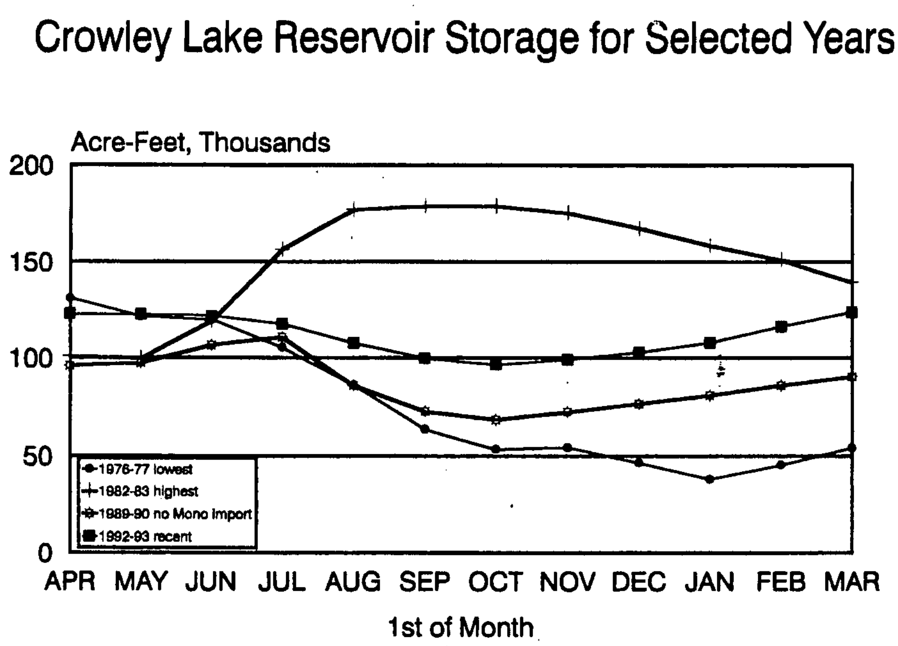
Lake Level Management

Annual precipitation in the Long Valley area is highly variable, and the management of the reservoir reflects to a large degree the annual runoff. Other important operational concerns for Crowley Lake, the largest reservoir in the DWP aqueduct system, include water system storage requirements, downstream irrigation demands, hydroelectric power generation, importation of Mono Basin water, and routine maintenance. Figure 27 illustrates reservoir storage variability between the highest and the lowest years for the period of record. Storage generally peaks coincident with high elevation snowmelt runoff. Peak storage is reached at a later date in wet years than dry years (Figure 28). Large reservoir fluctuations, such as those experienced at many west-slope reservoirs, are attenuated at Crowley since increases in reservoir outflows coincide with peak inflow periods.

The Department has determined that maintaining Crowley Lake at stable levels is beneficial for trout growth and fishery performance. Pister (1965) noted occasional unusually good growth of trout which was attributed to both reservoir management and a decreased period of winter ice conditions. During one such good growth period, Crowley surface acreage increased from 3,950 on November 1 to 4,450 on May 1, 1963. It was assumed that shoal area food production and conditions for trout growth were much improved under these conditions.

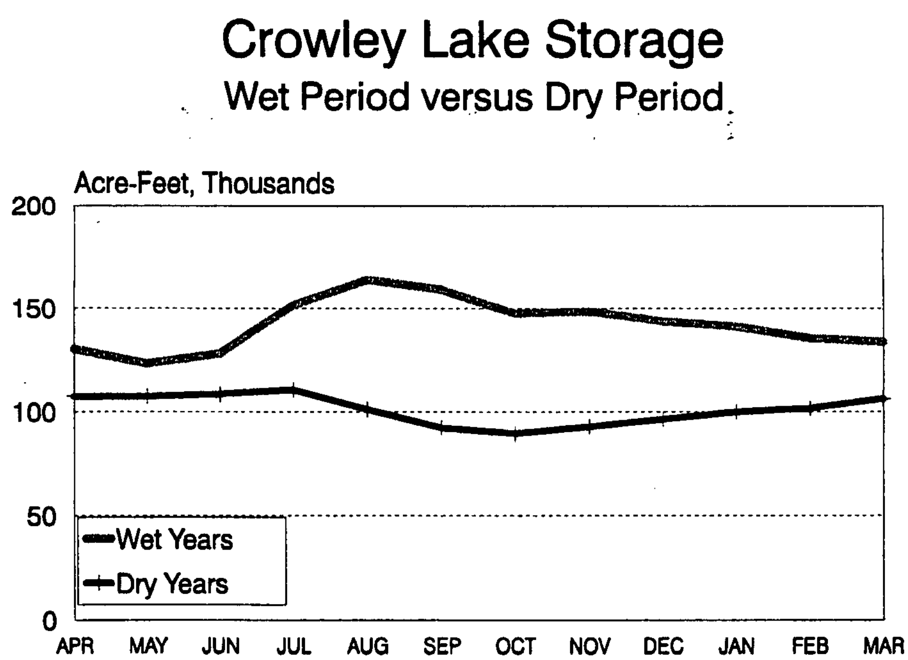
The presence of rooted aquatic vegetation in the littoral zone is important to the production of fish and invertebrates. In Crowley, Sacramento perch utilize the shallow areas for spawning and nursery habitats. Young-of-the-year perch feed mostly on small crustaceans that are usually associated with the bottom or aquatic plants (Moyle, 1976). The presence of beds of rooted aquatic vegetation is perhaps the most important characteristic of perch habitat in Crowley Lake.

Figure 27.



Years selected represent lake level extremes, first year without Mono Basin import and recent data

Figure 28.



Wet period is 1980-81 through 1985-86
Dry period is 1988-89 through 1992-93

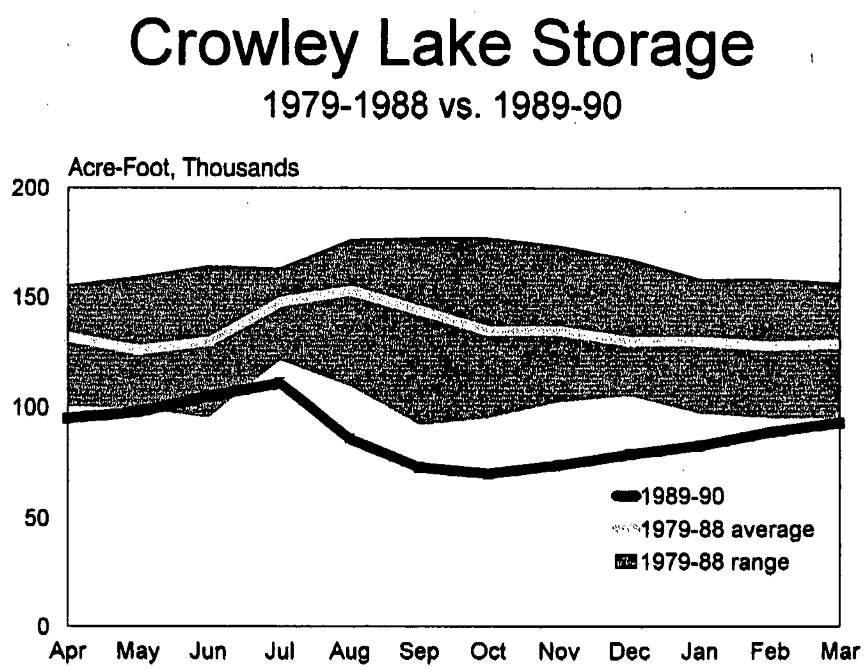
Foraging large trout are attracted to small SP and invertebrates associated with weed beds in the late summer and fall. Since this occurs in relatively shallow water, these large trout becom more available to anglers in float tubes and from shore, as was the case in the mid-1980's during high water years.

Rooted aquatic vegetation is usually abundant along much of the Crowley shoreline. In recent drought years, the reservoir has been drawn down, and by mid to late-summer weed beds have consolidated into thick, nearly impenetrable mats of rotting vegetation. Invertebrate production, dependent upon healthy vegetative communities, declines; rearing habitat for perch is lost as cover normally associated with this habitat collapses; and large trout are less attracted to shallow waters. Anglers, especially those fishing from shore, have difficulty landing fis through these consolidated mats. For these reasons, stable, or increasing lake levels during the vegetative growth period are desirable, and are necessary to achieve quality shallow water angling in the fall.

In 1989, a rapid drawdown apparently contributed to a large fisl kill. The nearly complete loss of the Sacramento perch population in 1990 through 1992 appears to be the direct result of rapidly lowering the lake to below-normal elevations in the fall. Due to drought conditions and the restriction on exporti Mono Basin water, there was a substantial reduction in the amou of water stored in Crowley Lake compared to the preceding ten years (Figure 29). A rapid drop during the period July through October resulted in a reservoir level below all previous ten ye minimums. Tributaries to the reservoir flowed over newly expos lake sediments and were observed to quickly incise new channels In the process, large volumes of sediments were flushed into deeper areas of the reservoir. The following spring thaw (1990 uncovered many thousands of dead perch scattered along the shoreline.

Water samples collected at Long Valley Dam by the DWP in Februa 1990 contained greater concentrations of mercury and other elements than samples from the upper Owens River (Doug Ball, pers. comm.). The differences in concentration suggest an in-reservoir source. Mercury accumulates in sediments just centimeters below the sediment/water interface. Mercury concentrations in the reservoir water samples were likely elevated due to the described sediment flushing event. It is unlikely that perch were killed or affected in any way from mercury poisoning. Rather, in this case, mercury is simply a detected marker of flushed sediments. It appears reasonable th the perch suffered asphyxia as oxygen-demanding substances were also liberated during the event.

Figure 29.



It appears that the degraded water quality that developed in deep zones of the reservoir had a disproportionate impact on Sacramento perch. During the fall period, trout are still active feeders and many remain in shallow water. Conversely, as the water temperature dropped, Sacramento perch, a warm water species, became inactive and migrated to deep water where they were more susceptible to the degraded water quality that developed.

Chemical analysis of flesh from large trout by the Department's water pollution laboratory disclosed no detectable levels of heavy metal concentrations, including mercury. The event described was episodic, and did not result in any known long term water quality or fishery impacts. The Sacramento Perch fishery appeared to have fully recovered by the 1993 season. This incident demonstrates that lake level management can have a profound impact on fish populations.

Maintaining reservoir storage at stable or increasing levels may not be compatible with reservoir operations by the DWP. An alternative water storage stratagem, which may benefit Crowley fisheries, would be to maintain reservoir storage at or above 125,000 acre feet during mid-June through October 31. Although this would not relieve all areas of consolidating aquatic vegetation, some reduction of this condition would be expected along the Sandy Point to Green Banks areas where reservoir morphology provides conditions for rooted aquatic vegetation ove a broader range of fluctuating water levels. These areas are characterized by drop off shelves that would remain mostly inundated at storage above 125,000 acre feet. Further evaluatic of vegetative growth and responses to reservoir management is needed.

DWP Algae Control

Algae have been a chronic problem for Crowley Lake anglers, yet it is not uncommon to hear about how the "algae problem is worse than ever". Algae are blamed for the occurrence of numerous fis kills through oxygen depletion, degradation of water quality foi Los Angeles consumers, reduced recreational opportunities and tl off-flavor taste that Crowley trout acquire later in the anglin season. However, the growth of desirable algae supports much o: the secondary productivity in reservoirs.

In 1981, the DWP initiated a water quality study to identify th cause, significance and magnitude of plankton growth as it relates to the degradation of water quality and to identify methods for the control of the plankton growth and the impacts these controls on the uses of the water (Melack, 1982). It was determined that the Crowley Lake environment favors the production of nitrogen fixing blue-green algae due to high concentrations of phosphorus combined with a general lack of inorganic nitrogen in the surface waters. The primary source c phosphorus loading was determined to be from the upper Owens River at Big Springs.

A planned chemical treatment of Crowley Lake in 1983 by DWP wit copper sulfate was intended to provide the following benefits: improve water quality, with an emphasis on taste and odor control; 2) enhanced reservoir recreation, including an increa: in the aesthetic quality of the water and improved taste of th fish; 3) increased dissolved oxygen concentrations in the reservoir and downstream; and 4) reduced power plant turbine corrosion.

The Department was concerned about the impacts that a reductio in primary productivity might have on trout growth and the fac that the efficacious concentration of copper sulfate for algae control is close to lethal concentrations for trout. A summer food habitats study in 1982 (see Food Habits) was conducted by the Department to assess what a reduction in zooplankton stanc crop might have on fish growth.

A chemical treatment of Crowley Lake with copper sulfate took place during the summer of 1983. Blue-green algae were temporarily reduced by the effort. However, trout growth, when observed the following angling season, reportedly suffered.

Dissolved Oxygen and Temperature

From May through September, 1993, a Hydrolab Surveyor 3 with DataSonde 3 was used monthly at seven stations to measure dissolved oxygen and temperature profiles in the water column (Appendix 6). Not all stations were sampled with equal effort.

Crowley Lake became thermally stratified in August at approximately 10 meters below the surface.

Dissolved oxygen (DO) concentrations in deeper areas of the reservoir were substantially depressed during August, and reached uninhabitable levels for trout (less than 2 mg/l) below approximately 10 to 13 meters. DO levels between 3 to 5 mg/l (milligrams per liter) limit trout growth, and DO levels below 3 mg/l may be lethal after prolonged exposure. In his 1960 report on Crowley Lake limnology, Pister noted ..." this oxygen deficiency at lower depth may very possibly be one of the factors contributing to the mortality of considerable numbers of rough fish and an occasional trout during the mid-summer months. This die-off is not believed to be serious enough to cause any concern regarding the survival of the fishery, but is large enough to be offensive to anglers, when dead fish drift in to shore and decompose."

Depressed oxygen concentrations may not significantly impact trout survival in Crowley; however, water exported from Crowley is taken from near the bottom and frequently lacks oxygen during the mid-summer period. This has resulted in fish mortality downstream in Pleasant Valley Reservoir and in the lower Owens River. The last such fish kill occurred August, 1996.

Aeration of the hypolimnion of Crowley Lake could effectively raise DO concentrations, potentially benefitting both Crowley and downstream fisheries. However, the destratification of Crowley, a secondary effect of many hypolimnetic aeration schemes, would have unknown effects on primary productivity and lake and discharge water temperatures. In the interim, DWP has taken several steps to incorporate oxygen into water released from Crowley to protect downstream fisheries. Operations of the Owens Gorge hydroelectric system are being modified to reduce the residence time of water in the penstock during off peak production periods. This reduces the occurrence of lowered DO by natural biological processes. DWP is developing a system by which air can be injected into the water at the Gorge power plants. DWP can also bypass a portion of Pleasant Valley Reservoir outflow through a valve which aerates the water. Flow in the Owens Gorge remains highly aerated, which increases oxyge concentration at the point where Crowley waters are discharged and mixed with the Owens River.

Temperatures at the surface during the survey period were above those optimal for trout growth. This condition coincides with depleted DO below the thermocline. Despite these occurrences, suitable habitat remained available for trout in the reservoir. This condition is common in eutrophic reservoirs in California.

Penstock Intake and Fish and Game Code §5980 - §5993

Water is diverted from the Owens River at Long Valley Dam throug a tunnel and penstock originating near the deepest location in the reservoir. The penstock and powerhouses are operated in a peaking mode resulting in times when no water is exported followed immediately with a maximum withdrawal rate of over 700 cubic feet per second (cfs). The time required to achieve the maximum water intake rate is typically less than a minute. Fish are entrained as evidenced by the large numbers of dead Sacramento Perch and tui chub periodically observed in power plant afterbays and in the tunnel pipeline when dewatered for maintenance.

There are provisions in the California Fish and Game Code (§5980 - §5993) that require the installation of fish screens for certain diversions. If it is determined that these sections apply to the Crowley diversion, the DWP may be responsible to screen the Crowley Lake penstock to prevent fish entrainment. Alternative screening technologies, including acoustic and electric hazing devices, both of which are currently being teste at other locations in California, may provide adequate protection.

Crowley Lake Tributaries

Upper Owens River

The upper Owens River is the largest tributary to Crowley Lake, having an average natural base discharge of 76 cfs above the Ea Portal of the Mono tunnel. This flow was augmented at East Portal with water diverted from the Mono Basin from 1941 to 198 increasing the average flow to 168 cfs, and altering some physical attributes of the river downstream.

Big Springs and Deadman Creek form the headwaters of the upper Owens River. It has been identified as the major natural source of phosphorus in the Crowley drainage, providing nutrients for the proliferation of aquatic plants, both in the river and in the reservoir.

Hot Creek, the largest tributary to the upper Owens River, is a source of nutrients as well as certain heavy metals. Arsenic has been detected in concentrations above current drinking water standards at certain Hot Creek spring groups, and is generally associated with the geothermal enrichment within the Hot Creek system. Through dilution, the level of arsenic at Crowley Lake does not violate current safe water standards; however, the DWP is considering the construction of a heavy metals treatment plant for Long Valley.

A Department-sponsored investigation determined that flows downstream of East Portal of 120 to 250 cfs provide habitat within 80% of the maximum for all life stages of brown and rainbow trout (Ebasco, 1993). Habitat estimates decrease rapidly as flows drop below 80 cfs. To minimize exceedence of bank-full capacity, flows less than 200 cfs are recommended from below East Portal downstream to the confluence with Hot Creek. The Department further recommends that natural in-basin supplies to the upper Owens River remain instream to provide at least base flow to avoid habitat loss. When diversions from the Mono Basin resume, they should occur at a relatively constant rate, avoid overbank flows and be used to attenuate high summer temperatures. No flushing flows are necessary, as flows above 20 cfs are believed sufficient to transport fine materials and maintain spawning gravel.

In 1990, a habitat characterization study was completed and habitat improvement projects were recommended (Ebasco 1993). These include plans to replace channel meanders cut off by high flows, stabilize eroded stream banks, and revegetate riparian habitats. Although the Department is not currently advocating the active intervention restoration program, suggested grazing management reform would benefit fishery resources and minimize fish losses to irrigation diversions.

McGee Creek

The mean annual flow of McGee Creek is 30 cfs. Much of the flow is diverted seasonally for pasture irrigation below Highway 395. Numerous unscreened diversions with associated fish losses are a concern to the Department. Water quality parameters for McGee and Convict creeks measured in 1992 did not reveal any significant water quality problems (Appendix 6); however, nonpoint sources of pollution may occur undetected by standard monitoring methods.

The McGee Creek channel is overwidened and devegetated as a result of over 120 years of season-long continuous livestock grazing. It now shows encouraging habitat improvements from alternative grazing management implemented by the DWP in 199[illegible] (see grazing section).

Convict Creek

Convict Creek joins McGee Creek approximately 1 mile west of Crowley Lake, and has a mean annual flow of 25 cfs. However like McGee Creek, flow is greatly reduced in the Crowley mea[illegible] by unscreened irrigation diversions. The creek is habitat f[illegible] spawning and rearing salmonids and Owens sucker.

The Sierra Nevada Aquatic Research Laboratory (SNARL) is loc[illegible] on Convict Creek approximately 1/3 mile west of Highway 395. SNARL researchers, initially financed by the Department, investigated riparian community resource changes related to improved livestock management (Knapp et al., 1993), and much the following is from their work.

The portion of Convict Creek on SNARL land serves as an exce[illegible] example of an ungrazed stream ecosystem having a deep and na[illegible] stream channel conformation with relatively unembedded substrates, heavy shading by riparian vegetation, and many d[illegible] undercut banks. Riparian vegetation along this reach is dominated by willow of all age classes and deep-rooted sedge grasses. Adjacent grazed sections of the creek, conversely, wide and shallow with few undercut banks, more embedded substrates, and little shading by riparian vegetation. The remainder of Convict Creek has large areas completely devoid riparian vegetation. However, recent improvements in grazin[illegible] management by the DWP have resulted in marked responses in riparian vegetation recovery under varying livestock use. Livestock distribution is now more controlled and grazing strategies appear to be more compatible with stream and ripa[illegible] systems. Of the creeks tributary to Crowley, Convict Creek shown the greatest habitat response to the new livestock management.

In the 1970's, a fish trap was operated on Convict Creek by researchers to monitor adult and juvenile trout movement. I[illegible] 1983, the creek rerouted during a high flow event, and bypas[illegible] the trap leaving it unusable. Restoration and operation of trap could provide species and strain specific information [illegible] for trout management.

Hilton Creek

Hilton Creek becomes divided as it runs through the community of Crowley Lake, reducing the value of this stream system for resident and migratory trout. The mean annual flow of Hilton Creek is 11 cfs.

Current and historic livestock management has resulted in sparse riparian vegetation and bank erosion that are detrimental to fisheries. The presence of large bed elements (cobble to small boulders) likely prevents further down cutting and gully formation. Though the stream is a minor tributary, it can become densely populated with adult trout seeking spawning habitat, which is sparse. Fish barriers, present under certain conditions at Highway 395, should be removed.

Crooked Creek

Crooked Creek, originating in Little Round Valley, is a small, spring-fed creek which is sometimes augmented with flow from Rock Creek via an Inyo National Forest irrigation diversion and/or the DWP Rock Creek Diversion. The creek has high sinuosity, undercut banks and good trout spawning habitat; though, prolonged low flow conditions have contributed to siltation. Irrigation diversions for sheep grazing exacerbate the siltation problem and restrict fish movement. This stream has good potential for habitat improvement through managed flow augmentation and removal of fish barriers. The mean annual flow of Crooked Creek is 4 cfs.

Irrigation Diversions

Unscreened irrigation ditches exist on the upper Owens River, Convict, McGee, Hilton and Crooked Creeks. Fish have been found in abundance in irrigation ditches, and some ditches may actually provide habitat for juvenile trout when watered. However, all irrigation ditches cease flowing at the end of the grazing season, in the fall, which results in a loss of trout and native fishes.

McGee Creek Diversion #29 was surveyed in September, 1989. A 40-meter section was blocked off with nets, and fish were captured during two passes of a Smith-Root Model 12 backpack electrofisher. A total of 166 trout were captured (162 rainbow trout; 4 brown trout) resulting in an estimated 173 trout (95% C.I. = 166 to 181) in the study reach. The extrapolated value is based on a short section of ditch and is valid only as an indicator of the potential magnitude of fish entrainment.

All but two of the rainbow trout and half of the brown trou sub-yearling fish, averaging 65 mm each for the rainbow tro 70 mm for the brown trout. Sub-yearling rainbow and brown were caught by similar methods in McGee Creek in September, These fish averaged 54 mm for the rainbow trout (n=210) and for the brown trout (n=545) (R. Knapp, unpublished data). from the creek and the irrigation ditch were of similar siz condition, indicating the potential of some irrigation ditc provide adequate, but ephemeral rearing habitat. Fish have little or no opportunity to return to the creek once water longer diverted, and are quickly consumed by predators.

Losses of wild trout to unscreened irrigation diversions ap to be the single largest source of anthropogenic fish morta on Crowley tributaries. The Department is responsible for screening costs on irrigation diversions, if that method is to limit wild trout mortality. This expensive option shoul be used where resource losses are great and the use of the diversion as a temporary rearing habitat is impractical. T issue will be addressed in the Management Direction section relief from this historic impact will require close coopera with the DWP.

Seasonal high stream flows provide vital forces that mainta fisheries habitat, channel form and adjacent vegetation, of channel riparian habitat, and possibly valley form (Platts, 1990). The attenuation of peak flows through an irrigation network alters some of these processes. Irrigation diversi during base-flow periods can reduce fish habitat and cause quality conditions lethal to fish and invertebrates.
The irrigation practices in Long Valley should be evaluated determine their impacts on fisheries, water quality, stream channel form, and the effectiveness of meeting irrigation objectives in light of new grazing management practices.

SURROUNDING LAND MANAGEMENT AND ASSOCIATE ENVIRONMENTAL CONCERNS

Although the Department originally conceived a plan for the alone, "Surrounding Land Use Practices" was ranked as the n one issue of concern at the June 1991 Crowley Plan scoping meeting. Specifically, the group prioritized the following actions under this issue: 1) identify the effects of land u practices on hydrology and water quality, 2) manage Crowley and the watershed as a single entity, 3) seek land use prac compatible with the management plan, and 4) determine effec proposed development at Big Springs.

Grazing

Livestock grazing is the most widespread land use practice in the intermountain region of the United States; this is also true of the area surrounding Crowley Lake. During its 150+ year history, livestock grazing has profoundly altered both geomorphic and ecological features of the landscape. The sensitive nature of riparian areas has made these ecosystems particularly vulnerable to impacts caused by livestock. In many areas, grazing has eliminated bankside and riparian vegetation, increased soil erosion and compaction, sedimentation, organic pollution, channel incision, and undesirable fluctuations in stream temperatures (Platts, 1990). Increases in nonpoint source pollution have resulted in deteriorating habitat quality for stream life and fisheries (Knapp et al., 1993).

Los Angeles Department of Water and Power

The lands surrounding Crowley Lake and its tributary waters have been grazed since around the 1870's by sheep, cattle and horses. Up to 100,000 livestock (mostly sheep) are reported to have used the Long Valley range during summer months in the 1880's. Overstocking of the range was reported in local newspapers in 1895 resulting in early livestock withdrawal from the area (D. Babb, pers. comm.).

Nearly all of the DWP lands in Long Valley (approximately 21,000 acres) continue to be leased for grazing. Most of these lands are located in the valley bottoms and meadows, and contain much of the riparian and wetland habitat in Long Valley. In 1992, the DWP initiated a program in Long Valley through which lessees cooperated with Dr. William Platts, a noted authority on grazing and fisheries interactions, to develop, implement, and monitor alternative grazing strategies. The goal of the resultant fencing projects has been to enhance riparian and upland habitats through better distribution and control of livestock, while maintaining current livestock production. The DWP characterizes these management strategies as "adaptive management". Changes in management strategies occur as required to meet the project goal.

The DWP implemented range and riparian fencing projects on Convict and McGee Creeks during the summer of 1992. They have reported increases in willow and other streamside vegetation. The pastures surrounding Mammoth Creek on the Chance Ranch were fenced during fall, 1994, and should likewise benefit from improved livestock distribution. The upper Owens River above the Benton Bridge Road crossing was fenced in 1996 and the reach of river below the bridge is scheduled to be fenced in 1998.

These alternative grazing strategies are substantial improvement over historic land management practices. When implemented fully improvements to fisheries will result as riparian recovery proceeds. To better determine the results of DWP fencing projects, the Department funded baseline habitat surveys in 1992 This effort by researchers from the Sierra Nevada Aquatic Research Laboratory, was expanded when funded by the Water Resources Center of the University of California. Their continuing work is funded by the U.S. Environmental Protection Agency, and focuses on physical and biological techniques to evaluate non-point source pollution.

Grazing plans identify the continued use of flood irrigation to increase forage, primarily for cattle and horses. Current irrigation practices also appear to maintain wetlands along the west shore of McGee Bay providing shorebird and waterfowl habita Water is diverted from Mammoth, Hot, Convict, McGee, Crooked, ar Hilton Creeks and the upper Owens River with an estimated 40 to diversions in seasonal operation. Under normal conditions, the DWP allots 5 acre feet of irrigation water for each acre of irrigated pasture. Due to the effects of the prolonged drought 1987 to 1994 on stream flows, the DWP placed restrictions on irrigation in the hopes of increasing instream flows for fish habitat maintenance. Irrigation was reduced by 10% during the 1994 season, and the DWP reports that ramping of flow changes ha also been implemented. The absence of diversion flow monitoring at many smaller sites makes an account of total water diverted unavailable. Even with diversion restrictions, flow into some ditches is frequently greater than that which remains in the creek.

Concerns remain over the loss of fish and stream flow into diversion canals and ditches. Tributary water quality may be degraded as stream flow is replaced by agricultural return flow poor water quality and higher temperature. Under drought conditions, limited flows may not adequately cleanse gravel substrates, reducing their quality as spawning and invertebrate habitats. Furthermore, natural stream channel healing processes may be hindered as high flows are attenuated by diversions. Th issue was raised by Department biologists in the 1950's and remains unresolved.

The DWP requires that at least 75% of their leased lands remain open for multiple public use activities, such as fishing, hikin hunting, photography, and other daytime activities. Currently, this includes all of Convict and McGee creeks and the upper Owe River. Mammoth Creek on the Chance Ranch is currently closed t public access.

Bureau of Land Management

The Bureau of Land Management (BLM) administers three grazing allotments in the Long Valley Management Area. The Hot Creek and Wilfred Creek allotments, located north of Crowley Lake, are cattle operations; the Little Round Valley allotment, located south of Crowley Lake, runs sheep.

Existing data demonstrate excessive use by livestock on most vegetative communities on BLM land in Long Valley, and that standards for utilization, as set forth in the BLM Resource Management Plan, have been exceeded (Terry Russi, pers. comm.). Some reductions in allowed AUMs are needed in order to meet BLM vegetation standards.

Inyo National Forest

The INF has developed allotment management plans for five cattle grazing allotments in the Crowley Lake area. Additionally, the Inaja Land Company runs cattle on INF lands adjacent to their fishing ranch under a special use permit. All allotments are for seasonal use on non-irrigated pastures. With the exception of the Turner allotment, these allotments have Allotment Management Plans at least 15 years old, and may not comply with the Standards and Guidelines of the INF Forest Plan. However, new habitat-type specific Standards and Guidelines are being developed, and should be enforced during 1996. Sensitive habitats, such as riparian areas, could receive better protection under the revised Standards and Guidelines.

Other Private Lands

Grazing occurs on four private ranches located on the upper Owens River upstream of DWP owned land, and one ranch located on Hot Creek. Three of the four ranches on the upper Owens River also have interests in angling recreation, as discussed in the section on recreational development. Livestock are excluded from riparian areas on two of the ranches that promote angling, and stocked at low densities on the third fishing/cattle ranch. Riparian habitats and stream banks are in good to excellent condition on these sections of the upper Owens River.

One of the privately owned fishing ranches, the Inaja Ranch, installed solar powered electric fences to completely exclude cattle from a 4.2 mile reach of the upper Owens River, and the vegetation response has been exceptional. According to ranch personnel, improved vegetation ground coverage and overhanging growth have increased terrestrial invertebrates and benefitted fisheries.

The Inaja Ranch implemented a new policy in 1994 that limited irrigation to only one side of the property at a time when the river drops below 70 cubic feet per second; thereby lessening th impacts of water diversion during drought.

One of the private ranches has not pursued an interest in anglir recreation. Heavy livestock use of riparian habitats on the ranch has resulted in excessive impacts to stream banks, channel form and vegetation. Woody riparian vegetation is lacking, and the present over-widened condition of the river results in highe heat gain. Water temperatures up to 80°F were recorded at a thermograph located near the downstream property line and above the confluence with Hot Creek (Ebasco, 1993). This is within 3° of the maximum short term thermal tolerance for rainbow and brow trout (Moyle, 1976). Water quality may further be degraded if agricultural return flows or pasture seepage enter the river across barren, manure covered soils.

Riparian restoration through improved grazing management could restore fishery values in this section as well as downstream in the upper Owens River.

Geothermal Development

In 1970, Congress passed the Geothermal Steam Act which classified geothermal resources as a leasable mineral. In 1972, the United States Geological Survey (USGS) established the Mono-Long Valley Known Geothermal Resource Area (KGRA). Its boundaries extend from the southern edge of the Mono Basin National Forest Scenic Area to Lake Crowley. The Federal Government sold geothermal leases here in 1980 and 1984. Approximately 27,600 acres are currently under federal lease in the areas around Casa Diablo and north of Mammoth. Portions of Little Hot Creek and Deadman Creek, tributaries to the upper Owens River, are included within these leases. Additional private leases are located in Chance Meadow and include Mammoth Creek, also tributary to Hot Creek and the upper Owens River system.

Geothermal power production in the Long Valley KGRA began in 198 with the completion of Mammoth Pacific I, a 10 megawatt power plant located at Casa Diablo. The operation of this facility his resulted in the loss of thermal wetlands in nearby areas and an overall reduction of enriching warm geothermal waters entering Mammoth Creek. In 1990, two additional 15 megawatt plants, Mammoth Pacific II and Pacific Lighting and Energy Systems I, began operations near the original plant. Additional impacts to surface resources which share the same underground geothermal reservoir were documented (USGS quarterly reports). These impacts include the total loss of flow at Colton Spring, a small thermal tributary to Mammoth Creek; total loss of thermal water at Chance Meadow Springs, which provided open water waterfowl habitat during winter months; a four foot reduction in the surface level of Hot Bubbling Pool, located ¼ mile north of Hot Creek Hatchery; and an approximate 30% decrease in the thermal flow of the Hot Creek headsprings at Hot Creek Hatchery.

A fourth power plant, Mammoth Pacific III, is currently proposed within the same development complex. It is anticipated that the operation of an additional facility will result in additional impacts to surface thermal water resources. These include Hot Creek Fish Hatchery and Hot Creek. The operation of Mammoth Pacific III should further lower thermal aquifer pressure in shallow zones, and further reduce or completely stop nearby thermal spring flow. It is possible that the additional development could result in the complete and permanent loss of some downstream thermal resources. As the thermal aquifer pressure declines, the underground waterways, or natural conduits such as faults or cracks, sometimes close through collapse and/or calcification. This process can temporarily or permanently shut off thermal water flow to the surface. A return of thermal aquifer pressure alone may not reopen these waterways.

Recreational Development

Campgrounds

Crowley Lake Fish Camp

Crowley Lake Fish Camp is operated by Sierra Recreation Associates, Inc., the DWP concessionaire for Crowley Lake. The camp headquarters is located at South Landing, but the concession includes recreational operation of the entire Lake and surrounding lands. The camp provides many services for the angling community, including: camping at South Landing (season-long) and at North Landing (extended opening weekend only), boat launch facilities, boat storage at dock or beach sites, bait and tackle shop, and boat rentals. Plans have been considered for improvements to the North Landing area with toilet facilities and maintained roads. A small access fee may be charged in subsequent years to cover North Landing improvements.

California State Fish and Game Commission policy on fish stocking allows the Department to stock public and private waters where a nominal fee for angling is charged to defray certain costs. The fee rate may be adjusted based on a cost of living index. For the 1994 angling season, the fee rate was not to exceed $4.50 per day per car or $1.15 per day per person. In 1994, the Crowley Lake Fish Camp charged $5.00 at South Landing for parking, but did not charge at other access points around the Lake. If access fees exceed the limit permitted by Commission policy, the Department may be prohibited from stocking fish. The current statewide fee schedule (1997) is $5.00 per car or $1.25 per person.

Water skiing, sailing, and wind surfing are also regulated through the camp, and generally do not appear to conflict with angling.

Crowley Lake Campground - BLM

Crowley Lake Campground is operated by the Bureau of Land Management from mid-April to late September. It is located approximately two miles west of Crowley Lake at an elevation of 7000 feet. The campground contains 47 RV/tent sites and several pit-type toilets. There are several pull-through trailer spaces, a disposal station for chemical toilets, and a group camp area. No reservations are required; campsite selection is first come-first served. Drinking water is available, but electric hookups are not. Fees are $6.00 per night.

McGee Creek Campground - INF

McGee Creek campground is located at an elevation of 7600 feet and is approximately seven miles driving distance west from Crowley Lake. It is a full service campground with water and sanitation facilities. Weather permitting, the campground is open concurrent with the angling season; the last Friday in April through October 31. There are 28 campsites, each complete with gazebo shade structure, table, fire ring, and tent pad. Cost per night is $8.00. Maximum length of stay is 14 days.

Convict Lake Campground - INF

Convict Lake campground is located at an elevation of 7600 feet and is approximately 11 miles driving distance west from Crowley Lake. The campground opens the weekend prior to opening of fishing season and closes the end of October. There are 88 sites available with parking pads ranging in length from 15 to 55 feet.

No hookups are available. However, RV water fill-up and dump stations are located at the entrance station approximately 1/4 mile from the campgrounds. Cost per night is $10.00.

Big Springs Campground - INF

The Big Springs Campground is located at the headsprings of the upper Owens River. Glass and Deadman creeks are tributary to the upper Owens River at the Big Springs confluence. The campground is at an elevation of 7300 feet. Facilities include 24 campsites, pit toilets and stream water. Maximum length of stay is 21 days. There is no fee at this campground.

This campground is located on known archeological sites and the INF has intentions to move the camp location. Furthermore, the campground does not meet the new standards and guidelines (S&G) in the INF Forest Plan. These S&G pertain to new development; however, they lend support for removing the campground from its current riparian location. Funding for relocation has not yet been identified; thus, no date has been set for the move.

Brown's Campground on the upper Owens River

Brown's Campground, a private facility on land leased from the DWP, is located approximately two miles north of Crowley Lake on the upper Owens River. There are 75 sites near the River for RV and tent camping. Restrooms, showers, and a store with cafe are available. Cost in 1994 was $10.00 per night with a maximum of four people per site.

Heavy angler use of the area combined with grazing has resulted in a general lack of woody vegetation and unstable erodible stream banks.

Private Fishing Ranches on the Upper Owens River

Alpers Owens River Ranch

Alpers Owens River Ranch is located near the head springs of the upper Owens River and is open to the general public on a guest reservation basis. Ranch guests may fish two miles of upper Owens River under a zero limit policy using barbless flies only. One and one half miles of artificial creek (Alpers Creek) are also available where guests may keep two fish. Additionally, Alpers Lake, a four acre impoundment, provides guests and the general public (for pay) catch-and-release float tube trophy fly angling.

Arcularius Ranch

The Arcularius Ranch, located on the upper Owens River, has been a popular angling resort open to the public, though the future ownership of the ranch is uncertain. The ranch has practiced zero limit angling in recent years.

Inaja Land Company

The Inaja Land Company owns 1,243 acres of land in the upper Owens River drainage. Included on this land are approximately 4.2 miles of the upper Owens River. The company is membership-owned and each of the 25 memberships are provided angling privileges and a cabin site.

Catch-and-release angling is generally practiced, though the company has no mandated policy. Guests and members are requeste to fill out a daily fishing summary form. Reported trout harves has been reduced (since the survey began in 1960) from a high of over 2,000 fish in 1970 to the current harvest of under 200 fish

Fish Hatcheries

Hot Creek Hatchery

Hot Creek Hatchery, California's first warm water trout hatcher was started in 1928 by the Rainbow Club of Bishop. In 1931, the Division of Fish and Game took over the hatchery and constructed two fish rearing ponds. The present day hatchery wa constructed in 1941 and utilized 38 earthen ponds for fish production. The hatchery was modernized in 1985, and the ponds were replaced with concrete raceways. The hatchery occupies 20 acres of leased INF and DWP lands.

The hatchery is a broodstock and production facility that provides fish to a large area of the state. Hot Creek Hatchery normal production goal is 280,000 pounds of catchable trout, planted in eastern Sierra waters; 100,000 subcatchable trout, planted into Crowley Lake; 1,000,000 fingerling trout, aerially stocked in back country lakes; and 10,700,000 eggs that are use throughout the Department's statewide hatchery program.

Hot Creek Hatchery stocks up to 100,000 Kamloops strain rainbow trout into Crowley Lake each August. The hatchery provides the Coleman strain rainbow trout eggs to Fish Springs Hatchery for subsequent use in Crowley and other waters. Hot Creek Hatchery also stocks trout into the upper Owens River and Convict and

McGee Creeks.

Hatchery compliance with Lahontan Regional Water Quality Control Board (Board) water quality standards was investigated by Department biologists and hatchery personnel, in cooperation with Board staff. It has been determined that the hatchery is in compliance with present water discharge requirements.

Alpers Owens River Ranch Trout Hatchery

Alpers Owens River Ranch first started producing trout in earnest in 1971. However, trout were raised in "catch out ponds" in the 1920's for ranch use only. From 1971 to 1974 three ponds were established for stocking irrigation ditches on the ranch. In 1983, the hatchery was expanded to commercial operations in Inyo and Mono County. Trophy-sized trout stocking started in 1986 at the request of marina owners in Mono County. Alpers now grows three-pound and larger rainbow trout for private sector and government fishing enhancement programs, producing approximately 40,000 pounds of rainbow trout per year (Tim Alpers, pers. comm.). As with other hatcheries, there is the concern that degradation of water quality may impact downstream resources. The Lahontan Regional Water Quality Control Board has indicated a Waste Discharge Permit will be required to assure water quality protection.

Road Development

Highway 395

California State Highway 395 parallels Crowley Lake along the southern shoreline and McGee Bay. Crooked, Whiskey, Hilton, McGee, Convict and Deadman creeks are all bisected by Highway 395 causing fish passage problems under certain conditions. A fish ladder requiring periodic maintenance has been installed on Convict Creek at its confluence with Highway 395. In cooperation with the California Department of Transportation, fish passage at Highway 395 on Crooked Creek was improved in 1994 and in 1996 through the construction of step pools and water deflectors.

Back Roads

Road access to Crowley Lake and tributary waters is generally via graded dirt roads on DWP property. Road use on DWP land is limited to existing roads; no new roads are planned for development. In fact, several access roads have been closed as the result of livestock fencing project implementation. The DWP has provided parking areas and walk-through gates for anglers in areas where road closures have limited access. Additional vehicular and recreational use limitations may be instituted, possibly affecting the North Landing and upper Owens River areas, to minimize vehicle impacts to riparian meadow areas and to control livestock. A small fee may be charged in the future for anglers utilizing alternative Crowley Lake access roads. In all cases anglers need to respect the "leave it like you find it" rule that applies to all gates.

Timber Management

Except for fuelwood cutting, timber is rarely harvested commercially on private lands in Mono County. The 1988 INF Forest Plan's Standards and Guidelines and State Water Quality Standards known as Best Management Practices are followed to assess and minimize the impacts of timber harvest on INF lands. The 1988 Forest Plan outlined a tentative 10-year timber sale action plan covering the period 1989-1998. Each timber sale is analyzed in an environmental document (NEPA) and a chosen alternative, along with mitigation measures, becomes the basis for the next season's timber sale contracts.

A new INF land management procedure, known as "Ecosystem Management", will be implemented by 1996 and will consider the ecological needs and desired conditions of large management areas. Timber harvests will be prescribed based on desired future condition.

Timber harvests have taken place in the watersheds of the upper Owens River, Glass Creek and Deadman Creek. The erosion of upper watershed soils and the potential for their transport to water courses remain a concern.

WATER DEVELOPMENT

Current Development

Crowley Lake

Crowley Lake is the largest reservoir in the DWP water system, providing 60% of the total storage capacity. Crowley also facilitates operation of the Owens Gorge hydroelectric system, although storage is regulated by the needs of the water system.

According to the DWP, management of Crowley Lake is based on a multitude of factors, with annual runoff and demand for water in Los Angeles playing the most significant roles. Water system demands, especially during below normal runoff years and without historic Mono basin diversions, may result in lower lake levels and less operational flexibility.

Water management in Crowley Lake has considerable influence on fish production, fish distribution and angling quality. Information and recommendations on water level management and fishery impacts at Crowley were provided to the State Water Resources Control Board by Department personnel during the Mono Lake Water Rights Hearings in 1993/94.

Water Diversions From the Mono Basin

Water has been diverted from the Mono Basin, a hydrologic system north of the Owens watershed, into the upper Owens River by the DWP since 1941. Those diversions increased the average upper Owens River flow below East Portal (terminus of the Mono Basin diversion tunnel) from a baseline of 76 cubic feet per second (cfs) to 168 cfs. Increased river flow resulted in channel erosion, widening and straightening, and destruction of riparian habitat. This contributed to the estimated net loss of 1.2 miles of upper Owens River stream length (Ebasco, 1993).

By court order, DWP stream diversions ceased in 1989 to protect Public Trust resources in the Mono Basin. Diversions into the upper Owens River will resume once targeted Mono Lake levels are achieved. The amount of water diverted has been determined by the California State Water Resources Control Board (Water Board) based primarily on resource needs in the Mono Basin.

At the Water Board hearings, the Department recommended water delivery practices to avoid large and sudden changes in flow. Flow augmentation from East Portal should not raise the river above 200 cfs to avoid erosive scour and potential bank damage. To mitigate bank damage, the total amount of water augmented in any given water year should be delivered in as consistent a manner as possible, given other considerations such as irrigation losses, summer water temperatures, operational constraints, and fishery impacts.

The Department's recommendations were incorporated into Decision 1631, the Water Board ordered: "Licensee's combined rate of diversion through the Mono Craters Tunnel under all bases of right shall be regulated so that the sum of discharge from East Portal and the natural flow in the Owens River at East Portal do not exceed 250 cfs as measured directly downstream of the East Portal discharge. Licensee shall make releases to the upper Owens River at a relatively stable rate consistent with operational limitations." It should be noted that the natural flow of the upper Owens River can exceed 250 cfs.

Domestic Water Diversions From Hilton and Whiskey Creeks

Hilton and Whiskey creeks flow northeast into Crowley Lake through the community of Crowley Lake. Many of the homes in this community have diverted the streams for use in landscape enhancement and irrigation. This has resulted in the degradation of water quality and reduced flows. The value of spawning and rearing habitats for wild trout has been lessened.

Mammoth Lakes Community Water Supply Developments

The Town of Mammoth Lakes is located approximately 12 miles northwest of Crowley Lake. The town is the major focus of both Mono County's population (approximately half of all Mono County residents live in the Town of Mammoth Lakes) and resort-style recreation. The Town's General Plan anticipates, based on the proposed number of alpine skiers, the need to accommodate up to 52,000 persons at one time at full "build-out". This is considerably more than the current capability of 29,000, and will require developing additional infrastructure. A major concern is the impact on the natural resources of the area that will accompany such a level of development. This is especially true of water resources, as the town already experiences severe water shortages during normal and dry years.

Of concern is the cumulative effects of nutrient loading on the Crowley system from upstream developments including golf course and airport expansions and ski areas.

Water for the Town of Mammoth Lakes is supplied from a combination of surface diversions from Mammoth Creek and several wells located on private land within the town limits. Surface diversions are regulated by the State Water Resources Control Board which has permitted diversion rates to protect the beneficial uses of Mammoth Creek flows. The ongoing development of ground water resources by the Mammoth Community Water District (MCWD) to meet the town's irrigation and growth demand is not regulated by the Water Board, and has been a cause of concern to the Department. The withdrawal of ground water in the Mammoth area of the magnitude needed to supply the Town may result in reduced spring flow elsewhere in the region. Resources at risk include Mammoth Creek, Hot Creek headsprings, the Owens tui chub

(State and Federally listed as "Endangered"), Hot Creek Hatchery, and the Hot Creek wild trout fishery.

Proposed Development

Increased Level of Crowley Lake

The DWP has studied the potential benefits of raising the level of Crowley Lake to increase water storage, but they report no active proposals. Previous concepts identified a number of unknown variables and potentially adverse impacts. In addition, uncertainties remain on water system operations resulting from the reduction of Mono Basin exports.

The project would inundate riparian and stream habitat and reduce wild trout production. Increasing water storage in Crowley would increase lake level fluctuations, a condition not usually beneficial to maintaining a quality fishery.

Geothermal Development

Geothermal development projects have been proposed which utilize water for cooling. Although this water consumptive method is more efficient for power production, these proposals have not been permitted due to the impacts on local water supplies. The Department has opposed geothermal development in Long Valley that results in further impacts to the regional hydrothermal system.

Dry Creek Well and Pipeline Project

In 1993, the Mammoth Community Water District (MCWD) supplied the Town of Mammoth Lakes with 2,916 acre-feet of water from both surface and ground sources (Gary Sisson, pers. comm.). MCWD has projected a cumulative need of 6,111 acre-feet of water in anticipation of the Town of Mammoth Lakes build out (INF, Sherwin Ski Area Final EIS).

A Finding of No Significant Impact (FONSI) was issued in April, 1994 for the proposed construction and operation of the Dry Creek Well and Pipeline project. This project would be one of four sources needed to augment the water supply for the Town of Mammoth Lakes to facilitate projected build out. A well field and pipeline would be constructed on INF lands within the Dry Creek drainage, which is tributary to the upper Owens River.

Under the identified preferred alternative, up to four wells would be drilled, each to an approximate depth of 1000 feet. Total allowable production would be limited to 1500 acre-feet, a reduction from the 2000 acre-feet originally proposed in this alternative. A 7,500 foot long, 14-inch, cast iron pipeline with two booster stations would be constructed to connect the well field with the existing MCWD distribution system. The project would be phased, with extractions reduced or halted based upon required monitoring results (INF, FONSI, 1994).

The Dry Creek project has the potential for significant environmental impacts, and in 1990 the Department recommended that the project be the subject of a focused Environmental Impact Statement (EIS). The EIS should include adequate alternative analysis, cumulative impact analysis, and a thorough analysis of impacts to Big Springs, Owens River biota, and other surface waters. The INF completed an Environmental Assessment (EA) and issued the FONSI.

The Department objected to the EA and FONSI, arguing that the EA contains discrepancies and contradictions which create confusion, and lacks a thorough environmental analysis for reasoned decision-making. As stated in the Department's specific comments, the EA and FONSI inadequately discuss information currently available on the proposal. The project is pending approval.

OTHER ISSUES

Avian Predators

Avian fish predators on Crowley Lake include: Red-breasted Mergansers, Common Mergansers, Western Grebes, Common Loons, American White Pelicans, Double-crested Cormorants, California Gulls, Ospreys, Bald Eagles, Great Blue Herons, and Common and Snowy Egrets (Brian Tillemans, pers. comm.).

Avian predation on Crowley Lake fish has occurred at unknown levels since the reservoir was first filled. Generally, this source of fish mortality was thought to be minor when compared with other sources such as angler harvest and spawning mortality. However, increased numbers of some bird species in recent years, most notably the American White Pelican and probably the Double-crested Cormorant, have raised concerns as to current levels of avian predation, since these species can consume large quantities of fish.

In the early 1980's, American White Pelicans utilized Crowley Lake as a spring and fall resting stop. Migrants of up to 500 birds would hold over on Crowley for relatively short periods on their way to or from breeding grounds (B. Tillemans, pers. comm.). Since 1987, however, from 105 to 220 pelicans have taken up summer residency each year at Crowley. The few birds that have been recovered during this time with leg bands have come from the Carson Sink and Klamath Lake Areas. This change in summer residency is believed to be related to drought impacts on historic pelican habitats, and may be long lasting.

The American White Pelican subsists mainly on fish (Ryser 1985). Estimates of food consumption by White Pelicans range from 5 to 20 percent total body weight per day (Perris, 1979; Jehl per. com.); with the average weight of an adult pelican being approximately 22 pounds. Considering that an average of 150 pelicans spend approximately 150 days per year on Crowley, and that they consume 12 percent (on average) of their body weight each day, then the total pelican fish consumption could reach 60,000 pounds of fish each year.

Many of the fish eaten by birds are likely not trout. Owens suckers and tui chubs are probably consumed in large quantity, especially during spawning periods when these fish are found in shallow waters. Sacramento perch fry are likewise found in shallow water and probably eaten by pelicans.

Trout Stocking Practices

Hatchery trout were traditionally stocked by the Department at the South Landing boat ramp. This stocking practice was convenient and appeared to work well during high water periods. However, during periods when lake levels were lower, it appeared that newly stocked fish lingered in shallow waters for days, and were more susceptible to avian and fish predation. Large numbers of gulls and other fish predators were observed in this area for extended periods after stocking. From 1989 through 1993, hatchery trout were stocked at South Landing point into the main body of the lake. Once stocked in this location, trout appeared to quickly disperse into deep water, presumably finding good water quality and avoiding predation. Trout were again stocked from the boat ramp in 1994 and 1995 since the lake level was high.

II. MANAGEMENT PROGRAM

Management Goals and Objectives

The goals of fishery management for Crowley Lake and tributary waters are:

1. To protect, maintain and enhance the Crowley Lake watershed for the benefit of recreational fisheries and other fish and wildlife species. Emphasis is placed on land and water management activities which result in healthy, naturally-functioning stream and lake environments and in the maintenance of surrounding lands for their ecological and aesthetic values.

2. To employ a combination of wild and hatchery-reared trout populations to utilize the richness of Crowley Lake and tributary resources to support sustainable angling recreation with the following performance objectives:

(a) Provide an opportunity to catch trout greater than 13 inches total length in Crowley Lake at an average rate of one fish per hour of angling effort for the first three months of the season,

(b) Provide the opportunity to catch trophy-sized trout (18 inches and greater) in Crowley Lake during the last three months of the angling season such that they comprise at least 20% of the catch, and

(c) Provide the opportunity to catch trophy-sized trout (greater than 16 inches) on the Crowley tributaries at a median rate of at least one fish per angling day.

3. To maintain self-sustaining populations of Sacramento Perch which provide anglers the opportunity to:

(a) Catch perch at a rate of three fish per hour of angling effort during the mid-season period (June through September), and

(b) To harvest liberal bag limits of at least 20 perch per angling day.

Management Direction

This section of the plan lists general and specific Departmental actions that are necessary to address major issues. Many of the suggested actions will require coordinated efforts with other agencies and individuals. Others will require additional funding not yet identified. Some issues require additional understanding as to their scope and magnitude before a range of curative alternatives can be developed.

*** Angling Regulations ***

Angling regulations are one of the most direct and effective means of managing harvestable populations. An assessment of existing angling regulations on Crowley lake and tributary fisheries ranked high (seventh out of 20) during the scoping for this management plan. Additionally, the scoping group supported regulations for resource protection with allowable use as a secondary objective.

An attempt has been made to simplify understanding of the regulations by listing each water separately. Additional protection for wild trout recruitment is offered by extending catch-and-release regulations to Highway 395 on the upper Owens River, and by extending special regulations upstream to Crowley Lake Drive on Hilton and Whiskey creeks and to the U.C. study area on Convict Creek. Additional recreational opportunities are gained by opening Crooked Creek to catch-and-release angling for the entire angling season and by regulating the reach of the upper Owens from Benton Crossing Bridge downstream to a new fishing monument with season-long general district regulations. The purpose of the monument is to avoid dispute as to the location of the river/lake confluence and to provide protection from over harvest of congregating fall spawning trout. Regulations below the monument are the same as at Crowley Lake. Additionally, trout greater than 16 inches are to be released on that portion of the upper Owens River above Benton Bridge. Protecting larger, and possibly older, individuals may increase the incidence of like individuals in the harvestable population, after these fish return to the lake. The 16-inch maximum size limit will allow for season-long harvests of catchable trout that are stocked in the upper Owens River below Benton Crossing Bridge.

The adoption of more restrictive regulations on the upper Owens River above Benton Bridge will impact anglers who prefer to keep fish. This loss of catch and keep opportunity, especially in the Big Springs area, will be offset with the implementation of more liberal angling regulations in the reach below Benton Bridge. Monitoring angler use, catch, and harvest will be critically important to assure that overharvest of wild trout is avoided. The Department will investigate the effects of the new angling regulations upon the fisheries intensively during 1996 and 1997. If goals are not being met, modifications will be recommended based on resource protection first, with allowable use as a secondary objective.

Recommendations:

1. Review current and proposed angling regulations every two years within the context of resource protection as a primary concern with optimal use as a secondary objective.

2. Continue monitoring Crowley Lake opening weekend angler catch success as an index of resource status and regulation impact.

3. Perform angler survey programs to determine catch and harvest rates for those tributaries where regulations may impact fishery resources.

* coordinate with wild trout project personnel on catch-and-release waters
* implement upper Owens River angler surveys in 1996
* install volunteer angler reporting stations (angler survey boxes) at Crooked Creek and Big Springs
* estimate trout losses from hooking mortality for bait, fly and lure anglers

** *Land Management* **

Land management is perhaps the most controversial issue discussed in this plan. As livestock grazing and related activities are the major land use for the area, it has received the greatest scrutiny. However, angler use of the region can be enormous, carrying a commensurate level of impact to important fish and wildlife resources.

Recommendations:

1. Encourage additional improvements to livestock distribution in riparian and upland habitats on public and private property along the upper Owens River, Hot and Mammoth creeks and in Little Round Valley.

* arrange meetings with landowners and lessees to discuss livestock management issues, as they pertain to fisheries/riparian habitats
* seek to jointly develop livestock land use compatible with

fish and wildlife resources

* involve the following agencies and consultants, as necessary:
    - Los Angeles Department of Water and Power
    - U.S. INF
    - U.S. Bureau of Land Management
    - Lahontan Regional Water Quality Control Board
    - U.C.S.B. Sierra Nevada Aquatic Research Lab.
    - grazing consultants

2. Reduce the impacts of pasture irrigation on fisheries and water quality.

* review the operations of all Crowley tributary diversions and determine critical periods of possible trout impact (i.e. diversion on/off schedules)
* evaluate trout losses during critical periods
* seek means to reduce trout losses which may include the following:
    - decrease flows in diversions gradually to encourage trout to return to the stream
    - decrease flows in diversions gradually and herd trout back toward the stream
    - construct holding/capture pools within major diversions and use to round up trout for return to the stream
    - adjust the schedule of start/stop sequences to reduce repeated kill events, possibly using ditches as juvenile habitat during extended flow periods
    - explore the use of electric fish fencing to discourage fish passage into diversion ditches
    - install fish screens on diversions where trout losses warrant such intensive action
    - coordinate all findings with the Los Angeles Department of Water and Power and appropriate ranch lessees and encourage joint implementation of beneficial actions

3. Through consensus agreement with all water users, seek a coordinated schedule of resource maintenance flows in all tributary waters during which streams will be allowed their full unimpeded flow for an appropriate period of time.

* determine quantity and timing of maintenance flows
* meet with water users and propose a coordinated plan

4. Continue to evaluate the progress of trout habitat improvement under new grazing management.

* use California Stream Bioassessment Procedures to monitor ambient physical, chemical and biological conditions of tributaries
* coordinate with and support researchers at the Sierra Nevada

Aquatic Research Laboratory on studies of Crowley area grazing management

5. Encourage recreational practices which maintain meadow and riparian habitats and are compatible with the fishery objectives of the plan.

* coordinate with DWP on the development of angler use plans for tributary and north Crowley Lake fisheries; consider the following actions:
  - implementation of the California Trout parking/angler use concept for the upper Owens River
  - provide designated parking, portable restroom facilities and picnic areas (day use only) at north landing, green banks and Leighton Springs
  - provide designated parking at several locations along the upper Owens River from Crowley Lake to Brown's Campground
  - survey anglers at the north lake area to determine acceptance of controlled parking areas with developed day use facilities, and a use fee to cover added expenses to the concessionaire.

6. Reduce the impact on aquatic resources of water diversions for landscape improvements at the Community of Crowley Lake.

* survey Hilton Creek water courses and determine water distribution and use
* check compliance with appropriate state and federal regulations
* Take appropriate actions to meet legal mandates, if warranted

7. Encourage the relocation of INF's Big Springs Campground on the upper Owens River away from the riparian zone.

8. Review private land parcels for possible acquisition to protect fish and wildlife resources and provide recreational opportunity in the Crowley Lake area.

9. Maintain and increase public access for recreational angling while protecting habitat.

** *Lake Level Management* **

Fluctuations in lake levels during the angling and aquatic vegetation growth seasons may impact the following:
* amount of productive shoal areas
* weed bed distribution and concentration
* water quality in shallow water areas including temperature, DO, and turbidity

* water quality - lake-wide (i.e. Sacramento Perch fish kill; see page 38)
* distribution of fish
* fish passage into spawning tributaries
* recreation (aesthetics, angling access)

In addition, reservoir operations result in the continual entrainment of fish during water export.

Recommendations:

1. Determine relationship between Crowley Lake water storage and the maintenance of productive shoal areas.

2. Determine the effects of lake level management on the distribution and production of algae and rooted plants, fish and other wildlife.

3. Coordinate with DWP on study results and seek consideration for fishery and other wildlife resource needs in their annual water storage plans.

4. Perform bioassessment toxicity studies on Crowley Lake bottom sediments.

5. Determine the quantity and timing of fish losses through entrainment into the Owens Gorge hydroelectric system.

6. If warranted, take corrective measures to reduce fish loss to entrainment.

** *Algae Control* **

An overabundance of algae may degrade water quality and reduce dissolved oxygen at depth and in certain coves and bays; most notably in the Crooked Creek arm of the lake. This condition has resulted in limited fish kills within Crowley Lake and in downstream waters. Additionally, abundant growth can interfere with angling and degrade aesthetic values around the Lake.

Recommendations:

1. Perform surveys to determine the extent and spatial distribution of algae and rooted aquatic macrophytes.

2. Perform water quality surveys and coordinate with DWP water quality personnel through the summer months to determine the condition of onset and the location of problem areas.

3. Encourage the control of anthropogenic nutrient input sources

to Crowley.

** *Trout Strain Management* **

The use of hatchery trout strains for Crowley Lake fisheries management has been refined through a stocking program guided by the performance of each individual strain. Three strains of rainbow trout are stocked according to their past performance. This method, achievable with hatchery put-and-grow rainbow trout, is not available when managing wild stocks of brown and rainbow trout, as they are not so easily studied nor manipulated. Managi wild stocks will require a better understanding of their life histories, factors limiting their ecological success and their contributions to the fishery. The protection of desirable traits within a wild population is especially significant since these traits can be passed on to future generations, or be gradually altered (i.e. fishery regulations which allow the take of only th largest individuals may eventually reduce the abundance of large individuals through genetic selection).

Recommendations:

1. Propose angling regulations which protect wild and hatchery stocks and their desirable traits first with allowable use as a secondary objective.
2. Conduct life history studies for wild and hatchery trout.

* restore and operate the Convict Creek fish trap
    - monitor the movement of juvenile trout downstream to Crowley Lake
* study juvenile trout in other Crowley tributary streams and determine age, propensity to be resident or adfluvial, and genetic stock, if possible

3. Collect wild spawning stocks of brown and rainbow trout from Crowley tributaries as broodstock. Plant marked progeny back in Crowley and monitor returns.

4. Establish future stocking allocations within the context of known strain performance.

** *Wild Trout Production* **

The production of wild trout is generally considered highly desirable, and this issue received a high priority by the scopin team. As fish habitats improve, and wild trout production and recruitment to the lake increases, a commensurate decrease in hatchery stockings could follow. Implementation of the above Management Directions can benefit wild trout production. In addition, the following actions are recommended:

Recommendations:

1. Perform standardized Department stream inventories to determine the need and potential for habitat improvement projects to benefit trout production in Crowley tributaries.

2. Improve spawning conditions for trout through riparian restoration, gravel enhancement projects, and flow augmentation during critical periods.

3. Oppose land and water projects which would have deleterious impacts on the flows or water quality needed to maintain abundant self-sustaining wild trout populations in Crowley tributary waters.

4. Conduct assessments of cumulative upstream impacts.

5. Remove all human-made barriers to fish migration.

6. Increase public education and awareness of regulations and management of wild trout.

8. Coordinate implementation of Management Plan with other land management agencies.

***** Environmental Services - Project Review and Habitat Protection***

Various environmental problems or issues were highlighted throughout the Land and Water Development sections. New developments, such as well drilling to supply domestic water needs, have potential cumulative impacts on area aquatic resources. The California Environmental Quality Act requires review of these projects by the Department as the trustee agency for fish and wildlife resources. Additionally, monitoring programs for existing developments, such as geothermal energy production, need to be maintained and periodically reviewed for adequacy. The Department's section responsible for coordinating this environmental review is known as the Environmental Services Division.

Department Actions:

1. Review and comment on proposed development projects. Seek mitigation as needed to avoid, minimize, or compensate for adverse impacts to fishery resources.

2. Participate in the Long Valley Hydrologic Advisory Committee.

Program Implementation Schedule

Action Item	Time Frame
**** Angling Regulations ****	
1. Review current and proposed angling regulations - simplify when possible.	Due September of odd years
2. Monitor Crowley Lake opening weekend catch	Annually
3. Implement UOR angler surveys.	1996-97 seasons
4. Install a survey box on Crooked Creek.	A
5. Estimate trout losses from hooking mortality for bait, fly and lure anglers.	B
**** Land Management ****	
1. Cooperate with upper Owens River landowners on minimizing livestock impacts to fisheries/riparian habitats.	A
2.a. Review operations of all irrigation diversions and determine critical periods for trout.	A
b. Evaluate trout losses during critical periods.	A
c. Seek means to reduce trout losses.	A
3.a. Determine resource maintenance flows.	Initiated by the DWP in 1997
b. Meet with water users and seek cooperation on a coordinated schedule of resource maintenance flows.	
4.a. Perform California Stream Bioassessment Procedures to monitor ambient physical, chemical and biological conditions of tributaries.	B
b. Assist researchers at the Sierra Nevada Aquatic Research Laboratory on studies of Crowley area grazing management.	Pending
5. Coordinate with DWP on angler use and access plans for tributary and north Crowley Lake fisheries.	A
6.a. Survey Hilton Creek water courses to determine water distribution and use.	B
b. Determine compliance with state and federal regulations on water diversion.	B

Program Implementation Schedule (Continued)

Action Item	Time Frame
c. Take appropriate actions to meet legal mandates.	C
7. Encourage the relocation of the INF's Big Springs Campground away from riparian habitat.	C
8. Consider private land acquisitions.	As available
9. Maintain and increase public access For angling.	Ongoing
**** Lake Level Management ****	
1.a. Determine relationship between Crowley Lake water storage and shoal areas.	B
b. Determine effects of water storage on distribution and production of algae, rooted plants, fish and other wildlife.	B
c. Perform bioassessment toxicity studies on Crowley Lake bottom sediments.	B
d. Coordinate with DWP on study protocols and results.	A
2.a. Determine the quantity and timing of fish entrainment at reservoir outlet.	B
b. Coordinate with DWP on study protocols and results.	A
**** Algae Control ****	
1.a. Perform surveys to determine the extent and spatial distribution of algae and rooted aquatic macrophytes.	C
b. Perform water quality surveys throughout the summer months to determine the condition of onset and the location of problem areas.	C
c. Seek opportunities to control undesirable nutrient input sources to Crowley.	A
**** Trout Strain Management ****	
1.a. Conduct life history studies of wild trout. Seek to restore and operate the Convict Creek fish trap. Monitor juvenile trout movement.	A
b. Propose angling regulations which protect wild stocks and their desirable traits.	September 1997

Program Implementation Schedule (continued)

Action Item	Time Frame
2. Collect eggs from wild brown and rainbow trout from Crowley tributaries and establish hatchery broodstock. Mark Progeny prior to stocking.	Done
3. Establish future stocking allocations within the context of known strain performance.	Annually
**** Wild Trout Production ****	
1.a. Perform standardized Department stream inventories to identify habitat improvement projects.	B
b. Improve spawning conditions for trout through riparian restoration, gravel enhancement projects, and flow augmentation.	B
c. Remove all undesirable man-made barriers to fish migration.	A
2. Oppose land and water projects that impact flows or water quality.	As needed
3. Increase public awareness of regulations and management of wild trout.	Ongoing
4. Coordinate implementation of Management Plan with land owners and other land management agencies.	Ongoing
**** Environmental Services - Project Review and Habitat Protection ****	
1.a. Review and comment on proposed projects.	Ongoing
b. Seek mitigation as needed to minimize impacts on fisheries resources.	As needed

Time Frames:

A = should be initiated within one year of plan completion.

B = should be initiated within three years of plan completion.

C = though desirable, the Department has no current time frame for implementation.

Where feasible, actual dates associated with the implementation of an action are provided. However, time frames are "targets" and may be modified by conflict with other work objectives, budget changes, or factors beyond the control of the Department. Time frames do not necessarily reflect the priority of an action, but may be based on the completion of other actions or commitments of the Department.

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ACKNOWLEDGMENTS

It is with great pleasure that I extend my gratitude to the multitude of volunteers who spent their valuable weekends and vacation hours assisting the Department on Crowley Lake fisheries studies. With a telephone call to Mr. Jim Edmondson, executive director of California Trout, a well supported multi-year study was launched. More than 200 volunteers, many of which were organized by Mr. Bill Emme, marked hatchery trout and assisted with angler interviews. The information gained during those studies are reported in this management plan and are the basis for current fisheries management at Crowley Lake.

I am grateful to Mr. Jim Edmondson and California Trout, along with Mr. Sam Carr and volunteers from the Izaak Walton League, who were instrumental in the construction, reconstruction and operation of the upper Owens fish weir.

Members of the Committee to save Crowley Lake have shown their dedication to improving fishery resources in the Long Valley area, and deserve special thanks. I look forward to our cooperative efforts as we bring this management plan to fruition.

The Los Angeles Department of Water and Power supplied valuable information included in this plan, for which I am grateful. As so much of the implementation of this plan is based on future cooperation between our departments and DWP ranch lessees, I extend my gratitude toward our future endeavors.

My friends, Mr. Michael Mohr and Dr. Thomas Jenkins, deserve special thanks for help with statistical problems and field studies.

I take great pleasure in acknowledging Phil Pister, my former supervisor and author of several reports on Crowley Lake. He remains a continual source of inspiration, information and good humor.

Finally, Alan Pickard, Darrell Wong, Steve Parmenter, and Dawne Becker of the Bishop Fisheries staff, and Chuck Knutson and David Lentz from the DFG Wild Trout Program deserve thanks for reviewing the plan and providing excellent comments.

Appendix 1. Summary of Trout Stocked.

Summary of Trout Stocked into Crowley Lake, 1941 - 1964

Year	Subcatchable	Fingerlings					
	Rainbow	Rainbow	Kamloops	Brown	Cutthroat	Brook	Total
1941	1,000			95,890			96,890
1942	21,905			124,426			146,331
1943	82,976				8,298		91,227
1944	125	210,538					210,663
1945	182,417	7,904					190,321
1946	13,510	185,600			718,782		917,892
1947	35,088	122,000					157,088
1948	28,340	54,793					83,133
1949	21,923	54,400			190,800		267,123
1950		128,800					128,800
1951	161,240						161,240
1952	156,890				100,000		256,890
1953	224,409			176,400	161,476		562,285
1954	175,224			114,895	194,035		484,154
1955	207,616		30,000		100,000		337,616
1956	238,690				158,400		397,090
1957	235,943				173,000		409,671
1958	212,183	135,390	182,080		226,725		756,378
1959	315,265		245,430		229,890	100,000	890,585
1960	295,802	14,500			183,760	66,000	560,120
1961	411,542	52,640	100,390		100,000		664,572
1962	298,350	111,740	104,000		122,128		636,218
1963	317,775	105,750	79,900		99,940		603,365
1964	306,595	485,300					791,895

Appendix 1 (cont.)

Summary of Trout Stocked into Crowley Lake, 1965 to Present										
YEAR AND SIZE PLANTED	RAINBOW TROUT	RT - HOT CREEK	RT - COLEMAN	RT - HOT CREEK X COLEMAN	RT - KAMLOOPS	RT - EAGLE LAKE TROUT	CUTTHROAT TROUT - LAHONTAN	BROWN TROUT	RAINBOW TROUT TOTALS	BRC CUT T
1965 Fingerling	1,481,425								1,481,425	
Subcatchable	345,954								345,954	
Catchable									0	
Broodstock	500								500	
1966 Fingerling									0	
Subcatchable	429,716								429,716	
Catchable									0	
Broodstock									0	
1967 Fingerling									0	
Subcatchable	456,275								456,275	
Catchable									0	
Broodstock	20,655								20,655	
1968 Fingerling	348,112								348,112	
Subcatchable	495,845								495,845	
Catchable									0	
Broodstock								475	0	
1969 Fingerling	81,840								81,840	
Subcatchable	322,668								322,668	
Catchable	4,987								4,987	
Broodstock									0	
1970 Fingerling	410,003								410,003	
Subcatchable	409,649								409,649	
Catchable	38,121								38,121	
Broodstock									0	
1971 Fingerling	60,725	124245			104,160		30,000		289,130	
Subcatchable	385,020								385,020	
Catchable	2,475								2,475	
Broodstock									0	
1972 Fingerling	155,200								155,200	
Subcatchable	101,380								101,380	
Catchable						2,995			2,995	
Broodstock	165								165	
1973 Fingerling	26,880								26,880	
Subcatchable	129,026					16,712			145,738	
Catchable	3,997								3,997	
Broodstock									0	
1974 Fingerling	177,259				11,685				188,944	
Subcatchable	197,928					10,620			208,548	
Catchable								35,280	0	
Broodstock									0	

Summary of Trout Stocked into Crowley Lake, 1965 to Present										
YEAR AND SIZE PLANTED	RAINBOW TROUT	RT - HOT CREEK	RT - COLEMAN	RT - HOT CREEK X COLEMAN	RT - KAMLOOPS	RT - EAGLE LAKE TROUT	CUTTHROAT TROUT - LAHONTAN	BROWN TROUT	RAINBOW TROUT TOTALS	BROWN AND CUTTHROAT TOTALS
1975 Fingerling	338,000					84,960			420,960	0
Subcatchable		11,875		202,620	39,600		34,800	47,580	254,095	82,380
Catchable					2,094	93,060			95,154	0
Broodstock					2,674				2,674	0
1976 Fingerling	343,296		7,750						351,048	0
Subcatchable									0	0
Catchable				194,140	58,960	51,456		117,600	304,556	117,600
Broodstock									0	0
1977 Fingerling								18,600	0	18,600
Subcatchable							3,395		0	3,395
Catchable	130,500				83,845			106,640	214,345	106,640
Broodstock									0	0
1978 Fingerling									0	0
Subcatchable				238,000				179,200	238,000	179,200
Catchable		2,900		60,000	16,320	7,040			86,260	0
Broodstock									0	0
1979 Fingerling	25,000						360,130		25,000	360,130
Subcatchable								50,000	0	50,000
Catchable	230			300,000	81,411	58,459			440,100	0
Broodstock									0	0
1980 Fingerling								116,912	0	116,912
Subcatchable								110,400	0	110,400
Catchable	94,000			283,150				50,400	377,150	50,400
Broodstock									0	0
1981 Fingerling	23,630							204,000	23,630	204,000
Subcatchable				351,000					351,000	0
Catchable					100,704				100,704	0
Broodstock	700								700	0
1982 Fingerling							32,200	420,700	0	452,900
Subcatchable				170,100					170,100	0
Catchable	3,372			167,500	22,810				193,682	0
Broodstock	50								50	0
1983 Fingerling	656,164								656,164	0
Subcatchable	289,800							108,000	289,800	108,000
Catchable					96,140			8,750	96,140	8,750
Broodstock	450								450	0
1984 Fingerling	131,475					55,800			187,275	0
Subcatchable	289,420							100,080	289,420	100,080
Catchable	4,770								4,770	0
Broodstock	366								366	0

Appendix 1 (cont.)

Summary of Trout Stocked into Crowley Lake, 1965 to Present

YEAR AND SIZE PLANTED	RAINBOW TROUT	RT - HOT CREEK	RT - COLEMAN	RT - HOT CREEK X COLEMAN	RT - KAMLOOPS	RT - EAGLE LAKE TROUT	CUTTHROAT TROUT - LAHONTAN	BROWN TROUT	RAINBOW TROUT TOTALS
1985 Fingerling			147,556			39,545	6,696		187,101
Subcatchable			460,970						460,970
Catchable									0
Broodstock	300								300
1986 Fingerling	76,169						23,040		76,169
Subcatchable	348,404				8,250	26,775			383,429
Catchable			7,718		470				8,188
Broodstock									0
1987 Fingerling	418,452	24,696			75,360		7,776		518,508
Subcatchable			301,433		50,445	65,660		102,380	417,538
Catchable		550	4,120						4,670
Broodstock								284	0
1988 Fingerling	63,800								63,800
Subcatchable			280,658					12,814	280,658
Catchable					101,620	101,620			203,240
Broodstock	276								276
1989 Fingerling									0
Subcatchable		38,160	263,647					78,400	301,807
Catchable			17,922		88,721				106,643
Broodstock									0
1990 Fingerling									0
Subcatchable						164,807			164,807
Catchable			16,800		70,875			15,480	87,675
Broodstock									0
1991 Fingerling								11,200	0
Subcatchable			95,147			85,420			180,567
Catchable					81,640				81,640
Broodstock									0
1992 Fingerling								1,058	0
Subcatchable			55,196			140,420		15,002	195,616
Catchable			57,910		83,655				141,565
Broodstock									0
1993 Fingerling					14,800				14,800
Subcatchable			24,098			168,625			192,723
Catchable			67,128		82,743				149,871
Broodstock									0
1994 Fingerling					18,700				18,700
Subcatchable			105,980		17,000	169,391			292,371
Catchable					67,360				67,360

Appendix 1 (cont.)

Summary of Trout Stocked into Crowley Lake, 1965 to Present										
YEAR AND SIZE PLANTED	RAINBOW TROUT	RT - HOT CREEK	RT - COLEMAN	RT - HOT CREEK X COLEMAN	RT - KAMLOOPS	RT - EAGLE LAKE TROUT	CUTTHROAT TROUT - LAHONTAN	BROWN TROUT	RAINBOW TROUT TOTALS	BROWN AND CUTTHROAT TOTALS
1995 Fingerling	524,827		20,040				15,000	3,300	544,867	18,300
Subcatchable	115,840		39,881			127,080			282,801	0
Catchable			123,008		57,225				180,233	0
Broodstock									0	0
1996 Fingerling*	43,200					114,000	58,400	38,558	157,200	96,958
Subcatchable	92,065		84,040			27,750			203,855	27,750
Catchable					23,760				23,760	0
Broodstock	331								331	0
1997 Fingerling										
Subcatchable										
Catchable										
Broodstock										
1998 Fingerling										
Subcatchable										
Catchable										
Broodstock										
1999 Fingerling										
Subcatchable										
Catchable										
Broodstock										
2000 Fingerling										
Subcatchable										
Catchable										
Broodstock										
2001 Fingerling										
Subcatchable										
Catchable										
Broodstock										
2002 Fingerling										
Subcatchable										
Catchable										
Broodstock										
2003 Fingerling										
Subcatchable										
Catchable										
Broodstock										

* 109,200 golden trout fingerlings were stocked in 1996.

Appendix 1 (cont.)

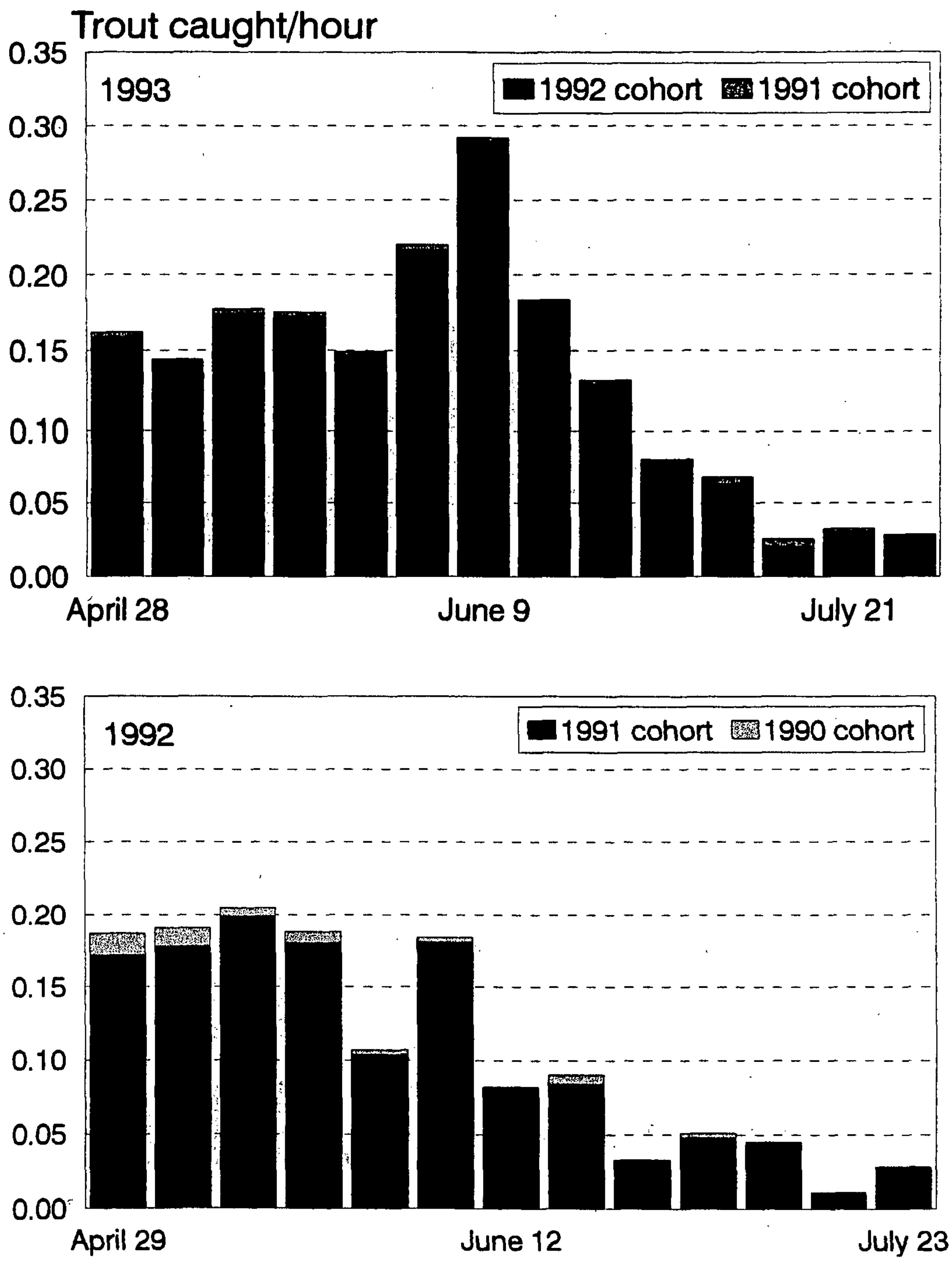
Summary of Trout Strains and Associated Marks Stocked into Crowley Lake, 1989-1992

Date Released	Mark	#Marked	#Stocked	Strain	Mean Size
8-92	LV-AD	83,655	83,655	RTKJ	3.9/lb
8-92	RV-AD	113,106	113,106	RTC	8.8/lb
9-92	AD	140,420	140,420	RT-ELT	8.7/lb
9-92	none	none	15,000	CT-L-I	484/lb
8-92	AD	15,002	15,002	BN-U	11.4/lb
Total RT = 337,181 of which 100% were marked					
8-91	LV	81,640	81,640	RTKJ	2.6/lb
8-91	RV	54,972	95,147	RTC	6/lb
8-91	AD	85,420	85,420	RT-ELT	9.6/lb
9-91	AD	11,169	11,169	BN	32/lb
Total RT = 262,207 of which 222,032 or 85% were marked					
8-90	LV-AD	58,050	70,875	RTKJ	3/lb
8-90	RV-AD	119,678	149,968	RTC	7/lb
9-90	AD	58,417	164,807	RT-ELT	8/lb
11-90	AD	15,480	15,480	BN	3/lb
Total RT = 385,650 of which 236,145 or 61% were marked					
8-89	LV	26,653	88,721	RTKJ	4/lb
8-89	RV	42,172	263,697	RTC	12/lb
5-89	RP	17,922	38,160	RTH	7/lb
Total RT = 390,578 of which 86,747 or 22% were marked					

RTKJ - rainbow trout, Kamloops strain
RTC - rainbow trout, Coleman strain
RT-ELT - rainbow trout, Eagle Lake Trout strain
RTH - rainbow trout, Hot Creek strain
CT-L-I - Lahontan cutthroat trout, Independence strain
BN - brown trout
BN-U - brown trout, Utah strain

MARK	FIN CLIPPED
LV	left ventral
RV	right ventral
AD	adipose
RP	right pectral
LV-AD	left ventral and adipose
RV-AD	right ventral and adipose

Coleman Rainbow Trout Catch Rates
Crowley Lake, Boat Anglers



Does not include opening weekend

Aqueduct Treatments - Total Copper Residuals			
Date	Treatment #	ug/l	Location
3-Oct-95	1	207	Alabama Gates
27-Feb-96	2	249	Alabama Gates 250 YARDS SOUTH
28-Feb-96	3	269	Alabama Gates 250 YARDS SOUTH
19-May-98	4	215	Alabama Gates Metering Bridge
20-May-98	5	215	Alabama Gates Metering Bridge
23-Jun-98	6	255	Cottonwood 200 YARDS SOUTH
24-Jun-98	7	263	Alabama Gates Metering Bridge
25-Jun-98	8	237	Alabama Gates Metering Bridge
18-May-00	9	24	Cottonwood Bridge

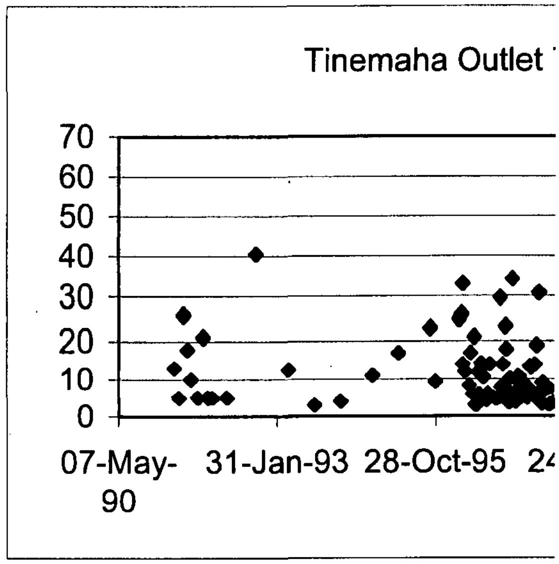
207.00
249.00
269.00
215.00
215.00
255.00
263.00
237.00
24.0

Data from Los Angeles Dept. of Water and Power.

Tinemaha Outlet Total Copper Residuals		
Date	Total Copper (ug/L)	
24-Apr-91	13.00	13
22-May-91	<10.00	5
19-Jun-91	26.00	26
16-Jul-91	18.00	18
07-Aug-91	10.00	10
18-Sep-91	<10.00	5
23-Oct-91	21.00	21
20-Nov-91	<10.00	5
17-Dec-91	<10.00	5
18-Mar-92	<10.00	5
17-Sep-92	40.50	40.5
14-Apr-93	12.50	12.5
23-Sep-93	<3.00	3
09-Mar-94	4.00	4
28-Sep-94	11.00	11
08-Mar-95	17.00	17
20-Sep-95	23.00	23
25-Oct-95	9.40	9.4
20-Mar-96	25.00	25
03-Apr-96	26.00	26
09-Apr-96	33.00	33
16-Apr-96	14.00	14
30-Apr-96	12.00	12
28-May-96	8.30	8.3
05-Jun-96	17.00	17
19-Jun-96	5.80	5.8
28-Jun-96	20.90	20.9
01-Jul-96	3.00	3
10-Jul-96	<3.00	3
24-Jul-96	11.90	11.9
30-Jul-96	6.00	6
07-Aug-96	5.30	5.3
13-Aug-96	14.30	14.3
21-Aug-96	13.30	13.3
27-Aug-96	10.50	10.5
11-Sep-96	4.20	4.2
25-Sep-96	6.10	6.1
07-Oct-96	14.00	14
30-Oct-96	5.00	5
12-Nov-96	4.60	4.6
04-Dec-96	5.00	5
09-Dec-96	29.60	29.6
18-Dec-96	7.80	7.8
30-Dec-96	13.90	13.9
08-Jan-97	8.20	8.2
14-Jan-97	23.30	23.3
22-Jan-97	17.90	17.9

# Samples	# ND	# >10
175	0	41

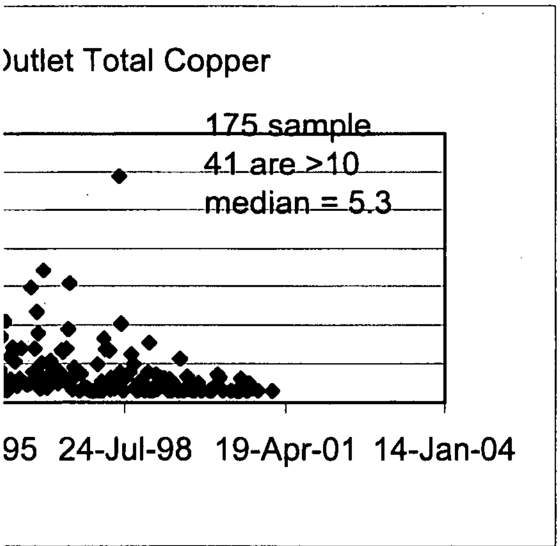
median
5.3



27-Jan-97	7.20	7.2
05-Feb-97	3.60	3.6
12-Feb-97	10.20	10.2
19-Feb-97	5.00	5
24-Feb-97	34.20	34.2
05-Mar-97	5.80	5.8
11-Mar-97	6.30	6.3
20-Mar-97	3.70	3.7
25-Mar-97	10.00	10
09-Apr-97	10.80	10.8
15-Apr-97	4.80	4.8
23-Apr-97	8.60	8.6
29-Apr-97	6.00	6
07-May-97	7.00	7
13-May-97	8.80	8.8
27-May-97	4.90	4.9
04-Jun-97	7.80	7.8
10-Jun-97	7.40	7.4
18-Jun-97	13.50	13.5
24-Jun-97	13.10	13.1
01-Jul-97	5.80	5.8
16-Jul-97	13.90	13.9
22-Jul-97	5.00	5
28-Jul-97	18.90	18.9
06-Aug-97	30.73	30.73
13-Aug-97	6.50	6.5
25-Aug-97	3.30	3.3
03-Sep-97	9.00	9
10-Sep-97	6.80	6.8
08-Oct-97	<3.00	3
15-Oct-97	7.40	7.4
22-Oct-97	3.50	3.5
12-Nov-97	3.80	3.8
25-Nov-97	3.60	3.6
01-Dec-97	3.20	3.2
10-Dec-97	<3.00	3
15-Dec-97	3.00	3
29-Dec-97	2.90	2.9
07-Jan-98	<3.00	3
12-Jan-98	<3.00	3
20-Jan-98	3.40	3.4
26-Jan-98	9.90	9.9
03-Feb-98	<3.00	3
11-Feb-98	<3.00	3
19-Feb-98	5.40	5.4
25-Feb-98	4.70	4.7
04-Mar-98	<3.00	3
09-Mar-98	16.50	16.5
18-Mar-98	13.80	13.8

24-Mar-98	3.90	3.9
31-Mar-98	5.50	5.5
15-Apr-98	13.40	13.4
22-Apr-98	3.30	3.3
22-Apr-98	6.30	6.3
27-Apr-98	5.40	5.4
11-May-98	3.70	3.7
20-May-98	3.60	3.6
26-May-98	5.80	5.8
09-Jun-98	4.00	4
17-Jun-98	58.80	58.8
23-Jun-98	7.80	7.8
29-Jun-98	20.30	20.3
13-Jul-98	<3.00	3
22-Jul-98	6.50	6.5
29-Jul-98	6.50	6.5
25-Aug-98	7.80	7.8
02-Sep-98	12.40	12.4
16-Sep-98	9.90	9.9
22-Sep-98	3.70	3.7
07-Oct-98	<5.00	3
13-Oct-98	<5.00	3
20-Oct-98	5.30	5.3
09-Nov-98	5.00	5
17-Nov-98	4.30	4.3
24-Nov-98	<3.00	3
14-Dec-98	7.80	7.8
21-Dec-98	15.40	15.4
29-Dec-98	<3.00	3
11-Jan-99	<3	3
26-Jan-99	4.20	4.2
01-Feb-99	7.20	7.2
08-Feb-99	3.30	3.3
16-Feb-99	3.80	3.8
23-Feb-99	6.50	6.5
01-Mar-99	4.40	4.4
10-Mar-99	5.70	5.7
15-Mar-99	5.70	5.7
23-Mar-99	6.20	6.2
30-Mar-99	4.00	4
14-Apr-99	5.00	5
20-Apr-99	3.00	3
27-Apr-99	6.00	6
11-May-99	3.00	3
18-May-99	5.10	5.1
26-May-99	4.10	4.1
01-Jun-99	3.50	3.5
15-Jun-99	3.40	3.4
21-Jun-99	3.00	3

30-Jun-99	11.3	11.3
21-Jul-99	3.10	3.1
27-Jul-99	3.00	3
12-Aug-99	6.60	6.6
19-Aug-99	3.40	3.4
25-Aug-99	4.20	4.2
08-Sep-99	3.40	3.4
15-Sep-99	ND	3
27-Sep-99	ND	3
20-Oct-99	5.00	5
09-Nov-99	ND	3
28-Dec-99	ND	3
12-Jan-00	ND	3
19-Jan-00	3.70	3.7
15-Feb-00	7.20	7.2
01-Mar-00	6.40	6.4
22-Mar-00	ND	3
10-May-00	ND	3
14-Jun-00	ND	3
19-Jun-00	ND	3
06-Jul-00	ND	3
11-Jul-00	6.10	6.1
26-Jul-00	4.50	4.5
17-Aug-00	ND	3
22-Aug-00	ND	3
30-Aug-00	5.00	5
13-Sep-00	3.77	3.77
20-Sep-00	3.69	3.69
25-Oct-00	ND	3
23-Jan-01	ND	3



)utlet Total Copper
175 sample
41 are >10
median = 5.3
95
24-Jul-98
19-Apr-01
14-Jan-04

Prepared by Lahontan Regional Board staff as Appendix to "Draft Functional Equivalent Document and Staff Report for Proposed Amendments to the Water Quality Control Plan for the Lahontan Region", September 1995

USE ATTAINABILITY ANALYSIS FOR OWENS LAKE, INYO COUNTY, CALIFORNIA

INTRODUCTION

The Owens Lake Soda Ash Company (OLSAC) has requested that the Lahontan Regional Water Quality Control Board (RWQCB) dedesignate several beneficial uses from a portion of Owens Lake occupied by a brine pool/mineral deposit from which it proposes to mine trona ore, and add Industrial Service Supply (IND) as a designated use. RWQCB staff are processing amendments to the *Water Quality Control Plan for the Lahontan Region*, or "Basin Plan" (California RWQCB, 1995a) to make these changes. RWQCB staff are also proposing tod add the IND use to the remainder of the Owens Lake bed (California RWQCB, 1995b). This Use Attainability Analysis (UAA) report has been prepared in compliance with U.S. Environmental Protection Agency guidance (USEPA, 1994) to provide justification for the proposed changes in beneficial uses. Other designated beneficial uses of Owens Lake, and the beneficial uses of wetlands, minor surface waters and ground waters of the Owens Lake area are not proposed for dedesignation and are not discussed in detail in this report.

Although additional field and laboratory work may be desirable in some cases, the USEPA allows States to conduct UAAs using existing data. This report uses information provided by OLSAC's consultant, MHA Environmental Consulting, Inc., and MHA's subcontractors, and other data available to RWQCB staff at short notice. The references cited below have been reviewed by RWQCB staff, and this use attainability analysis reflects staff's independent judgment.

WATER QUALITY STANDARDS

Designated beneficial uses are a part of California's water quality standards, together with narrative and numerical water quality objectives. Objectives, which are analogous to federal "water quality criteria", may be set at natural background water quality, or at levels which scientific evidence indicates are necessary for protection of beneficial uses. Beneficial uses may be uses known to exist within a particular water body, or potential uses which could occur in the future. The term "beneficial use" includes natural ecosystem functions and uses by plants and animals, as well as human uses of water. Federal regulations (40 CFR 131.10) direct that "In no case shall a State adopt waste transport or waste assimilation as a designated use for any waters of the United States".

Current standards for waters of the Lahontan Region are contained in the 1995 *Water Quality Control Plan for the Lahontan Region* (Basin Plan), as amended, and the U.S. Environmental Protection Agency's "National Toxics Rule" (40 CFR 131.26). The beneficial uses designated for Owens Lake in the 1975 South Lahontan Basin Plan included Warm Freshwater Habitat (WARM), Cold Freshwater Habitat (COLD), Saline Habitat (SAL), and Wildlife Habitat (WILD). The Municipal and Domestic Supply (MUN) use was added in 1989 in connection

PHYSICAL ANALYSIS

Hydrology

The Owens Valley floor lies at approximately 3,600 feet elevation and is surrounded by the Sierra Nevada to the west, the Inyo Mountains to the east, and the Coso Range to the south. Relict shorelines at an elevation of 3,880 indicate that Owens Lake was approximately 330 feet deep during the late Pleistocene. The brine pool "mineral deposit area" (Figure C-2) is located at the lowest point in the hydrologic basin, approximately 3560-3600 feet above mean sea level. The mineral deposit area is physically separated from the margins of the lake by an elevation gradient of approximately 8 to 48 feet.

The climate is dry, with precipitation ranging from 7-14 inches per year depending on elevation and location. At Owens Lake, typical precipitation is 4 inches per year and evaporation exceeds 70 inches per year. The Owens River was historically the main source of water flowing into Owens Lake. Other sources of inflow included precipitation falling directly on the lake surface, runoff from streams (perennial streams from the Sierra Nevada and ephemeral streams from the Inyo Mountains). Cottonwood and Ash Creeks had the largest tributary flows after the Owens River. Flash floods are an occasional, but potentially important source of water.

Due to natural topographical constraints the lake has had no outflow since the area began dessicating after the Pleistocene epoch, and due to evaporation rates that exceeded inflow to the lake, the water levels of the lake have been in a gradual state of decline, which led to natural high concentrations of salts and trace elements. With the completion of the Los Angeles Aqueduct and diversion of water beginning in 1913, the majority of the flow to Owens Lake from both the Owens River and Sierra streams was intercepted and exported from the Owens Valley. Prior to diversions by the Los Angeles Department of Water and Power (LADWP), the level of Owens Lake fluctuated due to diversions for irrigation and climatic variations. Between 1872 and 1878, the lake level was 3, 587 above mean sea level and the lake covered an area of about 72,000 acres. Diversions of tributary streams began in 1878; in 1905, following a 10 year drought, the lake had an area of 44,000 acres. At the time LADWP diversions began in 1913, the lake area was 62,000 acres. By 1924, the lake had "essentially dried to its present condition" (DRI, 1993).

The size of Owens Lake now varies from year to year: lake level records between 1938 and 1987 show that the lake reached an area of at least 20,000 acres in 31 of 39 years, and dropped blow 5,000 acres in 26 of those years. The lake area increases due to spring flow and runoff in the winter and spring, and decreases with evaporation. In years with above normal precipitation, larger quantities of water are discharged to the lakebed via the Owens River and the spillgates of the Los Angeles Aqueduct. (DRI, 1993). The U.S. Army Corps of Engineers has established the ordinary high water mark of Owens Lake at an elevation of 3,553.55 feet, which corresponds to a lakebed surface area of approximately 20,000 acres (MHA Environmental Consulting, 1994b).

Geology/Soils

Owens Lake lies within a fault-bound basin or graben between the upraised blocks of the Sierra Nevada and the Inyo Mountains. The lake bed consists of Holocene alluvium and lacustrine deposits. Soils on the lakebed generally have water at one to six inches below the surface for most of the year (GBUAPCD, 1995b). The present playa surface is covered by a thin layer of windblown sand and clay, intermixed with an alkali crust. Underlying the windblown deposits are lake sediments ranging from interfingering silty sand to sandy silt and organic clayey silt. The lake sediments extend to depths greater than 7,000 feet below the existing lake bed (Figure C-3).

The geotechnical investigation for the proposed OLSAC project (Leroy Crandall and Associates, 1990) included study of soils in the area of the proposed brine storage pond. In December 1990, ground water was located within two feet of the surface. Soils consisted of silty sand, sandy silt, and organic silt. The organic silt was relatively soft in consistency and emitted a strong sulfurous odor when excavated. Soils in the pond area were "classified as severely corrosive to ferrous metals and copper and deleterious to concrete". Liquefaction potential in the pond area in the event of an earthquake was judged to be "moderate to high". Field and laboratory permeability test were performed by LeRoy Crandall and Associates in March 1990. The results led to recommendations for use of a permeability of 1x10-6 centimeters per second for the organic silt for preliminary design purposes. OLSAC staff believe that this permeability is low enough to be adequate to isolate industrial wastes discharged to the mining area from surrounding surface and ground waters.

CHEMICAL ANALYSES

Approximately 100 million tons of salts were dissolved in Owens Lake prior to 1913. These salts became increasingly concentrated as fresh water inflow decreased and water evaporated from the lake, and eventually precipitated, forming the current lakebed mineral deposit and saturated brine solution. The dissolved solids content of the brine increased from 120,000 ppm (prior to 1913) to about to 320,000 ppm under current conditions. The present total dissolved solids (TDS) level is about nine times as salty as ocean water and comparable to that of the Dead Sea (about 335,000 ppm; Gavrieli et al, 1989), another naturally saline lake which has been drastically affected by human diversions of freshwater inflows. References cited by Bowen (1994) include a figure of 135 grams per liter (135,000 ppm) for the southern arm of Great Salt Lake in 1971. The calculated TDS concentration of Mono Lake, which supports a highly productive aquatic ecosystem, was about 90 g/l (90,000 ppm) in August 1989, about 2.5 times the salinity of ocean water (Jones & Stokes, 1993).

The lake brine level, which is dependent on precipitation and runoff water, varies in elevation from just below the surface to several inches above the surface. The composition of the salts is typical for evaporated waters derived from granitic and volcanic terrains. Brine chemistry is controlled by evaporative concentration, precipitation, and temperature. The "trona ore deposit" within the area proposed for dedesignation of several beneficial uses consists

Fish

Sada (1989) conducted a literature review, interviews with DFG biologists, and field surveys of spring and seep aquatic habitats potentially affected by the OLSAC project to determine whether populations or habitat for the federally and state listed endangered fish species, the Owens tui chub (*Gila bicolor snyderi*) and Owens pupfish (*Cyprinodon radiosus*) was present in the OLSAC project area. Sada provides summaries of the life histories, habitat requirements, and known recent occurrence of these species. His report concludes that it is highly unlikely that these species currently occupy habitats which could be affected by the OLSAC project.

Invertebrates

Brine shrimp (*Artemia*) were reported from Owens Lake in 1876 and 1906. Bowen (1994) surveyed four sites on the western edge of Owens Lake in an unsuccessful search for the presence of *Artemia* cysts. Dr. David Herbst of the University of California has identified the presence of brine shrimp cysts in freshwater seeps at Bartlett point and Cottonwood Creek, and the abandoned UMETCO ponds at Keeler. Bowen concluded that Owens Lake is not a site for a continuing population of *Artemia*, although transient populations might occur in certain years when fresh water mixes with lake water. Bowen believed that further search for living *Artemia* from the original population would be unproductive because of the high salt concentrations in the Owens Lake remnant since 1920 and the low viability of cysts beyond 40 years. Bowen also concluded that the lowering of the carbonate concentration in the brine pool through mining would not affect the potential for recolonization of Owens Lake by brine shrimp in the event that flooding reduced the salinity of the brine pool. A literature review indicates that the chloride/sulfate ratio is a more important factor ionic tolerance of brine shrimp from other carbonate salt lakes than the carbonate concentration.

A literature review and consultation with other biologists by Hadley (1994) indicates that four species of brine flies occur in the Owens Lake area. Brine flies have high food value for various bird species, and historically were used as food by Native Americans in the Mono Lake area. At Owens Lake, brine flies inhabit pools in saline mudflats between the freshwater wetland/spring areas on the lake margin and the hypersaline brine pool. Although fresh water from precipitation or tributary springs may float on the surface of the saturated lake brine briefly due to lower density, wind action rapidly leads to mixing and return to a saturated state. Such temporary freshwater pools are also unsuitable for brine fly breeding habitat The proposed storage/evaporation ponds associated with the OLSAC project are expected to be too saline to support brine flies.

Wildlife

GBUAPCD (1995b) lists two species of amphibians, 25 species of reptiles, 35 bird species, and about 22 species of mammals present in the Owens Lake area. The Owens River area at the northern end of the lake has been identified as an important tule elk (*Cervus elaphus*

USE ATTAINABILITY

General Considerations

The USEPA's Water Quality Standards Regulation (40 CFR 131) directs that State water quality standards "should, wherever attainable, provide water quality for the protection and propagation of fish, shellfish and wildlife, and for recreation in and on the water and take into account their [sic] use and value of public water supplies, propagation of fish, shellfish and wildlife, recreation in and on the water, and agricultural, industrial, and other purposes including navigation". The Water Quality Standards Regulation defines "existing uses" as "those uses actually attained in the water body on or after November 28, 1975, whether or not they are included in the water quality standards". "Designated uses" are uses "specified in water quality standards for each water body or segment whether or not they are being attained". "Use attainability analysis" is "a structured scientific assessment of the factors affecting the attainment of the use which may include physical, biological, chemical, and economic factors". At a minimum, uses are considered attainable if they can be achieved by the imposition of effluent limits required under Sections 301(b) and 306 of the federal Clean Water Act and cost effective and reasonable best management practices for nonpoint source control.

The Water Quality Standards Regulation (40 CFR 131.10[g]) allows states to remove beneficial uses which are not existing uses if the state can demonstrate that the designated use is not feasible for one of a number of reasons. Reasons for dedesignation applicable to Owens Lake include infeasibility of attaining the use due to:

a. Naturally occurring pollutant concentrations;

b. Natural, ephemeral, intermittent or low flow conditions or water levels;

c. Dams, diversions, or other types of hydrologic modifications, where "it is not feasible to restore the water body to its original condition or to operate such modification in a way that would result in the attainment of the use"

States may not remove existing beneficial uses except under limited circumstances, as in the case where another use requiring more stringent criteria is added.

The dedesignation of several potential beneficial uses discussed below can be justified under federal guidance because Owens Lake has high concentrations of salts and trace elements due to natural sources and naturally fluctuating inflows, which have been greatly exacerbated by diversion of tributary streams and ground waters. The following is a detailed analysis for each use or category of uses proposed for change in the Basin Plan amendments. The Wildlife Habitat use, which is not proposed for dedesignation because it is an existing use, is also discussed.

beryllium (0.004 mg/l), and cadmium (0.005 mg/l). The brine has a pH of 10.5 units, which violates the MCL for pH (6.5-8.5 units). Drinking water MCLs also require that waters be non-corrosive; given the high pH and the reported corrosivity of the sediments, the brine probably violates this MCL.

The salts and trace elements in the brine come from natural sources, such as weathering of rocks and geothermal fluids, although their concentration has been accelerated by human water diversions. There are higher quality and more economically feasible water sources in the vicinity. Treatment of this surface brine to municipal and domestic water quality standards would probably not be economically feasible. It is unrealistic to assume that LADWP's diversions will cease, or that the level of Owens Lake will ever be returned to prediversion conditions.

Under the proposed Basin Plan amendments, wetlands, ground water, and minor surface waters of the Owens Lake watershed would continue to be designated MUN. Conditions will be included in permits for any future industrial discharges to surface waters of Owens Lake to ensure that ground water uses are not impaired.

Water Contact Recreation (REC-1) Use

The REC-1 beneficial use is defined in the Basin Plan as:

> *"Beneficial uses of waters used for recreational activities involving body contact with water where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water-skiing, skin and scuba diving, surfing, white water activities, fishing, and use of natural hot springs."*

As the Basin Plan explains, the beneficial uses of surface waters of the Lahontan Region generally include the REC-1 use in order to implement the "swimmable" goals of the federal Clean Water Act, except for a few cases, such as agricultural reservoirs, wastewater reservoirs, drinking water aqueducts, and some special wildlife areas where access for REC-1 uses is restricted or prohibited by the entities which control those waters. REC-1 uses were added in the 1995 Basin Plan for most water bodies which did not already have them designated, including Owens Lake, in order to reflect the federal "swimmable" goal.

USEPA guidance (1994) discusses criteria for water contact recreation uses largely in terms of protection of human health in relation to ingestion of water, particularly in relation to bacteria standards. It states that: "Recreation in and on the water....may not be attainable in certain waters, such as wetlands, that do not have sufficient water, at least seasonally". However, physical factors, which are important in determining attainability of aquatic life uses, may not be used as the basis for not designating a recreational use consistent with the CWA Section 101(a)(2) goal. This precludes states from using low flows and physical factors in general as grounds for dedesignating a recreational use. "The basis for this policy is that the States and

> *"Beneficial uses of waters used for recreational activities involving proximity to water but not normally involving body contact with water where ingestion of water is reasonably possible. These uses include but are not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, tidepool and marine life study, hunting, sightseeing, and aesthetic enjoyment in connection with the above activities".*

<u>Warm and Cold Freshwater Habitat (WARM and COLD) and Inland Saline Water Habitat (SAL) Beneficial Uses</u>

The WARM use is defined in the Basin Plan as:

> *"Beneficial uses of waters that support warm water ecosystems, including, but not limited to, preservation and enhancement of aquatic habitats, vegetation, fish, and wildlife, including invertebrates."*

The COLD use is defined as:

> *"Beneficial uses of waters that support cold water ecosystems, including, but not limited to, preservation and enhancement of aquatic habitats, vegetation, fish and wildlife, including invertebrates."*

The SAL use is defined as:

> *"Beneficial uses of waters that support inland saline water ecosystems, including, but not limited to, preservation and enhancement of aquatic saline habitats, vegetation, fish, and wildlife, including invertebrates.*

The WARM and COLD uses were designated for Owens Lake as a whole in the 1975 South Lahontan Basin Plan before the Owens Lake wetlands were recognized as separate water bodies with their own beneficial use designations; it was recognized that some springs and seeps around the margin of the lake may provide habitat for organisms requiring either warm freshwater or cold freshwater habitat. The chemical information discussed above shows that the brine pool is clearly too saline to support freshwater habitat uses. It is appropriate to remove the WARM and COLD beneficial uses from the Owens Lake brine pool; since the brine pool had reached its present state by the 1920's, these have not been "existing uses" since before the 1976 threshold date..

Owens Lake does provide inland saline water habitat; however, the quality of this habitat has been partially impaired by the concentration of salts and trace elements due to declining lake levels. Table C-2 provided by MHA Environmental Consulting, compares the brine chemistry of Owens Lake with USEPA saline aquatic life criteria (these criteria are probably based mostly on bioassays of marine organisms), and demonstrates a number of exceedances. Owens Lake historically supported brine shrimp (*Artemia*), and brine flies still survive in less saline waters on the lake margin. Studies (Bowen 1994) have shown that brine shrimp and

Of the three aquatic habitat uses currently designated for Owens Lake, only the Inland Saline Water Habitat (SAL) use appears to be an existing and attainable use. This use is not proposed for dedesignation; within the constraints of the physical/chemical environment at Owens Lake, retention of the SAL use meets the "fishable" goal of the Clean Water Act.

Commercial and Sportfishing Use (COMM)

The COMM beneficial use is defined in the Basin Plan as:

> *"Beneficial uses of water used for commercial or recreational collection of fish and other organisms including, but not limited to, uses involving organisms intended for human consumption."*

As explained in Chapter 2 of the Basin Plan, this use was added for all surface waters in the Lahontan Region in the 1993-95 update. It applies to even to waters which do not support fish, such as hypersaline Mono Lake which supports a commercial brine shrimp operation; The cultural resources analyses in GBUAPCD (1995a and b) refer to archaeological sites, located just above the late prehistoric shoreline, which show human use of Owens Lake for hunting, boating, and food supplies such as brine fly larvae and shellfish. Review of the information provided by OLSAC indicates that does not appear to be any existing (since 1976) or potential commercial or recreational use of Owens Lake related to harvesting the few aquatic species which now occur, or could feasibly occur, in the brine pool. Removal of this use designation from the brine pool is appropriate. The COMM use for the remainder of the lakebed is not proposed for dedesignation.

Wildlife Habitat (WILD) Use

This use is defined as:

> *"Beneficial uses of waters that support wildlife habitats, including, but not limited to, the preservation and enhancement of vegetation and prey species used by wildlife, such as waterfowl."*

The draft EIR/EIS for the OLSAC project (MHA Environmental Consulting 1994a) concludes that its impacts on snowy plover habitat on the bed of Owens Lake can be mitigated to less than significant levels through measures such as identification of nests before construction, timing construction activities to avoid the nesting season, training personnel to identifiy potential nesting habitat, minimizing the construction area, and building bridges across dredge lines to allow plover chicks to cross. Because of this mitigation, and because reclamation activities following the conclusion of mining are expected to restore the brine pool surface to near natural physical conditions, dedesignation of the wildlife habitat beneficial use from the brine pool does not appear to be appropriate. The attainability of the wildlife habitat use on the remainder of the lakebed may be enhanced through the proposed establishment of wetland vegetation by the Great Basin Unified Air Pollution Control District (GBUAPCD, 1995a).

WILD uses. If brine shrimp returned to the lake, a COMM use would be feasible. Higher lake levels and lower salinity would support a REC-1 use. Even pre-diversion salinity levels would exceed the Sources of Drinking Water Policy TDS criteria, but treatment of brine pool water to support a MUN use would be more feasible than at current salinity levels. However, although plans are underway to restore some of the public trust uses of the eastern portion of the lakebed, it is unrealistic to assume that Owens Lake will ever be restored to pre-diversion conditions.

The nonattainable uses summarized above meet USEPA criteria for dedesignation in that they cannot feasibly be attained due to naturally high "pollutant" concentrations and naturally low or fluctuating tributary flow conditions, exacerbated through human diversions of tributaries. These nonattainable uses cannot reasonably be attained through effluent limitations on point source discharges and application of Best Management Practices for nonpoint source discharges. Surface waters of the Owens Lake brine pool do not meet the SWRCB's criteria for classification as "sources of drinking water". This Use Attainability Analysis supports the changes in beneficial use designations for Owens Lake proposed as amendments to the 1995 *Water Quality Control Plan for the Lahontan Region.*

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TABLE C-1. Naturally Occuring Trace Metals in Lake Brine and Ore Within the Owens Lake Brine Pool

Metal	Brine Concentration (ppm)	Ore Concentration (ppm)
Aluminum	0.6	496
Antimony	0.2	3.0
Arsenic	110.0	3.0*
Barium**	2.0	70.0
Beryllium**	0.04	0
Boron	278	171
Cadmium	1.0	0
Calcium	ND***	4, 983
Chromium VI	ND	0
Chromium III	1.3	7.7
Cobalt**	0.5	0
Copper	0.5	0
Fluoride	31	3.0
Iron	ND	1,096
Lead	0.1	0
Magnesium	ND	1,780
Manganese	ND	0
Mercury	ND	0
Molybdenum**	1.5	0
Nickel	1.0	3.0
Phosphorus	206	0
Potassium	5, 306	1,535
Selenium	ND	0
Silicon	231	395
Silver**	0.1	0.7
Strontium	ND	0
Thallium	ND	0
Tin	ND	0
Titanium	ND	0
Vanadium	1.0	6.0
Zinc**	0.2	12.0

* Arsenic in solids is from entrained brine. All arsenic is soluble.

** These metals were not detected in the lake brine, but have been set at detection limits. Actual levels could be significantly less.

*** "ND" = "Not Detected"

SOURCE: MHA Environmental Consulting, Inc.(1995), reporting analyses conducted by Innochem Engineering Limited for Vulcan Chemicals.

Table C-2. *Inorganic Standards for Saline Water Aquatic Life Protection Compared to Native Lake Brine*

	Native Lake Brine	**Saline Aquatic Life Protection**	
Analyte	**(ppb)**	**4 day average[1] (ppb)**	**1 hour average[1] (ppb)**
Aluminum	600	NS[2]	NS
Ammonia		35	233
Antimony	200	500[3]	1500[3]
Arsenic	95,000	36	69
Barium[4]	2,000	NS	NS
Beryllium[4]	50	9.3	43
Boron	278,000	NS	NS
Cadmium	1,000	NS	NS
Chromium (III)	1,300	NS	NS
Chromium (IV)	ND[2]	50	1100
Cobalt[4]	500	NS	NS
Color	ND	NS	NS
Copper	500	2.9	2.9
Fluoride	31,000	NS	NS
Iron	ND	NS	NS
Lead	100	5.6	140
Magnesium	ND	NS	NS
Manganese	ND	NS	NS
Mercury (inorganic)	ND	0.025	2.1
Molybdenum[4]	1,500	NS	NS
Nickel	1,000	8.3	75
pH	10.5 (pH)	NS	NS
Phosphorus	206,000	NS	NS
Potassium	5,036,000	NS	NS
Selenium	ND	71	300
Silicon	231,000	NS	NS
Silver[4]	100	0.92[3]	2.3
Strontium	ND	NS	NS
Thallium	ND	NS	NS
Tin	ND	NS	NS
Titanium	ND	NS	NS
Vanadium	1,000	NS	NS
Zinc[4]	200	49	54

[1] *Continuous Concentration (4 day average) in parts per billion (ppb); Maximum Concentration (1 hour average) in parts per billion (ppb)*
[2] *NS=No Standard; ND=Not Detected; NT=Not Tested;*
[3] *Proposed standard*
[4] *Metals were not detected in the lake brine, but have been set at their detection limit.*

SOURCE: *MHA 1994; Central Valley Regional Water Quality Control Board (CVRWQCB) Compilation of Water Quality Goals 1993*

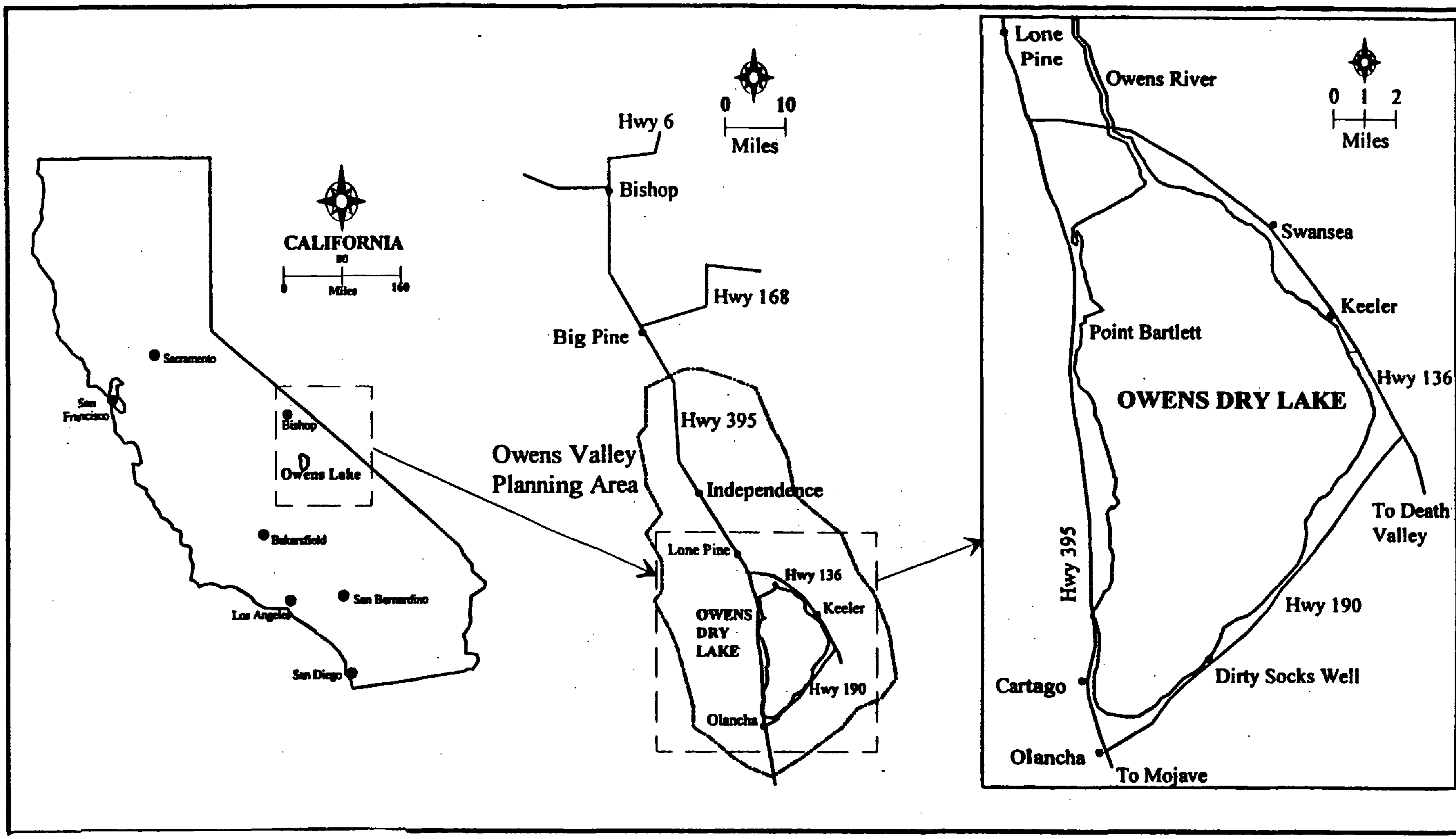
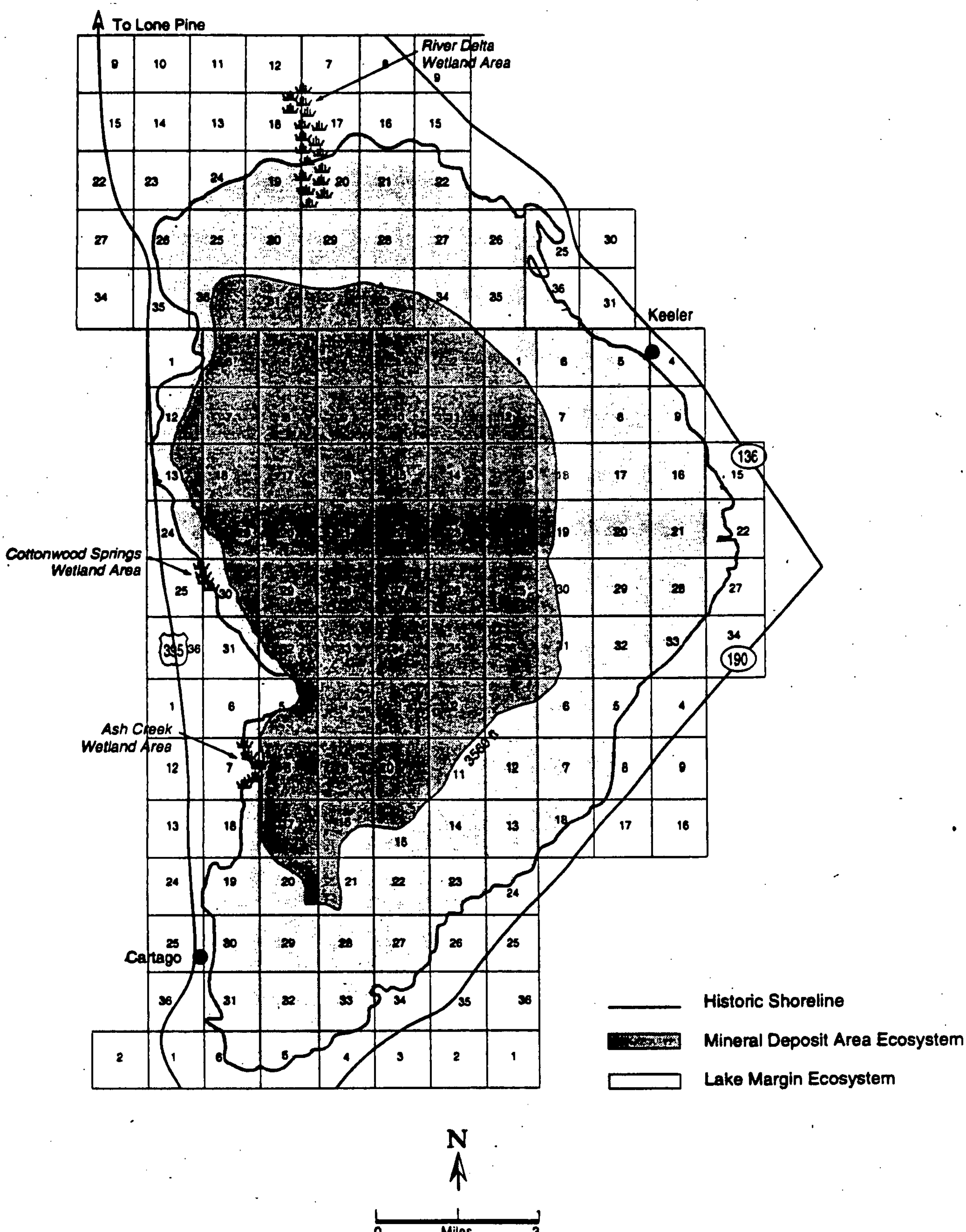


Figure C-1. Vicinity Map for Owens Lake. Source: GPUACD 1995a.

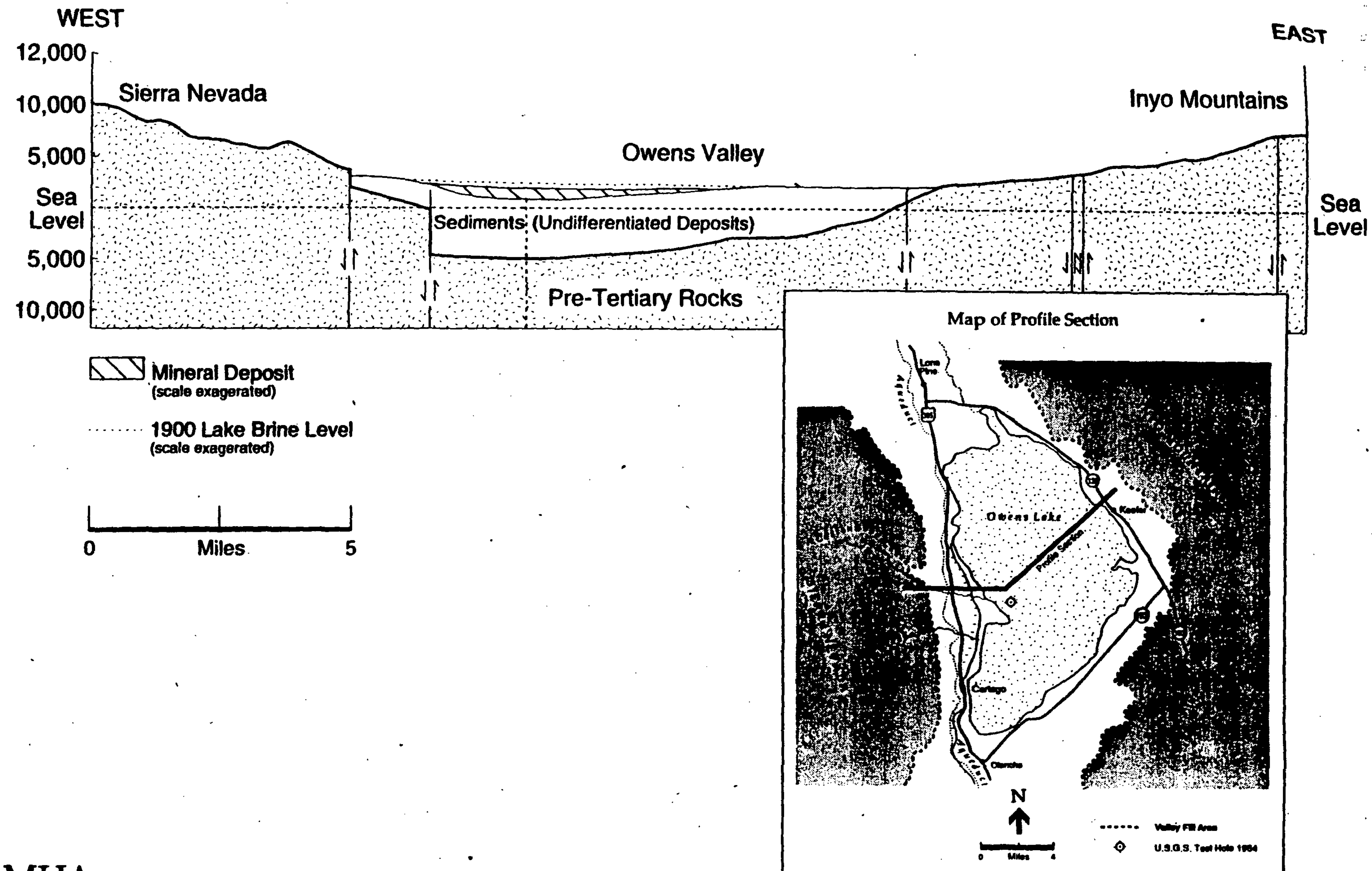
vicinity.ds4 - tds - 7/27/95

Figure C-2. **Ecosystems at Owens Lake**



MHA Environmental Consulting, Inc.

Figure C-3. Cross-Section Through Owens Lake



MHA *Environmental Consulting, Inc.*

Source: CH2M Hill 1981

City of Los Angeles Water Services

Water Quality

ARSENIC

GENERAL INFORMATION

The current Interim Primary Standard for arsenic of 50 micrograms per liter (ug/L) in drinking water was established in 1976 to protect against skin cancer. This standard was scheduled for finalization with the other Phase II compounds in 1991. However, due to new evidence implicating arsenic in the development of other, more serious internal cancers, the Maximum Contaminant Level (MCL) for arsenic was delayed.

Epidemiological studies conducted in 1988 and 1990 on populations in Taiwan exposed to high levels of arsenic (300-800 ug/day) in drinking water show a higher than expected incidence of internal cancers of the liver, kidney, lung, and bladder, in addition to skin cancer. Researchers suspect that exposure to arsenic is responsible for the higher incidence, but genetics, nutrition, or other variables may also contribute to its development.

Arsenic is a difficult contaminant to study, because it does not induce cancer in laboratory animals. It has been shown, in fact, to be an essential nutrient in many animal species and may be an essential element in extremely small amounts for humans as well. In greater amounts however, arsenic is believed to be a potent carcinogen. Arsenic does not appear to induce cancer through the usual modes of initiation and/or promotion, but possibly through a late-stage process. The human body has some defenses against arsenic toxicity.

When amounts below 200-250 ug/day are ingested, the human body can detoxify arsenic by the addition of methyl groups. However, while this provides protection from toxic non-carcinogenic effects, it does not necessarily protect against carcinogenic effects. One hypothesis actually suggests that methyl groups used for arsenic detoxification are directed away from DNA synthesis, thereby causing chromosome damage and indirectly causing cancer. Further studies are needed, especially on U.S. populations.

THE REGULATION (draft)

The Environmental Protection Agency (EPA) has hinted at setting an MCL somewhere between 0.5 and 20 ug/L. To assess the risk associated with exposure to arsenic, EPA uses the linearized multistage model. Based on this model, a one in a million excess cancer risk level would be at 2 parts per trillion (0.002 ug/L). However, current commercial analytical technology cannot detect arsenic at levels below 2 ug/L.

The expected date of the rule is dependent on reauthorization of the Safe Drinking Water Act. Efforts to reauthorize the Safe Drinking Water Act in 1996, may include an arsenic regulatory schedule and changes to the standard setting process. Current draft legislative language would require EPA to finalize the rule by 2000. Drinking water associations, working with EPA hope to see an arsenic regulation based on "good science" which will be worthy of the investment customers may be asked to make.

IMPACT TO LADWP CUSTOMERS

Drinking Water

The Los Angeles Aqueduct supply (LAA) contains low levels of arsenic. The long-term average arsenic level in this raw water supply is 22 ug/L. After the water is blended and treated, the level drops to an annual average of 10 ug/L, well below the current standard of 50 ug/L. The major contributing source of arsenic is Hot Creek near Lake Crowley. Mean annual flow from this creek is 22 cubic-feet per second (cfs), although flows have ranged from 7 to 79 cfs. At the new proposed levels, treatment to reduce arsenic from the entire LAA supply (600 cfs) will be quite costly. A treatment facility at Hot Creek would be more cost-effective, but siting a facility in such an environmentally-sensitive area will be very difficult.

In addition to the Hot Creek supply, Los Angeles Department of Water and Power (LADWP) anticipates that many local wells may require treatment. Historically, arsenic in the local well supply has been undetectable based on a detection limit of 10 ug/L. Currently, LADWP is in the process of monitoring all of its local wells using the newer detection limit of 2 ug/L. reatment. Only 2 of the more than 50 wells sampled to date have had detectable arsenic levels.

In addition, the Association of California Water Agencies has been conducting an occurrence evaluation of arsenic in California water supplies at the 0.5 ug/L level. This survey will provide the EPA with some concrete occurrence data which will also be used by ACWA to assess the inancial burden to the customers.

Ocean Discharge
The Bureau of Sanitation is required under the Clean Water Act to comply with an arsenic ocean discharge standard of 12 ug/L per day. The LADWP has been working with the Bureau of Sanitation to help limit the amount of arsenic in sewer discharge. One of the interim operational changes currently being evaluated is the addition of ferric chloride and polymer at the Cottonwood Treatment Plant, located north of Haiwee Reservoir for arsenic reduction in the raw water.

Back to Water Services Home Page

City of Los Angeles Water Services

Water Quality

LEAD AND COPPER RULE

GENERAL INFORMATION

The Lead and Copper rule was developed to minimize health risks associated with lead and copper in drinking water. To accomplish this goal the rule focuses on the two causes of lead and copper in drinking water . These causes are 1) leaching from lead pipes, brass faucets, and internal (home) plumbing, that is increased if the water is corrosive and 2) lead in source waters.

THE REGULATION

The Lead and Copper Rule went into effect on January 1, 1992.

- Action Levels were established for lead and copper at the consumer's tap. These action levels are set at 15 micrograms per liter (ug/L) for lead and 1300 ug/L for copper.
- Homes must be sampled once every six months for one year. The number of homes to be sampled is based on the size of the population served by the utility.
- Homes to be sampled must have lead pipes or have been built or replumbed between 1983 and 1986 and have copper plumbing with lead solder. This requirement targets those homes that are most likely to have problems with excess lead and copper in their drinking water.
- For utilities serving less than 50,000 people: If the action levels are exceeded in more than 10 percent of the tap samples, then the utility is required to a) provide optimal corrosion control, b) begin public education, c) install source water treatment, if necessary and d) replace any lead service lines. If the utility does not exceed the action level in more then 10 percent of its samples, then it is only required to monitor once a year.
- For utilities serving more than 50,000 people: Regardless of the results of the initial home monitoring, the utility must provide optimal corrosion control, then monitor again, once every six months for a year. If after providing corrosion control the action level is exceeded in more than 10 percent of the tap samples, then the system is required to a) begin a public education program, b) install source water treatment, if necessary, and c) replace any lead service lines.
- For public education, the utility is required to use television, radio and newspaper media to provide information regarding the health effects of lead and the precautions consumers should take to prevent high lead exposure from water.

IMPACT TO LOS ANGELES

The Los Angeles Department of Water and Power (LADWP), based on the population it serves, is required to sample at least 100 customer taps, for two six-month periods and sample source water quarterly for one year. LADWP is also required to complete corrosion studies and install corrosion control treatment regardless of the levels of lead and copper found at the source and/or at the tap. The capital cost of corrosion control treatment is estimated to be $1-2 million with an additional $4 million per year in operation and maintenance costs.

Although the city of Los Angeles is fortunate not to have lead in its raw water sources or distribution system, there is always the potential of lead solder from home plumbing or lead from brass faucets contributing lead to drinking water.

LADWP conducted two rounds of in-home monitoring in 1992. In each round, 122 samples were collected and tested for lead and copper. These homes were built or replumbed between 1983 and 1986 and had copper pipes with lead solder. Of these homes, less than 10% had lead levels above 15 ug/L. Nevertheless , LADWP in collaboration with the L.A. County Health Department, prepared a public education brochure targeted at protecting young children and expectant mothers who are most at risk for adverse health effects from lead and copper. The brochure provides information about the different venues of lead contamination from the environment and specifically addresses the issue for L.A. county residents.

Back to Water Services Home Page

City of Los Angeles Water Services

Water Supply Fact Sheet

Sources of Water for Los Angeles

The City has three principal water supply sources: the *Los Angeles Aqueduct (LAA), local groundwater*, and purchased water imported by the *Metropolitan Water District of Southern California (MWD).*

LAA. Since the addition of the Second LAA in 1970, aqueduct supplies have provided for about two-thirds of the City's needs, on average about 400,000 acre feet per year (AF/Y). Court decisions to provide additional aqueduct water to benefit the environment in the Mono Basin and the Owens Valley have limited the City's aqueduct deliveries. As a result, long-term projections for LAA deliveries are about 350,000 AF/Y which will satisfy about half of our City's water needs.

Local Groundwater. The City is entitled to 110,000 AF/Y from the San Fernando Basin (SFB), Central, Sylmar and West Coast groundwater basins. Since 1970, local wells have produced about 95.000 AF/Y accounting for

15 percent of the City's total water supply. About 80 percent of this groundwater comes from the SFB with the remaining basins making up the balance. In emergencies or during prolonged drought periods, additional groundwater can be extracted from the SFB. As of October 1995, the City had credit for approximately 296,000 AF in underground storage. The availability of groundwater supplies is expected to increase to 152,000 AF/Y by 2015 when recycled water will be used to recharge and replenish the water stored in the SFB.

MWD. Founded in 1928, MWD today serves 27 member agencies in Southern California encompassing 5,200 square miles with a population of nearly 16 million people. MWD is a regional water "wholesaler" as opposed to the DWP which acts like a water "retailer" providing water directly to individual customers rather than agencies. Since 1970, the City has purchased an average 125,000 AF/Y from MWD or 20 percent of the City's total supply. The City's annual MWD purchases can vary significantly depending on the need to supplement LAA deliveries if dry conditions exist.

During the drought of 1987 - 1992, for example, MWD supplied more than 60 percent of the City's needs.

Recycled Water. Now a permanent fixture in the City's water supply picture, there are plans to use recycled water to meet increased demands related to growth. To date, two water recycling projects have been completed by the Department and provide an estimated 3,000 AF/Y. The City has established recycled water production goals with 30,000 AF/Y expected by the year 2000; 85,000 AF/Y by 2015. The East Valley Water Recycling Project will contribute a significant portion of this amount, producing 35,000 AF/Y within the next 20 years.

Alternative Water Supplies

Water marketing, increased conservation of local stormwater runoff and seawater desalination are alternative supply options for Los Angeles. Today, these options are far more costly than traditional supplies. The Department will follow closely developments in these areas and will continue to support the MWD in its efforts to develop supplemental supplies such as their pilot desalination project and water marketing efforts.

Water Conservation

Water conservation will be a key element in meeting the City's anticipated water needs and improving reliability. The City has invested more than $60 million over the past five years in conservation programs. Another $10 million annually is budgeted for the next 10 years. The City has implemented all 16 provisions of the Best Management Practices, a program subscribed to by all major water agencies in the state to promote efficient water management. Among the Department's prominent conservation programs are the Ultra-Low-Flush Toilet Replacement Program (responsible for replacing more than 500,000 toilets), the Technical Assistance Program (providing financial incentives for commercial/industrial conservation retrofitting) and a water rate structure that rewards conservation and penalizes wasteful water use.

Water Demands

Annual water demands in Los Angeles are about 628,000 AF with an average per capita use of 135 gallons per day. About two-thirds of the City's demand is for residential uses, equally shared by single-family and multi-family units. About one quarter of the demand is for commercial and governmental uses, with a very small amount used by industry. The City's water demand is expected to grow to almost 750,000 AF/Y, a 20 percent increase to support an additional 900,000 residents expected by 2015.

Facilities

The Los Angeles Aqueduct System (LAA)

First LAA - Completed in 1913, the 233-mile Owens River Aqueduct transports snowmelt from the eastern slopes of the Sierra Nevada. An engineering landmark, the aqueduct travels through 142 tunnels and across nine major canyons to deliver water to Los Angeles using only the force of gravity. In 1940, the aqueduct was extended 105 miles north to the Mono Basin. An 11-mile tunnel was drilled through the Mono Craters to obtain water from the Mono Basin's four mountain streams. The Mono Basin Project extended the length of the First LAA to 338 miles and increased the capacity of the system to almost 300 million gallons per day (336,000 AF/Y).

Second LAA - To keep pace with the City's growing water demands, the Second LAA was completed in 1970 to transport additional water from the southern Owens Valley to Los Angeles. The completion of the Second LAA increased the Los Angeles Aqueduct System capacity to almost 500 million gallons per day (560,000 AF/Y).

Aqueduct Reservoirs. There are seven reservoirs in the LAA system with a combined storage capacity of approximately 325,000 AF. Long Valley Reservoir (Crowley Lake) is the City's largest storage reservoir. It's storage levels are the principal indicator of the City's water supply conditions.

On its way to Los Angeles, water from both aqueducts passes through 11 power plants generating low-cost, pollution-free hydroelectric energy. The energy generated is over one billion kilowatt-hours, enough to supply the needs of 220,000 homes.

Reservoir	Capacity
Grant Lake	47,000 AF
Long Valley	183,200 AF
Pleasant Valley	3,000 AF
Tinemaha	6,300 AF
North and South Haiwee	39,300 AF
Bouquet	26,400 AF
Fairmont	490 AF

These reservoirs run north to south in the system

In-City Treatment and Distribution Facilities

The Department operates a state-of-the-art water treatment plant in Sylmar that uses a combination of ozonation, filtration and chlorination to produce water that meets or exceeds all drinking water standards. This treatment plant was put in service in 1988 and has a treatment capacity of 600 million gallons per day. Additionally, two groundwater treatment facilities have been constructed by the Department to remove contaminants from wells in the San Fernando Basin.

Treated water is distributed to the City by a system consisting of about 7,200 miles of water mains ranging from four inches to 10 feet in diameter. The oldest pipes were installed in 1885. Storing and regulating water in the city is done with the use of 81 tanks and 17 reservoirs. In areas of higher elevation, 85 pump stations deliver water. There are about *5,500* fire hydrants connected to the city. Water use is measured by about 660,000 metered service connections.

Capital Improvement Programs and Infrastructure Management

The reliability of water service is tied to the integrity of City distribution, storage and treatment facilities. Every year the Department allocates a substantial amount of resourcesto rehabilitate and maintain its infrastructure. Field crews routinely inspect and monitor the LAA System and perform the necessary repairs and maintenance. Seismic stability of dams at both in-City and LAA reservoirs also are monitored to ensure earthquake safety.

An innovative pipeline rehabilitation program has cement-mortar-lined approximately 850 miles of old water mains to date. An average $34 million has been budgeted annually for the next 10 years to line an additional 130 miles per year. Water meters are being replaced to provide additional accuracy. Computers are being integrated into daily operations to provide services such as control, telemetry and water quality monitoring. Water Services expenditures are expected to rise over the next five years as the Department complies with new water quality standards and continues to replace aging water mains. A capital improvement program planned for some of the City's open reservoirs will cost an estimated $417 million over the next decade in order to bring the reservoirs into compliance with new standards.

Miscellaneous/Hydrologic Facts

- DWP Established 1902
- Population Served 3.6 million
- Employees *9,000*
- Service Area 465 square miles
- Water Services operations are financed solely by water revenue. Capital funds are raised through the sale of bonds. No tax support is received.
- The Department is the largest municipally-owned utility in the United States.Graphics Recommendations:

Back to Water Supply Page

ADAPTED FROM UNITED STATES DEPARTMENT OF THE INTERIOR GEOLOGIC SURVEY									
PROCESS DATE 6-10-98									
STATION	DATE	TEMPER-ATURE WATER (DEG C)	DIS-CHARGE, INST. CUBIC FEET PER SECOND	SPE-CIFIC CON-DUCT-ANCE (US/CM)	PH WATER WHOLE FIELD (STAND-ARD UNITS)	PH WATER WHOLE LAB (STAND-ARD UNITS)	ARSENIC DISS OLVED AS	COPPER DISS-OLVED (UG/L AS CU AS	LEAD DISS-OLVED (UG/L AS PB)
		-10	-61	-95	-400	-403	-1000.00	-1040	-1049
10265143	07-13-88	25.7	5.81	146	8.74	8.5	46.00	5	1
HATCHERY	10/19/88	10	E2.1000	221	8.3	8	4.00	5	4
AB SPRINGS	4/11/89	14.5	8.74	165	8.2	7.9	20.00	4	7
	7/18/89	23.5	5.25	135	8.6	8.6	52.00	5	1
	10/18/89	12	2.09	202	8.6	8.1	38.00	3	2
	1/9/90	2.5	5.3	192	7.97	7.9	21.00	3	2
	4/25/90	17	3.49	168	8.7	--	3.00	2	--
	7/17/90	24	3.3	142	8.86	8.4	52.00	6	2
	10/16/90	12.55	1.3	195	8.49	8.1	46.00	6	8
	1/17/91	5.5	1.25	251	8.04	7.7	54.00	28	10
	4/16/91	13.5	3.09	195	7.48	7.9	29.00	13	22
	7/22/91	24.5	2.4	155	8.24	8.2	43.00	4	--
	10/22/91	13.5	2.78	154	8.7	8	27.00	4	1
	1/13/92	0.5	4.57	165	8	7.8	20.00	6	9
	4/14/92	15.5	4.16	187	8.4	8.2	29.00	6	9
	7/6/92	22	5.03	105	8.9	8.2	19.00	6	3
	10/19/92	14.5	2.24	156	8.4	8.1	26.00	3	2
	1/25/93	2.5	3.4	220	7.7	7.7	60.00	23	24
	4/12/93	14	8.7	187	8.3	8.1	24.00	11	12
	7/13/93	13	65.6	71	7.64	7.6	11.00	7	7
	10/13/93	10	9.71	120	7.72	7.5	11.00	6	6
	1/10/94	5.5	3.3	175	8.22	7.7	15.00	10	11
	4/12/94	5.5	5.53	170	8.03	7.6	17.00	8	10
	7/11/94	25	6.74	101	8.52	7.6	16.00	6	8
	10/19/94	5.5	3.18	168	8.14	7.5	23.00	6	7
	1/17/95	0	8.94	166	7.74	7.6	18.00	10	9
	4/18/95	0.5	13.7	186	7.87	7.7	18.00	10	16
	10/16/95	14.5	19.4	127	8.15	7.9	16.00	6	4
	10/16/95	--	--	--	--	7.7	17.00	6	4
	1/24/96	0.5	9.62	150	8	7.7	17.00	7	11
STATION	**DATE**	**TEMP**	**CFS**	**COND**	**pH FIEL**	**pH LAB**	**AS**	**CU**	**PB**
		-10	**-61**	**-95**	**-400**	**-403**	**-1000.00**		
10265143	4/23/96	13	17.4	141	8	7.7	<1.00	5	5
HATCHERY	7/16/96	18	38.5	86	7.78	7.4	13.00	8	4
AB SPRINGS	10/16/96	11	7.11	154	8.18	7.8	20.00	6	8
	1/14/97	1	24.9	133	--	7.4	13.00	5	5
	4/15/97	8.5	13.8	157	8.16	7.819	11.73	4	4
	7/15/97	16	31	89	7.92	7.538	8.81	4	13
	10/20/97	8	9.6	145	8.02	8.106	12.40	4	4
10265147	11/6/84	--	--	--	--	9.6	45.00	3	2
ABOVE GORGE	01-15-97	7.5		195				1	1
	4/16/97	12		212					
	7/16/97	15		169					

	10/22/97	12		214							
	11/19/97	7.5	42.4	219	8.82	8.058	36.00				
	12/18/97	8		227							
	1/16/98	8		231							
	2/12/98	10.5		236							
	3/19/98	14		253							
	4/17/98	11		246							
10265150	11/16/82	19.5	88.6	340	7.5	7.7	140.00	--		--	
FLUME BELOW	6/3/83	17.1	216	216	7.4	7.5	70.00	--		--	
GORGE	7/6/83	22.5	312	153	6.7	7.3	52.00	--		--	
	8/8/83	18.7	183	246	7.1	7.4	88.00	--		--	
	10/3/83	21.5	100	363	7.3	7.7	120.00		3	3	
	11/2/83	20.3	84	410	7.4	7.5	150.00		2	2	
	12/14/83	16.5	89	416	7.3	7.5	130.00		3	3	
	4/5/84	23.7	63	490	7.5	7.6	170.00		2	1	
	5/10/84	25.5	73	444	7.5	7.6	160.00		3	1	
	6/20/84	21	118	297	--	7.5	83.00		4	2	
	7/24/84	27.5	100	362	7.4	8.2	120.00		7	2	
	9/2/84	24.5	67	445	7.5	7.9	160.00		1	1	
	10/10/84	24.7	60	471	7.4	7.5	160.00	0.000 1		0.000 3	
	11/11/84	24	62	460	7.4	8.6	150.00	0.000 2		0.000 2	
	10/19/85	32.7	44	552	7.6	8	240.00	0.000 2		0.000 1	
10265150	4/12/86	24.8	70.7	447	7.6	7.6	180.00		3	1	
FLUME BELOW	7/27/87	36	41.8	579	--	8.7	110.00	--		3	
GORGE	7/12/88	34	57	470	7.78	7.7	230.00		1	1	
	7/19/89	37	42.2	586	7.7	7.8	270.00		1	--	
	7/18/90	33	38	591	7.59	7.7	280.00		1	2	
	01-15-97	21.8		423							
	4/16/97	23		466							
	7/16/97	25		356							
	10/22/97	30		510							
	12/18/97	24.5		514							
	1/16/98	24		481							
	2/12/98	26.5		511							
	3/19/98	30.5		523							
	4/17/98	27.5		499							
373940118494001	12-18-97	92		1750							
SPRINGS IN	1/16/98	93		1760							
GORGE	2/12/98	92.5		1760							
	3/19/98	92.5		1729							
	4/17/98	92.8		1730							
373942118494201	03-16-83	89	--	2670	8.4	8.5	990.00	--		--	
	8/19/83	91.5	--	2740	8	8.1	1100.00	--		--	
	10/4/83	90.6	--	2520	8.1	8.4	1200.00	--		--	
	12/13/83	88.3	--	2530	8.2	8.4	900.00		4	-- <1	
	5/8/84	91.4	--	2510	8.1	8.4	900.00	--		-- <	
	9/3/84	91	--	--	8.3	8.5	930.00	-- <		--	
	2/4/85	92.4	--	--	8.1	8.5	940.00	10.000 <		10.000 <	
	7/16/85	92.8	--	2030	7.8	8	1100.00	00.00 <6		00.00 <2	
	4/8/86	92.3	--	1820	8	8.2	1100.00	-- <		-- <	
	4/8/86	92.3	--	1820	8	8.2	1100.00	-- <		-- <	
	7/28/87	93.7	--	--	7.56	8	1100.00	-- <		-- <	
	7/11/88	93	--	--	8.08	8.3	1300.00	-- <		-- <	
	7/19/89	95	--	--	7.8	8.3	1100.00	--		--	

	7/18/90	95.5	--	--	8.11	8.4	1000.00	-- <	--	
	4/16/92	81	--	1830	7.6	8.1	1100.00	--	--	
374010118465301	04-10-86	56.6	--	1810	6.6	6.9	470.00	18	15	
	8/29/87	58.4	0.075	--	6.78	7.2	86.00	17	15	
	7/14/88	57.6	0.06	--	6.95	7.6	380.00	18	16	
	1/12/89	57.4	0.05	--	7	7.3	470.00	16	15	
	7/17/89	57.5	0.057	--	6.7	7.3	200.00	18	15	
	1/10/90	57.1	0.1	--	6.96	7.4	150.00	19	16	
374125118502501	08-19-83	82.2	--	2830	6.7	6.8	600.00	--	--	
	1/17/84	80	--	2810	6.7	7	580.00	3	20	
	5/9/84	81.2	--	2730	6.8	7	590.00	4	20	
	9/3/84	82.7	0.08	--	6.8	7	620.00	3	21	
	11/12/84	82.6	--	--	6.8	8.9	450.00	10.000 4	10.000 20	
	4/10/86	82.4	--	2010	6.53	6.9	720.00	4	20	
	8/29/87	82.8	0.12	--	6.6	7.3	<650.00	4	21	
	7/14/88	82.8	0.12	--	6.95	8.9	590.00	3	21	
	1/13/89	82.6	0.12	--	6.8	7	850.00	3	20	
	7/17/89	82.5	0.133	--	6.7	7.5	300.00	3	20	
	1/9/90	82.7	0.12	2100	7.11	7.4	700.00	3	21	
	7/18/90	82.8	0.12	--	7	7.2	610.00	1	21	
	1/18/91	82.6	0.123	1990	6.9	7.2	700.00	3	20	
	7/24/91	82.8	--	2030	7.63	7.8	710.00	3	19	
	1/15/92	82.7	0.119	1920	8	8.1	710.00	3	20	
	4/16/92	82.6	--	1980	7.6	7.8	710.00	2	20	
	7/8/92	82.7	--	1920	7.7	7.7	690.00	5	20	
	1/26/93	82.8	0.13	1900	7.12	7.1	780.00	3	21	
	7/15/93	82.7	0.13	1910	7.82	8.2	650.00	3	20	
374501118561501	08-07-91	11	--	201	7.49	7.7	--	--	-- <	
STATION	**DATE**	**TEMP**	**CFS**	**COND**	**pH FIEL**	**pH LAB**	**AS**	**CU**	**PB**	
		-10	**-61**	**-95**	**-400**	**-403**	**-1000.00**			

OWENS VALLEY

PM_{10} PLANNING AREA

DEMONSTRATION OF ATTAINMENT

STATE IMPLEMENTATION PLAN

Dr. Ellen Hardebeck, Air Pollution Control Officer
Great Basin Unified Air Pollution Control District
157 Short Street
Bishop, California 93514

(760) 872-8211
FAX - (760) 872-6109

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EXECUTIVE SUMMARY

PURPOSE OF THE SIP

The Owens Valley PM_{10} Demonstration of Attainment State Implementation Plan (SIP) has been prepared by the Great Basin Unified Air Pollution Control District to meet federal requirements in the Clean Air Act Amendments of 1990 (CAAA). The SIP includes an analysis of the particulate matter air pollution problem in the Owens Valley and provides a control strategy to bring the area into attainment with the National Ambient Air Quality Standard (NAAQS) for particulate matter.

FEDERAL CLEAN AIR ACT AND THE SIP

On July 1, 1987, the US Environmental Protection Agency (USEPA) revised the NAAQS, replacing total suspended particulates (TSP) as the indicator for particulate matter with a new indicator called PM_{10} (i.e., particulate matter less than or equal to 10 microns in diameter). The intent of the new, health-based standard for particulate matter was to prevent concentrations of suspended particles in the air that are injurious to human health. PM_{10} can penetrate deep into the respiratory tract, and lead to a variety of respiratory problems and illnesses. On August 7, 1987, the USEPA designated the southern Owens Valley as one of the areas in the nation that violated the new PM_{10} NAAQS. Figure 1 shows the boundaries of the nonattainment area, which is known as the Owens Valley Planning Area. Subsequent air quality monitoring by the District has shown that the bed of Owens Lake -- most of which is owned by the State of California and managed by the California State Lands Commission (SLC) -- is the major source of PM_{10} emissions contributing to air quality violations in the Owens Valley Planning Area. In January 1993, the southern Owens Valley was reclassified as a "serious nonattainment" area for PM_{10}.

The USEPA required the State of California to prepare a SIP for the Owens Valley Planning Area that demonstrates how PM_{10} emissions will be decreased to prevent exceedances of the NAAQS. The District is the agency delegated by the State to fulfill this requirement. In accordance with Section 189(b) of the CAAA, an Attainment SIP for serious nonattainment areas must be submitted to the USEPA by February 8, 1997 that demonstrates conformance with the federal air quality standards through the implementation of a program of control measures. By statute, attainment of the NAAQS for PM_{10} must be accomplished by December 31, 2001, or, at the discretion of the EPA under Section 188(e), may be extended to December 31, 2006.

This document was prepared to satisfy the requirements for a SIP that demonstrates attainment with the PM_{10} NAAQS. The SIP includes a PM_{10} control strategy to reduce wind blown PM_{10} emissions from 35 square miles of exposed playa at Owens Lake. The control strategy includes using gravel coverings, managed vegetation, and shallow flooding to accomplish PM_{10} emission reductions at Owens Lake. It is anticipated that the control strategy can be implemented in four and a half years and bring the area into attainment by December 31, 2001 as require CAAA. After the District Board adopts the SIP, it will be sent to the California Ai Board for review and approval. Once approval is granted by the State, it will then b submitted to the USEPA in compliance with federal requirements.

HEALTH IMPACTS OF PM_{10} FROM OWENS LAKE

Particulate pollution is generally associated with dust, smoke and haze and is meas which stands for particulate matter less than 10 microns in diameter. These particle extremely small, less than a tenth the diameter of a human hair. Because of their sr can easily penetrate into the lungs. Breathing PM_{10} can cause a variety of health pr can increase the number and severity of asthma and bronchitis attacks. It can cause difficulties in people with heart or lung disease, and it can increase the risk for, or c existing respiratory infections. The National Ambient Air Quality Standard is inter people who are especially sensitive to elevated levels of PM_{10}, which includes; chil elderly and people with existing heart and lung problems. The PM_{10} NAAQS for a average is set at 150 $\mu g/m^3$. At much higher concentrations of PM_{10}, even healthy i can be adversely affected by the dust. The USEPA has set an episode level of 600 level that can pose a significant risk of harm to the health of the general public, inc otherwise healthy individuals (40 CFR 51.151).

The NAAQS for PM_{10} is frequently violated in the planning area because of wind b from Owens Lake. Wind speeds greater than about 17 mph (7.6 m/s) have the pote wind erosion from the barren lake bed. Ambient PM_{10} readings are the highest mea country. One PM_{10} reading from Keeler on April 13, 1995 reached 3,929 $\mu g/m^3$, m times higher than the PM_{10} NAAQS. From 1987 through 1995 the PM_{10} NAAQS v about 19 times per year in Keeler, 5 times per year in Olancha and 2 times per year

Studies of dust transport from Owens Lake show that violations of the standard car experienced more than 50 miles away and expose many more people to violations c standard than just the residents near Owens Lake. Figure 2 shows the extent of pos violations from Owens Lake dust storms. About 40,000 permanent residents betwe and Bishop are annually affected by the dust from Owens Lake at concentrations th above the federal PM_{10} standard. In addition, many visitors spend time in the dust to enjoy the many recreational opportunities the Eastern Sierra and high desert hav Lone Pine annually hosts the Lone Pine film festival which draws thousands of vis outside the area. The National Park Service is concerned about the health hazard p estimated 250,000 to 350,000 visitors that are expected to annually visit the Manza Historic Site, 15 miles north of Owens Lake. The Park Service is concerned becau percentage of the visitors to Manzanar will be older visitors who are more prone to respiratory threats, and that they will spend 3 to 4 hours outdoors in a potentially h environment.

SOURCES OF PM_{10} EMISSIONS

Air pollution emissions in the nonattainment area are dominated by PM_{10} emissions from wind erosion from the exposed Owens Lake playa. Other wind erosion sources in the nonattainment area are: off-lake sources of lake bed dust, small mining facilities and some areas near Lone Pine and Independence that have been disturbed by human activity. There are a lack of large industrial sources in the Owens Valley and the only other source of criteria pollutant emissions are wood stoves, fireplaces, unpaved and paved road dust, and vehicle tailpipe emissions. In the future, the USDA Forest Service will also be emitting PM_{10} from prescribed burning activities in and around the nonattainment area. The prescribed burning activity, however, is not expected to be done on high wind days when the Owens Lake dust storms occur. Predicted high wind days are avoided when doing prescription burns for fire safety reasons.

Wind erosion at Owens Lake comprises more than 99% of the 24-hour and annual emission inventories. Wind erosion emissions can be separated into on-lake and off-lake source areas. The on-lake source areas are the wind erosion areas on the historic playa of Owens Lake. Figure 3 shows the identified source areas that have been used for the attainment demonstration SIP. Off-lake sources of wind blown dust are caused by dust that was initially entrained from the exposed playa and then deposited in areas off the lake bed. These dust deposition areas, which are located adjacent to the lake bed from Keeler to Olancha, become secondary sources of dust that can be entrained under high wind conditions.

The locations of on-lake source areas were determined by field mapping of eroded areas after storms. The boundaries of the eroded areas were mapped using a global positioning system (GPS). These data were transferred to the Geographic Information System to map the boundaries and determine the area size. Off-lake source area locations are based on observations of dust storms in 1994 and 1995, and by use of aerial photos of deposition areas.

A number of methods have been used to estimate PM_{10} emissions from Owens Lake dust storms including; high altitude photography, salt efflorescence, sun photometry, and portable wind tunnel measurements. A range of annual emissions from around 130,000 to over 400,000 tons of PM_{10} per year were estimated using these methods.

PM_{10} CONTROL MEASURES

Control measures are defined as those methods of PM_{10} abatement that could be placed onto portions of the Owens Lake playa and when in place are effective in reducing the PM_{10} emissions from the surface of the playa. For approximately the last 12 years the District and other researchers have been involved with the study of the lake environment and the mechanisms that cause Owens Lake's severe dust storms. For the last six years the District has pursued a comprehensive research and testing program to develop PM_{10} control measures that are effective in the unique Owens Lake playa environment. Control measures that were tested on the lake but have been rejected as effective dust control measures for the SIP included the use of sp chemical dust suppressants, surface compaction, sand fences, and brush fences. These were discussed in the Owens Valley PM_{10} Planning Area Demonstration of Attainmen Projects Alternatives Analysis document. For the attainment demonstration, three PM measures will be used; shallow flooding, managed vegetation and gravel.

Shallow Flooding for PM_{10} Control: The surfaces of naturally wet areas on the lake l those areas typically associated with seeps and springs) are resistant to wind erosion th dust. Shallow flooding mimics the physical and chemical processes that occur at and a natural springs and wetlands. In these areas, water discharges across the flat lake bed s raising the level of the shallow groundwater table to the surface. The areal extent of w dependent upon the amount of water discharged to the surface, evaporation rate and la topography. The size of the wetted area is less dependent on soil type because, once th table is raised to the playa surface, surface evaporation is soil-type independent. Shall flooding provides dust control over large areas with minimal infrastructure and it requ minimal ongoing operation, maintenance and lake bed access.

This control measure consists of releasing water along the upper edge of the PM_{10} emi elevation contour lines and allowing it to spread and flow down-gradient toward the c lake. To attain the required PM_{10} control efficiency, at least 75 percent of each square control area must be wetted (i.e., standing water or surface saturated soil) between Se and June 15 each year. This coverage can be determined by aerial photography. To m project water use efficiency, flows to the control area will be regulated at the outlets s sufficient water is released to keep the soil wet. Although the quantity of excess wate minimized through system operation, any water that does reach the lower end of the c will be collected and recirculated through the system. At the lower end of the flood ar intermediate locations along lower elevation contours, excess water will be collected collection berms keyed into lake bed sediments and pumped back up to the outlets to

Due to the generally flat, uniform nature of the lake bed, the outlet water would sprea areas to create a random pattern of shallow pools. These pools would be generally les inches deep. Pooled areas will produce no PM_{10}, and will act as sand traps to prevent abrasion and dust generation. Damp and saturated soils also resist wind erosion. Loca areas or "islands" of non-wetted soil tend to self-level; the soil blows off the higher is captured in the pools. Thus, over time the high areas would become lower and the lo would become higher. This leveling process can be expected to occur over a period o years. In some limited cases, it may be necessary to mechanically level high areas. T occur primarily where previous earthwork performed on the lake bed prevents natura spreading of PM_{10} control waters.

Shallow Flooding has been shown to be effective for controlling wind blown dust in dominated soils on the lake bed. Between 1993 and 1996 a 600-acre test was condu sand sheet between Swansea and Keeler (Figure 4). Effectiveness was evaluated in four ways; a) from aerial photographs assuming that flooded areas provided 100% control, b) from portable wind tunnel measurements of test and control areas, c) from fetch transect (2-dimensional) analysis of sand motion measurements; and d) from areal (3-dimensional) analysis of sand motion measurements. The average control effectiveness was 99% after the surface water covered 75% of the test area. Wind tunnel tests showed an area-wide PM_{10} emission rate of 4.1×10^{-6} g/m^2-s, for the shallow flood site when 75% of the surface area was covered with water. This emission rate, which is used for the attainment demonstration modeling, applies to periods when the hourly average wind speed is greater than 25 miles per hour at 10 meters.

Where shallow flood water is distributed across the playa, opportunistic plant species are expected to establish themselves where conditions are favorable. Limited stands of cattails (*Typha* sp.), sedges (*Carex* sp.), saltgrass (*Distichlis spicata*), and other species associated with saturated alkaline meadows of the region have colonized the immediate vicinity of the water outlets on the flood irrigation project. Based on testing performed by the District at the North Flood Irrigation Project test area, naturally established vegetation can be expected to immediately occur on about 0.5 percent of the area that is controlled with shallow flooding. This percentage may increase over time.

The expansive shallow flooded areas and the naturally established vegetation provide ephemeral resting and foraging habitat for wildlife use. Insect and shorebird utilization of wet areas created by District testing on the lake bed was common during control measure testing. Based on these previous experiences, it is anticipated that shallow flooding will create large areas of plant and wildlife habitat in areas where very little previously existed.

Water flows between September 15 and June 15 will be maintained to provide the required 75 percent of the area in standing water or saturated soil. During cool weather when evaporation rates are low, it may be possible to shut off flows completely for short periods as long as saturated soil conditions are maintained. To maximize water use efficiency, water flows should be minimized during the summer months when PM_{10} standard violations are infrequent and evaporation rates are high. It is a mandatory element of this project that minimal water flows be maintained between June 15 and July 31 to sustain established vegetation and wildlife. Between July 31 and September 15 the flows may be shut off completely. Based on the District's large-scale tests of shallow flooding, operating the shallowing flooding control measure in this manner is predicted to use approximately four acre-feet per year (ac-ft/yr) of water per acre controlled. Careful management of shallow flood areas may allow for even less water to be used.

Maintenance activities associated with shallow flooding would consist of minor grading and berming on the control areas to ensure uniform water coverage and prevent water channeling. Staffing requirements for operation and maintenance of the shallow flooding areas are estimated at approximately one FTEE per 3,200 acres of flooded area.

Managed Vegetation for PM_{10} Control: Where water appears on the playa surface wi quantity and quality sufficient to leach the salty playa surface and sustain plant growth, vegetation has naturally become established. The saltgrass meadows around the playa r and the scattered spring mounds found on the playa are examples of such areas. Vegeta surfaces are resistant to soil movement and thus provide protection from PM_{10} emissior managed vegetation strategy creates a mosaic of irrigated fields provided with subsurfa drainage to create soil conditions suitable for plant growth using a minimum of applied Because this measure relies on earthen infrastructure for water distribution, it is best su use in clay soils that can be used for the construction of ditches, berms, channels and re that allow for level border irrigation strategies that leach and drain readily through the f structure of the soil. The proposed methods of soil reclamation are similar to those usec elsewhere in this country and world-wide for desalinization of salt-affected soils, allow soils to be useful for plant growth.

This control measure consists of a creating a farm-like environment containing small (approximately 4 to 20 acre) confined fields constructed on contour that are irrigated w shallow pulses of water (Figure 5). The amount of water required to leach the soils to v level suitable for salt-tolerant species depends on specifics of soil type and of surface tı Studies at the test plot indicate that between 3½ and 6 feet of water will be necessary tc two-foot deep soil profile to a level suitable for planting with saltgrass. This amount of be delivered to the fields in 4 to 6 irrigation events, which can take place during a peric 3 to 4 months. As the salt levels in the leached plots decline, plants can be introduced t fields and irrigated using the same methods. Therefore, if leaching began during the wi months, saltgrass could be planted during the spring of the same year.

To attain the required PM_{10} control efficiency, a cover of at least 50 percent live or dea vegetation is necessary. Data from test plots on the lake indicate that such cover can be during the third growing season. Total cover will include both live and dead plant mat both function equally well to prevent PM_{10} emissions. Field studies on Owens Lake te: confirm that the target saltgrass cover of 50 percent can be sustained with two ac-ft/yr irrigation water. Percent cover can be measured by the point frame method.

Saltgrass (*Distichlis spicata)* will be the only plant species considered by this SIP to b introduced to the fields. It is tolerant of relatively high soil salinity, spreads rapidly via and provides good protective cover year-round even when dead or dormant. Saltgrass subsist with minimal amounts of applied water during the summer, and dust control ef remains undiminished, provided that adequate irrigation has stimulated plant growth a provided stored water in the plants' rooting zone during the spring months.

Recent field and wind tunnel research using Owens playa sands and actual saltgrass v has been conducted. These studies indicate that even sparse populations of saltgrass f very effectively in reducing sand migration and PM_{10} within the stand. The field studi concluded that for the coarse sands of the north sand sheet on Owens Lake, 95% reduction in sand movement can be achieved with a saltgrass cover of between 16 to 23%, depending on wind speed and direction. Wind tunnel studies showed that a vegetation cover of 12 to 23% will significantly reduce the amount of entrained sand and PM_{10}.

The tests performed used Owens Lake saltgrass that was positioned in loose, sandy soil. This test condition is more erosive than the actual soils in vegetated areas of the playa, which are less erodible because they are more compacted due to repeated wetting. The soils proposed for the managed vegetation are clay soils, some of which have a shallow layer of windblown sand on top of them. Although wind tunnel tests showed that 23% cover could achieve 90% or more reduction of saltation and PM_{10}, the actual clay soils on the playa will be less erodible after the vegetation is growing. Control effectiveness is therefore expected to be higher than that measured in the wind tunnel, even at these low cover values. The plan for managed vegetation, however, is to achieve cover values of at least 50%, a value that would include dead or dormant stems that would provide erosion protection without presenting a transpirative surface. This level of cover could be retained with minimal water use during the summer, and would function during winter months as well without irrigation. Control effectiveness at this higher level of cover would be greater than that demonstrated in the loose, sandy soils.

Based on field studies done at Owens Lake and elsewhere, the District concludes that more than 99% reduction of soil erosion and PM_{10} will be achieved at Owens Lake with a salt grass cover of 30 to 50%. For modeling and emissions inventory purposes the controlled PM_{10} emissions from the vegetation managed area is estimated at 1% of the uncontrolled emission rate.

Although saltgrass is the only plant species that will be deliberately introduced to the managed vegetation area, other plants species are expected to establish themselves opportunistically. The species typical of transmontane alkaline meadows elsewhere in the region, such as inkweed (*Nitrophila occidentalis*), Nevada sedge (*Scirpus nevadensis*), and yerba mansa (*Anemopsis californica*) would be expected to appear, adding diversity and wildlife habitat value to the fields. On saltgrass test plots established by the District on the playa, evidence of use by rabbits, rodents, insects, spiders, and even coyotes was found. The mosquito and salt cedar control programs discussed above would also take place on the managed vegetation control measure.

Every effort will be made to limit the potential for introduction of exotic pest plant species into source emission areas that will be controlled through the use of managed vegetation. Test plots established on the playa have not been invaded by exotic pest plants. Fortunately, the existing saline soil conditions inherent to the lake bed are inhospitable to most plants including exotic pest plants such as tamarisk, puncture weed and Russian thistle and noxious grasses such as *Cenchrus*. Exotic pest plants and noxious grasses will be removed from the source emission area (if present) prior to planting with saltgrass. Another potential source for the introduction of exotic pest plants would be from the saltgrass stands harvested for rhizomes to vegetate the panels. Exotic pest plants will be removed from the saltgrass stands (if present) prior to harvesting. Removal will be accomplished through an appropriate combination of mechanical and chemical control methods. Berms and other elements of infrastruc constructed from lake bed soils, which are not likely to be subject to invasion fron plants due to the high levels of salinity.

Managed vegetation is predicted to utilize approximately two ac-ft/yr of water per controlled. The distribution of the water over the entire vegetated area will be irreg at any given time some fields will be irrigated for maximum growth while others minimal amounts of water allowing for minimal stand maintenance. Water use wil during the initial stages of development of this measure, as it will take 3½ to 6 fee leach the top two feet of soil to a salinity level tolerable to saltgrass.

Operation and maintenance activities for managed vegetation would consist of im irrigation schedule for the fields, and necessary repair to water transmission and de structures and to the berms and ditches associated with the fields. Staffing requirer operation and maintenance of the managed vegetation area are estimated at approx FTEE per 1,500 acres of vegetated area.

Gravel Cover for PM_{10} Control: A four-inch layer of coarse gravel laid on the su Owens Lake playa will prevent PM_{10} emissions by: (a) preventing the formation o evaporite salt crusts, because the large spaces between the gravel particles interfer capillary forces that transport the saline water to the surface where it evaporates ar salts; and (b) raising the threshold wind velocity required to lift the large gravel pa larger than ⅜- inch diameter) so that transport of the particles is not possible by w typical of the Owens Lake area. Gravel blankets can work effectively on essentiall soil surface. Gravel test plots on Owens Lake have been in place for approximatel continue to completely protect the emissive surfaces beneath (Figure 6). Gravel pl lake bed surface will be durable enough to resist wind and water deterioration and will be approximately the same color as the existing lake bed.

Under certain conditions, it may be possible for some of the gravel blanket to settl soils and thereby lose effectiveness in controlling PM_{10} emissions. This may occur the soil has a high clay and silt content and where shallow groundwater is present periods at the surface. Settlement of gravel particles would occur until the clay/gra formed acted to support the gravel above. To prevent the loss of any protective gra into lake bed soils, a permeable geotextile fabric will be placed between the soil ar This will prevent the loss of any gravel.

Gravel areas must be protected from water- and wind-borne soil and dust. The gra be the last control measure to be installed. Therefore, wind-borne depositions will Gravel areas will also be protected from flood deposits with flood control berms, d channels and desiltation/retention basins. These measures will ensure that the gravel blanket will remain an effective PM_{10} control measure for many years.

To attain the required PM_{10} control efficiency, 100 percent of all areas designated for gravel must be covered with a minimum layer of four inches of gravel that is larger than ⅜-inch in diameter placed over a permeable geotextile fabric. The gravel material shall be at least as durable as the rock from the three sources analyzed in this document. The material shall have no larger concentration of metals than found in the materials analyzed in this document. The color of the material used shall be such that it does not significantly change the color of the lake bed.

A gravel cover forms a non-erodible surface when the size of the gravel is large enough that the wind cannot move the surface. If the gravel surface does not move, it protects finer particles from being emitted from the surface. Gravel and rock coverings have been used successfully to prevent wind erosion from mine tailings in Arizona. The potential PM_{10} emissions from a gravel surface can be estimated using the USEPA emission calculation method for industrial wind erosion for wind speeds above the threshold for the surface. PM_{10} will not be emitted if the wind speed is below the threshold speed.

Based on a particle size mode of ¼ inch, the proposed gravel cover will have a threshold wind speed of 90 miles per hour measured at 10 meters. This wind speed is rarely exceeded in the Owens Lake area. A more typical gust for Owens Lake may be around 50 miles per hour.

The proposed 4-inch thick gravel cover is intended to prevent capillary movement of salt and silt particles to the surface. Fine sands and silts that fill in void spaces in the gravel will allow the capillary rise of salts and reduce the effectiveness of a gravel blanket to control PM_{10} at Owens Lake. In addition, finer particles will lower the particle size mode and lower the threshold wind speed for the surface. Gravel blanket tests were performed at two sites on Owens Lake starting in June 1986. These tests showed that four-inch thick gravel blankets composed of ¼ inch and larger rocks prevented capillary rise of salts to the surface. Observations of ungraveled test plots in the same area, one with no surface covering and another with local soil, showed that salts would otherwise rise to the surface.

Because fine particles should not be allowed to cover or significantly invade the gravel, the gravel blankets would be the last measure implemented after all other erodible areas are controlled.

The PM_{10} emissions are expected to be zero for the gravel cover since the threshold wind speed to entrain gravel, and thus PM_{10}, is above the highest expected wind speeds expected for the area. This will result in 100% reduction of PM_{10} from areas that are covered by a gravel blanket.

Once the gravel cover has been applied to the playa, limited maintenance would be required to preserve the gravel blanket. The gravel would be visually monitored weekly to ensure that the gravel blanket was not filled with sand or dust, or had not been inundated or washed-out from flooding. If any of these conditions were observed over a substantial area, additional gravel would be transported to the playa via truck (unless the conveyor system was still in place and operational) and applied to the playa surface via truck and/or low ground-pressure bulldozer or grader. Operation and maintenance staffing requirements are estimated to be one FTEE per five square miles of gravel and an ongoing maintenance amount of gravel of 3,200 cubic yards per square mile per year.

PROPOSED CONTROL STRATEGY

The selection of the proposed control strategy was made after careful consideration of eight alternatives that were reviewed by the public, regulatory agencies and the City of Los Angeles. The range of alternatives that were considered not only accomplished the District's primary goal of bringing the area into attainment with the PM_{10} NAAQS, but also harmonized with the State of California's obligation of land and resource stewardship and of public trust values with respect to the Owens Lake bed which was exposed when the water of the Owens Valley was diverted into the Los Angles Aqueduct.

The selected PM_{10} control strategy combines into an overall plan to control dust from Owens Lake the three control measures: shallow flooding, managed vegetation and gravel covering (Figure 7). The project requires the use of an estimated 51,000 acre-feet (ac-ft) of water per year. This amount of water may decrease over time as improved water use techniques are developed and as the lake bed becomes vegetated.

The SIP and the proposed implementation order do not prescribe the source(s) of water from which the City of Los Angeles must supply the water-based control measures. An available water source for the control measures is the Los Angeles Aqueduct. The control measures would use approximately that amount of water that analysis indicates could be supplied from the Los Angeles Aqueduct without causing significant impacts or water shortages to the City of Los Angeles, or significant indirect impacts to any other area. Fifty-one thousand acre-feet per year represents approximately 13% of the water that the Los Angeles Department of Water and Powei (LADWP) exports to the City of Los Angeles. Over the last 20 years the LA Aqueduct flow to the City has averaged 395,000 ac-ft per year. Although the District has chosen at this time not to specify the source of water to be used in the water-based control measures, it reserves its authority under both state law (in determining which control measures are reasonable) and under federal law (in determining which control measures are the "best available") to prohibit the use o water resources which cannot be tapped without causing significant adverse environmental consequences.

An air quality modeling analysis was performed to show that the proposed control strategy would reduce the PM_{10} emissions to a level that will bring the areas around Owens Lake into compliance with the 24-hour PM_{10} NAAQS of 150 $\mu g/m^3$. Air quality modeling utilized the US

EPA approved guideline model, Industrial Source Complex - Short-term version 3. After the proposed control strategy is implemented, ambient PM_{10} design concentrations are expected to be highest in the area near the southeast shoreline, with a PM_{10} design concentration of 66.6 $\mu g/m^3$ (Figure 8). The design concentration refers to the third highest value in two years, which must be less than 150 $\mu g/m^3$ to show compliance with the standard. The NAAQS allows for one day per year on average to exceed 150 $\mu g/m^3$.

IMPLEMENTATION SCHEDULE AND PHASING

The Proposed Project is projected to be implemented in phases, on an area-by-area basis, over a period of more than four years. The order of implementation within each area will generally be as follows: roads, electrical lines, water supply pipelines, flood control channels, containment and diversion berms, flood irrigation, vegetation and gravel. There are two reasons for this order: (a) it allows most of the support infrastructure construction to occur before access is restricted by the wet soils caused by the water-based measures; and (b) it provides the opportunity to observe the actual coverage and effectiveness of the proposed water-based measures, and to maximize their extent, before the graveled areas are installed. Because gravel is the most costly measure to install, every attempt should be made to minimize its extent, and therefore, it should be the last measure to be implemented. However, if the gravel is protected from wind- and water-borne soil deposits, it can be installed at any time or can replace water-based measures, if necessary.

The three control measures, flood irrigation, managed vegetation and gravel, will also each be installed in phases. The first phase of each measure will consist of a moderately large segment of the total, approximately 1,200 acres, that will allow construction and operation techniques to be refined. Subsequent phases can then take advantage of this knowledge to lower the costs associated with these later phases. Table 1 shows proposed phasing of each of the control measures on the playa. Area letters in Table 1 refer to areas indicated in Figure 7.

PM_{10} EMISSION REDUCTION TREND

An estimate of the PM_{10} emission reduction trend over the four and a half year implementation period can be estimated using the information shown in Table 1 and an approximation for the amount of PM_{10} per acre of playa controlled. Using the model estimated peak day PM_{10} emissions, an estimate of 0.48 tons of PM_{10} per acre of lake bed controlled is estimated for 22,400 acres that are intended for controls. Figure 9 shows the estimated peak-day emission trend line for the SIP control strategy. More than 99% reduction of peak-day PM_{10} emissions is expected over five years with the implementation of the control strategy. A similar trend line would also be estimated for the reduction of annual emissions.

Table 1. Control Area Sizes for Annual Implementation.

Area - Control Measure		Area Controlled in Each Year (acres) 1997	1998	1999	2000	2001
A	Shallow Flooding	1,210	---	---	---	---
B	Shallow Flooding	2,320	4,640	---	---	---
C	Gravel	---	---	---	3,365	---
D	Managed Vegetation	---	1,200	2,400	5,100	---
E	Gravel	---	---	---	---	1,940
F	Shallow Flooding	---	---	---	225	---
		3,530	5,840	2,400	8,690	1,940
	Total = 22,400 acres					

COST AND EMPLOYMENT

The comparative preliminary cost estimate for the construction of the proposed project is million. The comparative preliminary cost estimate for annual operation and maintenanc million. These estimates assume that the water supplied from the Aqueduct is replaced b City with purchases from the Metropolitan Water District at a cost of $450 per acre foot. the construction and annual cost estimates, the 25-year annualized cost is $38 million. It estimated that the proposed project will create between 84 and 91 jobs during constructi 14 long-term jobs for operation and maintenance of the control measures.

CONCLUSION

The proposed control strategy using a combination of shallow flooding, managed veget gravel covering as shown in Figure 7 can be implemented in four and a half years to me federal attainment deadline of December 31, 2001. Investigations performed on the lak show that these control measures are feasible and that they will significantly reduce PM emissions. Air quality modeling has shown that this strategy can reduce PM_{10} impacts around the historic lake shore to below the federal 24-hr PM_{10} standard.

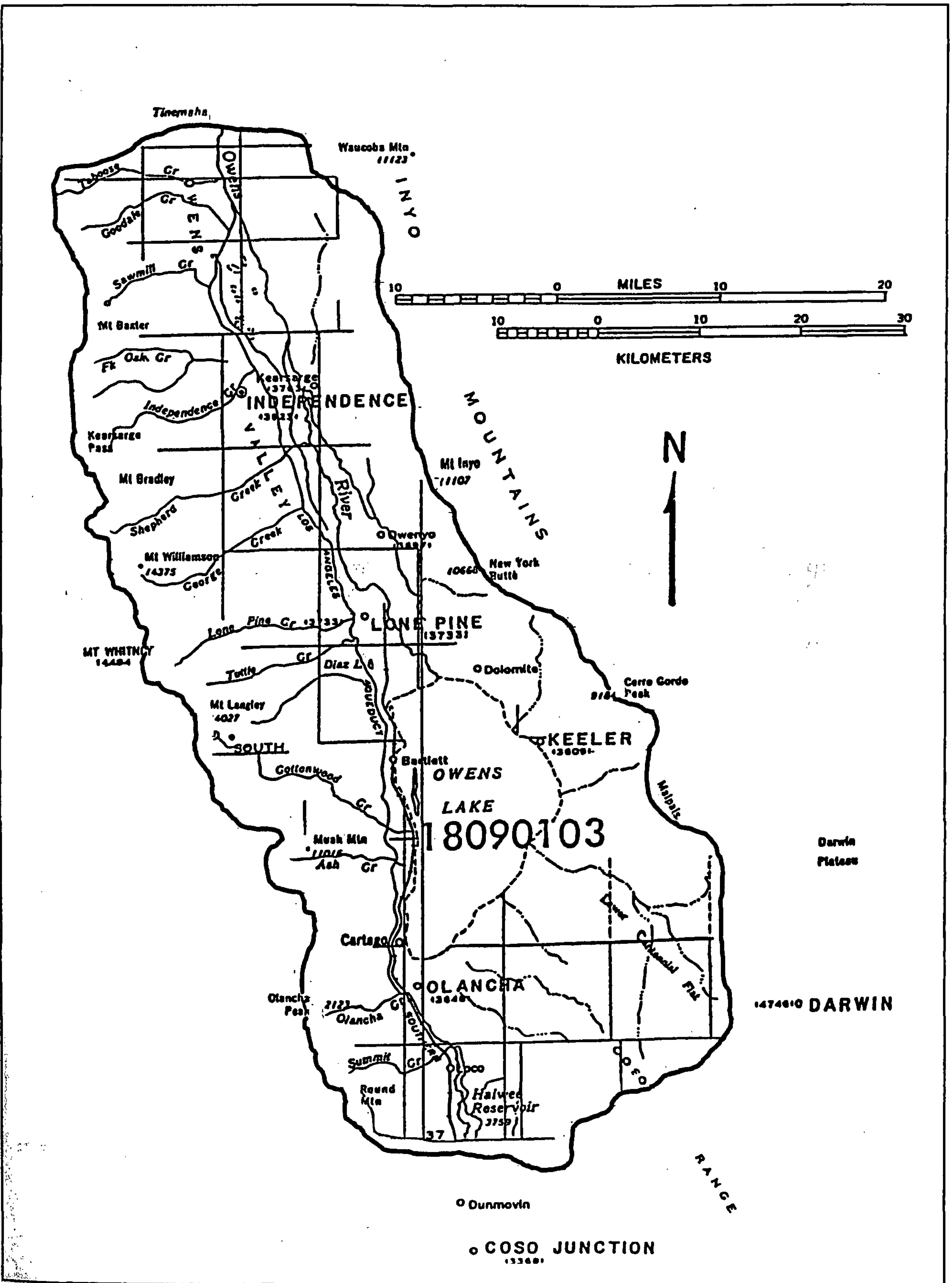


Figure 1: Boundaries of the federal PM10 non-attainment area.

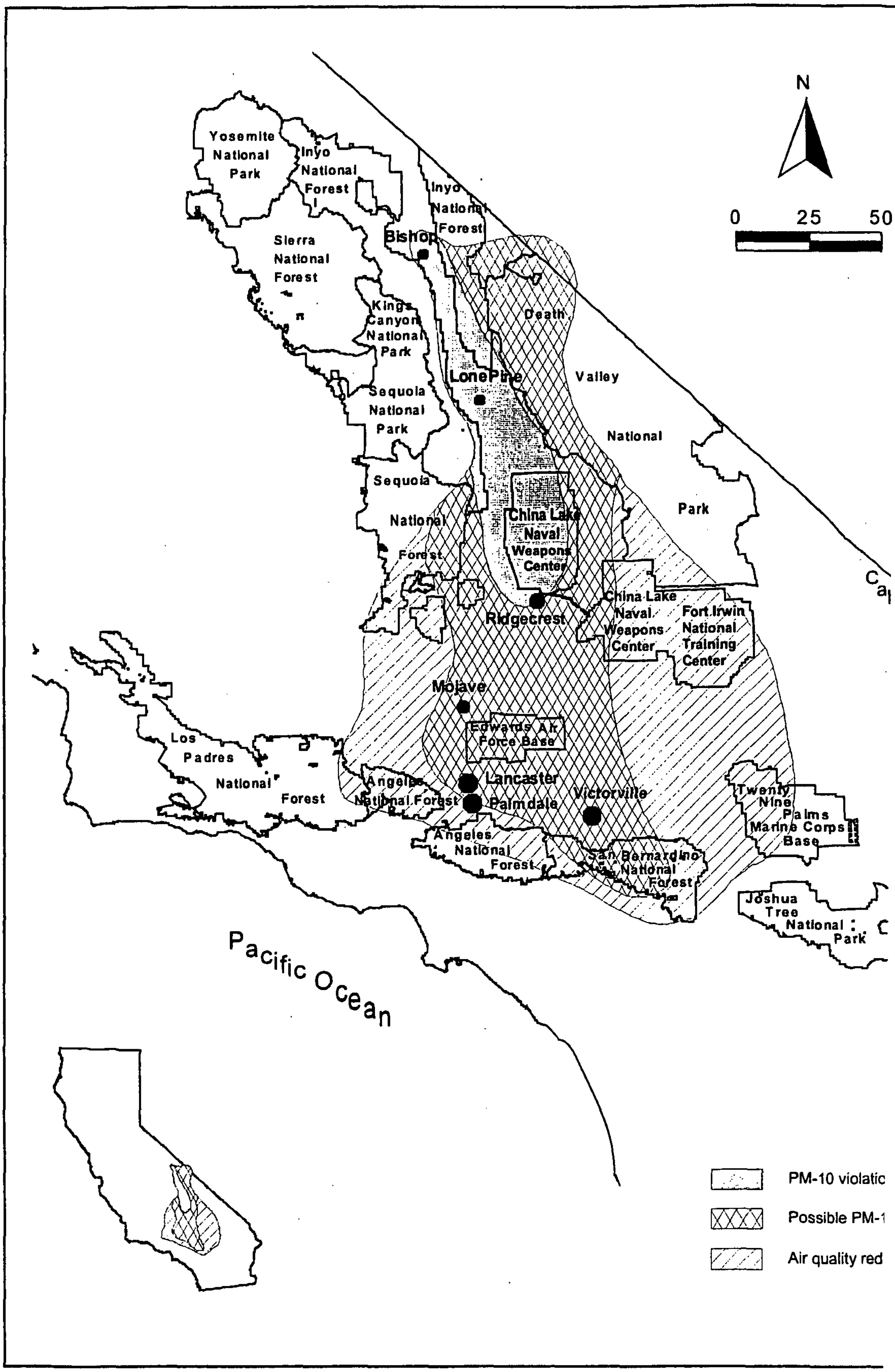


Figure 2: Projected area affected by dust from Owens Lake.

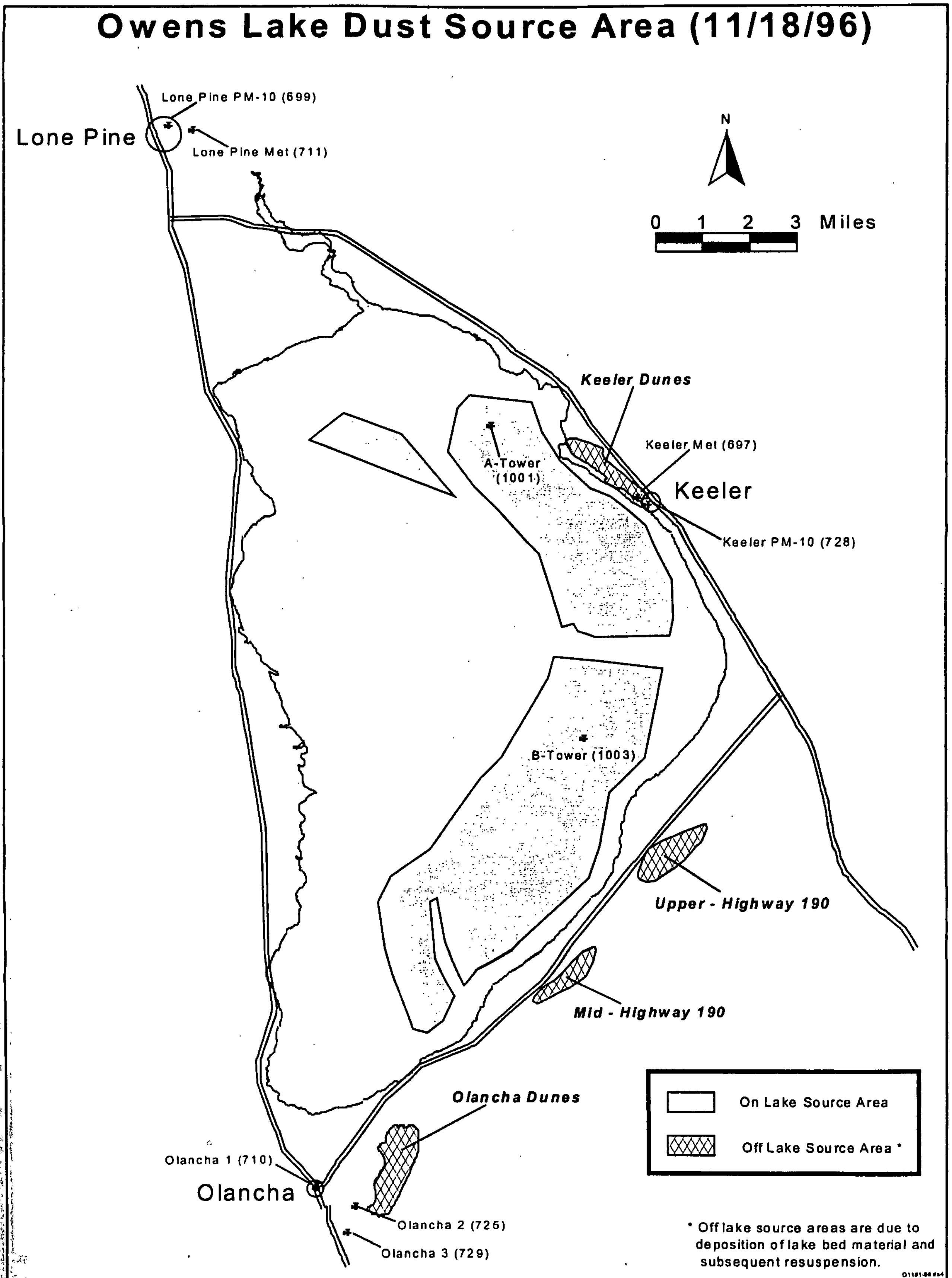
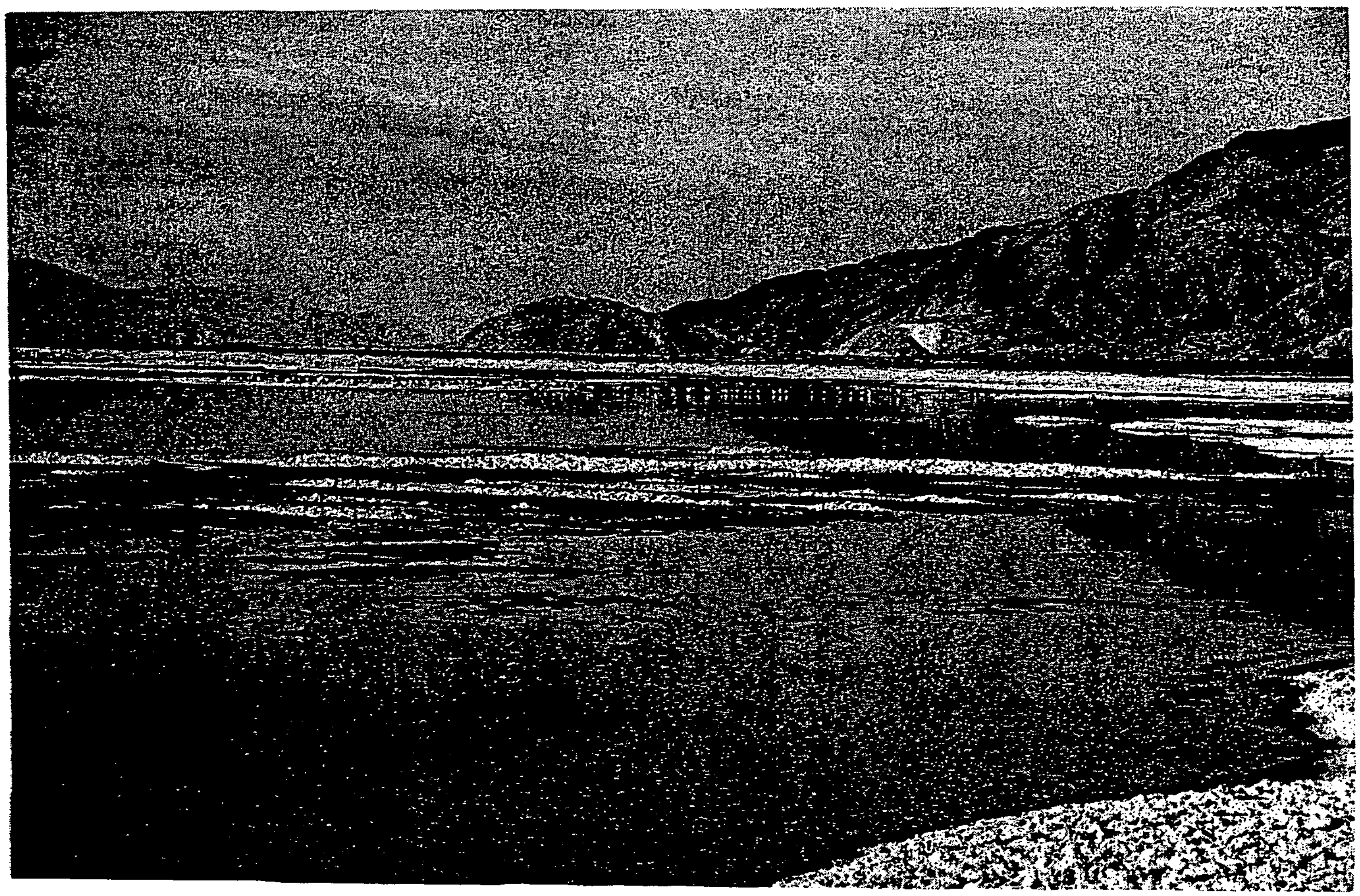


Figure 3: Owens Lake dust source areas for PM_{10} wind erosion.



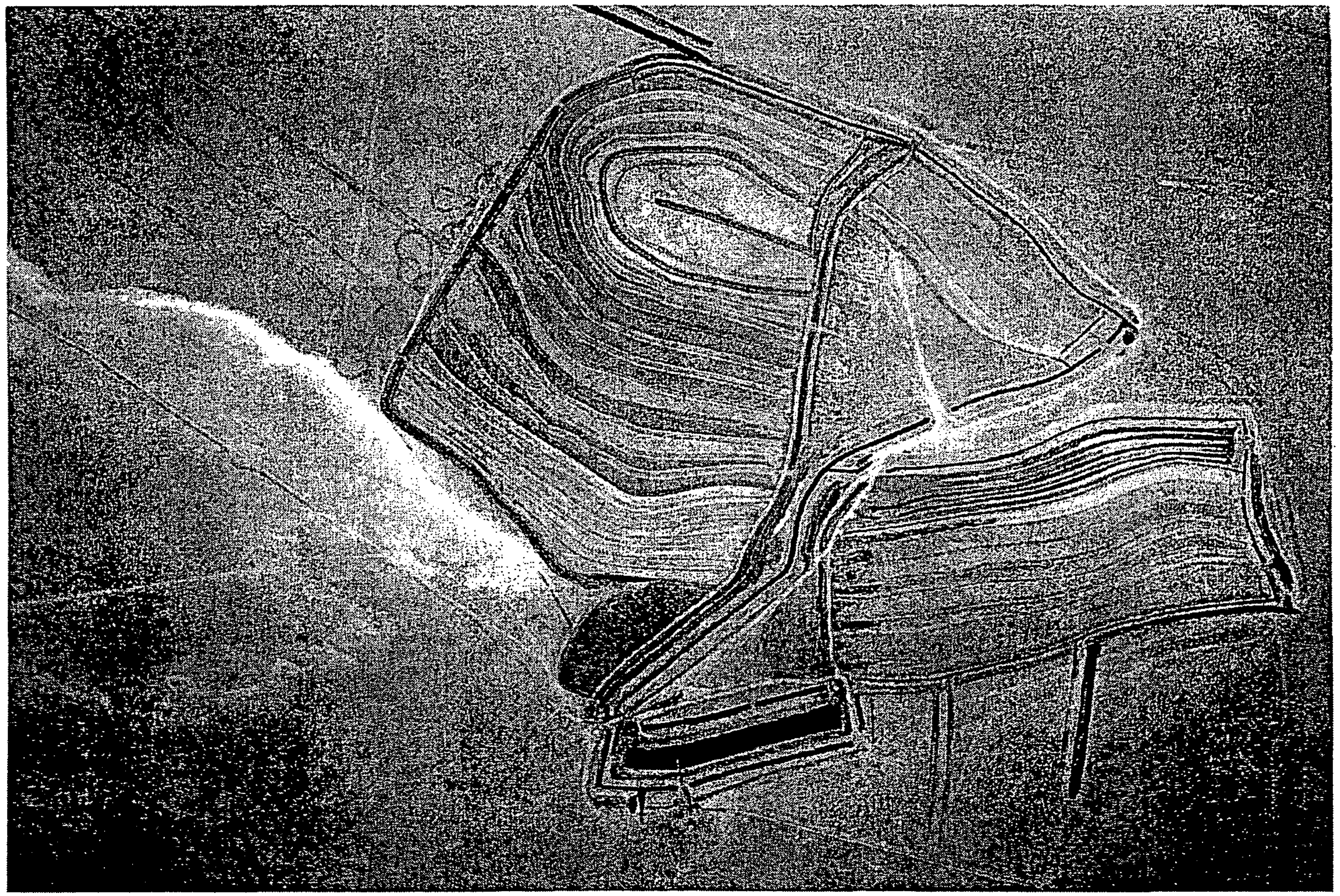


Figure 5: Managed vegetation - test site aerial photograph.

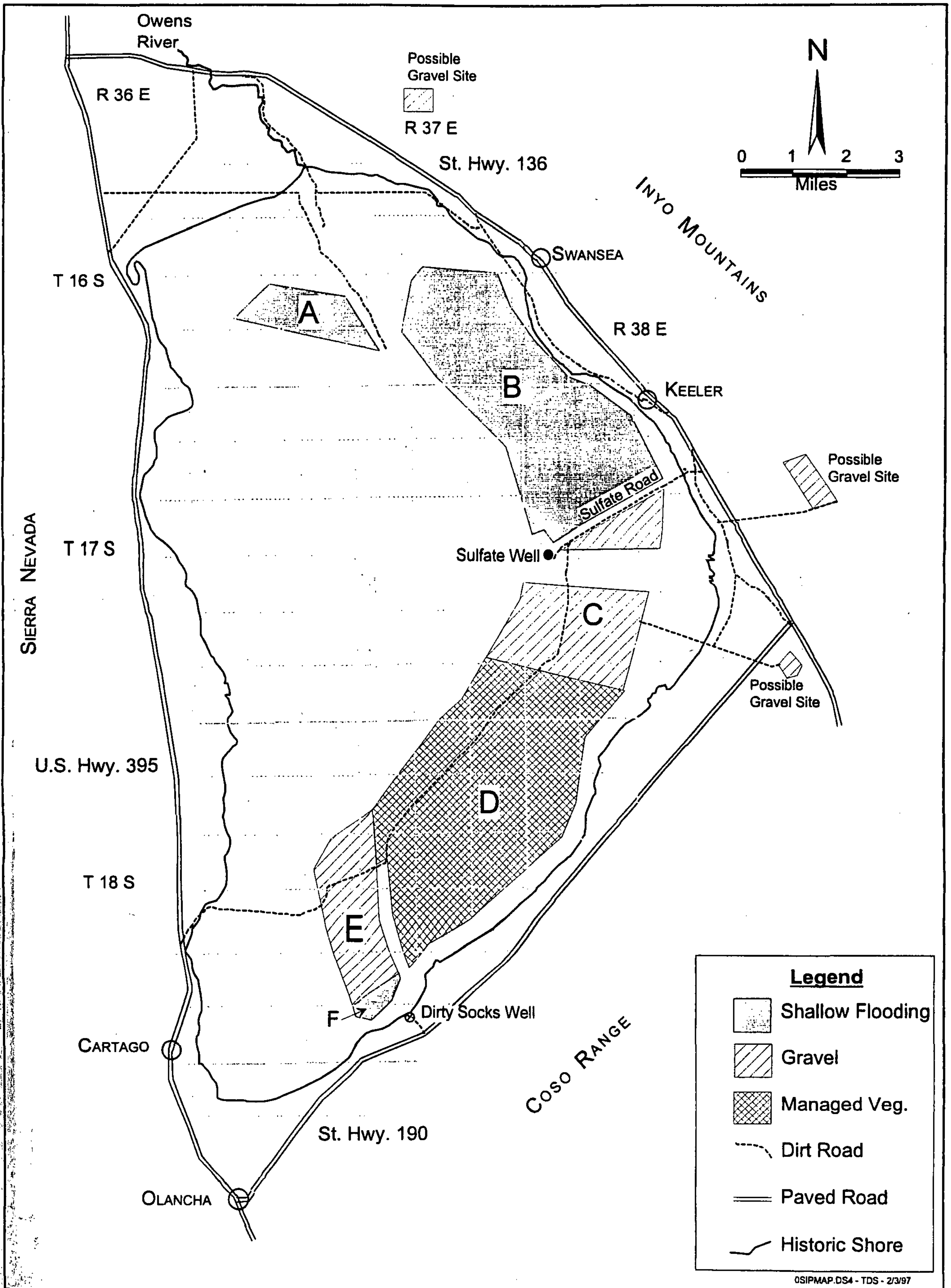


Figure 7: Proposed control strategy

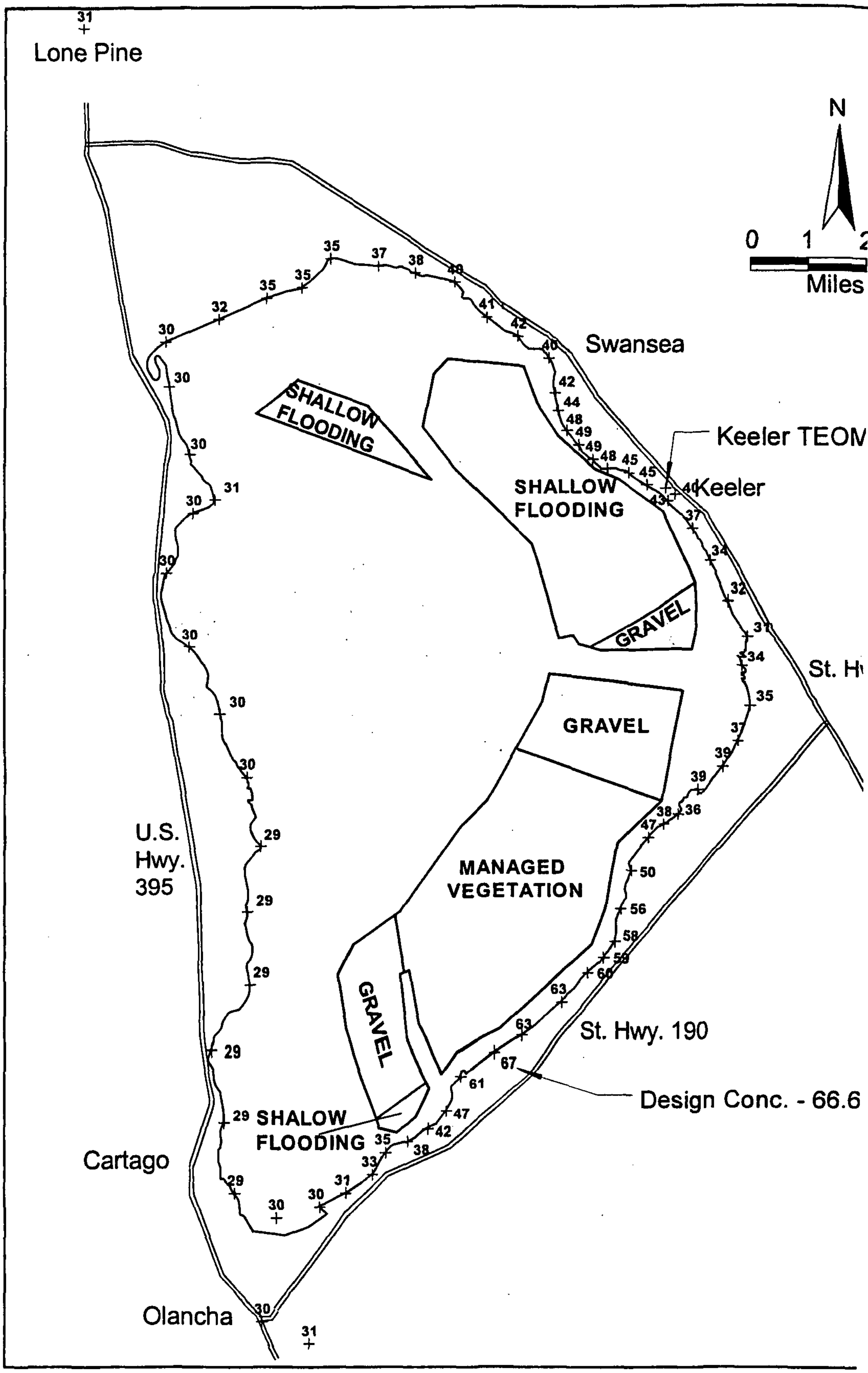


Figure 8: Air quality model: Third highest 24-hr PM_{10} concentrations for 1994-95 proposed SIP controls.

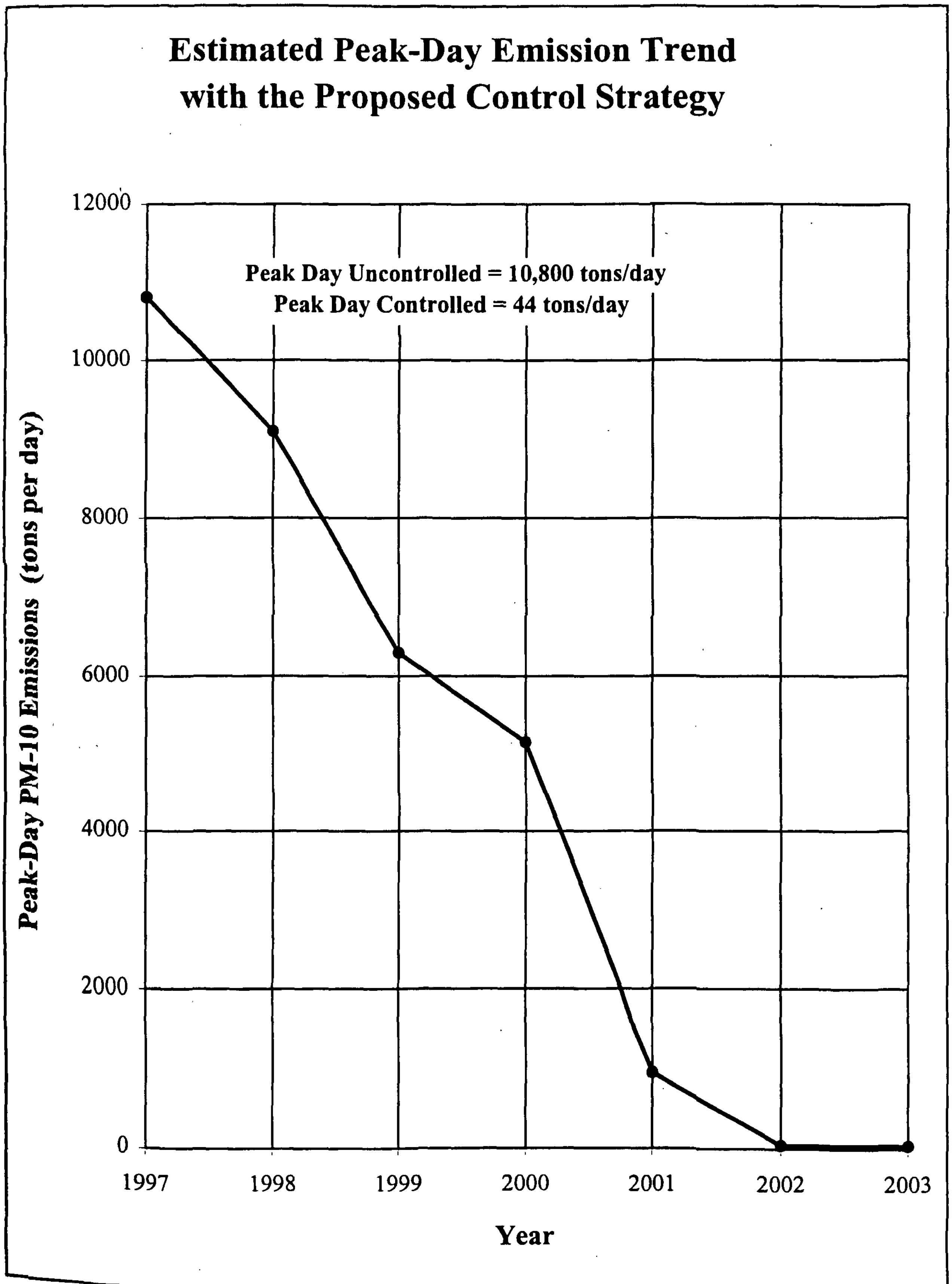


Figure 9: Estimated peak-day PM_{10} emision trend with the proposed control strategy.