FRIENDS OF
DEER CREEK

132 Main Street
Nevada City, Ca 95959
530.265.6090

Joe Karkoski
Regional Water Resources Control Board
Rancho Cordova, CA

February 28, 2007

Dear Joe,
We are submitting the *Deer Creek Watershed Mercury Survey*, conducted by Friends of Deer Creek during the 2005 – 2006 water year. This research was funded by the Regional Water Quality Control Board based on our suspicion that mercury contamination existed in the Deer Creek watershed due to the extensive historic mining practices and use of mercury to amalgamate gold in this region. This report is being sent to you because our results indicate that there is pervasive mercury contamination throughout the Deer Creek watershed, which we feel should be evaluated for 303(d) listed status.

Some of the data in this report, along with data from USGS and BLM, were the basis for Nevada City recently receiving an EPA Brownfields grant to perform mercury and heavy metal assessment of abandoned mines located on Nevada City lands in the Deer Creek watershed.

Please let us know if you need any other information or if you have any questions. You can contact our hydrologist, Carrie Monohan, or myself, at the office number above.

Thank you for your consideration.

Sincerely,

Joanne Hild,
Executive Director

Deer Creek Watershed Mercury Survey

Friends of Deer Creek
Marisha Finkler, M.S. and Carrie Monohan, Ph.D.

Draft 2-28-2007

Supported by funding appreciably given by:
Regional Water Quality Control Board

ABSTRACT

The purpose of the Deer Creek mercury survey was to identify mercury sources in the Deer Creek watershed and to characterize mercury transport in the watershed with respect to the quantity, location, and timing. This survey was conducted over the course of one water year beginning in October 2005 and ending in October 2006. Samples of unfiltered total mercury (THg) in sediment, and unfiltered total mercury in the water column, as well as total suspended solids (TSS) were taken during a range of storm events during which stream discharge was also measured. The study objectives were to:

- ❖ Identify mercury source locations and loading in the Deer Creek watershed for the purposes of remediation and informing the TMDL process
- ❖ Determine the extent and magnitude of mercury contamination in the Deer Creek watershed

Twenty-four initial sediment samples were collected throughout the watershed in August and September of 2005. The initial sediment samples were used to locate eight storm water sampling sites along Deer Creek. These loading sites spanned the length of Deer Creek from below Scots Flat Reservoir (DCL1) to the confluence with the Yuba River (DCL8). Storm samples were collected at these eight loading sites during 10 sampling events representing a range of flow conditions, including 2 low-flow irrigation season events, 4 high-flow storms, and 4 intermediate flow winter and spring events. For each storm sampling site total mercury, total suspended solids and discharge were measured. In addition, 64 post storm season sediment samples were collected in June 2006, to further locations potential source regions identified by the storm sampling.

There was a consistent trend of mercury concentration increasing in the downstream direction during storm events, with elevated mercury concentrations on tributaries at DCL3 (Little Deer Creek) and DCL4 (Gold Run Creek), and low mercury levels below reservoirs Scotts Flat Reservoir, above (DCL1), and Lake Wildwood Reservoir, below (DCL6). Large storm events generally had greater mercury concentrations (i.e. storm events on 12.31.05 and 12.28.05). Mercury and TSS on Deer Creek were very highly correlated (R^2=0.9) indicating that large storm events that mobilized sediments were a significant mechanism in the transport of mercury throughout the watershed.

Of the storm water samples collected, 58% exceeded the USEPA Criterion (CA Toxics Rule) of 50 ng/L. Mercury concentration in the water measured during storm events from all water bodies ranged from 0.34 ng/L to 1033 ng/L. The average mercury concentrations for the Deer Creek mainstem sites across all storm events was 60.02 ng/L (average of DCL 1, 2, 5, 6 and 8,). The average mercury concentration for Little Deer Creek, (DCL3) was 206.97 ng/L and the average mercury concentration for Gold Run (DCL4) was 275.95ng/L, across all storm events.

Of the sediment samples collected, 94% of the sediment samples in Deer Creek were above background levels (mean 1.92 mg/kg). The Deer Creek watershed sediment

samples exceeded the San Francico Bay TMDL (0.2 mg/kg) and the USEPA PRG (2.3 mg/kg), suggesting that Deer Creek is a highly impacted watershed.

The data suggest unknown mercury sources between DCL2 (Willow Valley Rd) and DCL5 (Champion Mine) where most of the major Nevada City district mines including numerous hydraulic mines were located. However, the largest jump in mercury concentrations was between DCL5 (Champion Mine site) and DCL6 (Lake Wildwood inlet) on the mainstem of Deer Creek.

The ultimate goal of this study was to locate and quantify mercury sources in the Deer Creek watershed in order to isolate concentrated hotspots that could be remediated to improve water quality. The data indicate that the there are elevated mercury levels throughout the Deer Creek watershed.

INTRODUCTION

The Deer Creek, Yuba and Bear watersheds were the location of some of the most extensive gold mining in the Sierra Nevada from 1848-1942. Hundreds of hydraulic and hardrock gold mines were located in the Deer Creek watershed, and mercury used in gold processing is still present in the watershed today.

Hydraulic mining in the Deer Creek watershed moved over 20 million cubic yards of gravel and soil, washing away entire hillsides, changing the river's geomorphology, and transporting mercury downstream. Mercury, was used to amalgamate gold in both hydraulic and hard rock mining. It has been estimated that 30 million pounds of mercury, imported from mines in the Central California coastal range, was utilized in the process of extracting gold in the Sierra Nevada. Annual mercury losses at mine sites ranged from 10 to 30 percent of the amount used to recover gold, with an estimated total loss in the Sierra Nevada of 11-12 million pounds of mercury into the environment (Churchill, 2000).

Miners sluicing for gold in Deer Creek, circa 1850

Historical mining occurred throughout the Deer Creek watershed along fault lines rich with gold. Deer Creek was used as a water and power source for mining and gold processing, and for discharge of mine wastes. The extent and magnitude of historical mining activity across the Deer Creek watershed warrants a comprehensive assessment for mercury contamination in the Deer Creek watershed. In addition, the long lasting nature of mercury means that the mercury used over one hundred years ago is still present in the sediment today and the bioaccumulative properties of methyl mercury means that there is a direct exposure pathway for mercury contamination in the food chain.

A study conducted by the U.S. Geological Survey found that Little Deer Creek, a tributary to Deer Creek and Scotts Flat reservoir on Deer Creek, had fish with mercury levels above the CA Office of Environmental Health Hazard Assessment screening levels. Little Deer Creek and Scotts Flat reservoir are listed on California's 303 (d) list under the Clean Water Act as having impaired beneficial uses due to mercury contamination. As a result, Nevada County issued an Interim Public Health Notification (Nevada County Department of Environmental Health, 2000) and a draft fish consumption advisory (CA Office of Environmental Health Hazard Assessment, 2003). This study is an effort to further characterize the Deer Creek watershed and locate the sources of contamination in order to prioritize sites and strategies for remediation and restoration efforts. This study was conducted by Friends of Deer Creek, a watershed group located in Nevada City California, in collaboration with the Regional Water Quality Control Board.

Deer Creek Circa 1908, looking west from immediately downstream of Champion Mine. Note how channel is completely filled with gravels from mining activities.

METHODS

Site Description

The Deer Creek watershed is located on the western side of the Sierra Nevada Mountains in northern California. It consists of eighty-five square miles of land with an elevation range of 700 to 5000 ft. over a distance of 34 miles. The Deer Creek watershed encompasses the rural communities of Nevada City, Grass Valley, Penn Valley, and Lake Wildwood, all of which rely on Deer Creek for drinking water and recreation. Deer Creek is a major tributary of the Yuba River, which drains to the Sacramento River watershed and ultimately the San Francisco Bay.

All of the water released from Scotts Flat reservoir has been diverted by the Nevada Irrigation District (NID) canal system during the dry season, leaving tributary inputs to supply the flow that reaches the Yuba. The NID canal system was developed to divert water from the headwaters of the South Yuba to service hydraulic mines in the Deer Creek and Bear River watersheds. Today, NID operates this canal system in conjunction with an extensive system of dams and diversion to supply water to western Nevada County and Placer County, using Deer Creek as a managed water conveyance system thereby significantly modifying its natural flow regime. During the irrigation season, water from the South Yuba is diverted into the south fork of Deer Creek, stored in Scotts Flat reservoir and Deer Creek reservoir (Lower Scotts Flat), and diverted into 5 major water supply canals before reaching Lake Wildwood, a private reservoir and residential development several miles above Deer Creek's confluence with the lower Yuba River. During winter the reservoirs in the upper portions of Deer Creek drastically reduce peak flows of natural floods, and the diversions minimize instream flows.

Site Selection methods

Mercury in sediment was measured primarily to help locate sources of elevated mercury mobilized in the water during storms. Site selection was not random but biased toward areas of likely contamination: drainages from known mine sites, sampling along tributaries with high mercury concentrations in water, and above and below potential sources as well as within depositional areas on the main stem of Deer Creek.

From the results of the initial sediment sampling, storm sampling sites were chosen for repeated event driven sampling of total mercury in water and total suspended solids (TSS). In areas where storm water sampling indicated elevated mercury concentrations additional sediment sampling was conducted to target source areas. Additional sediment samples were collect along the tributaries Gold Run (DCL4), Woods Ravine (DCL9), and Little Deer Creek (DCL3) and on the main stemb between Champion Mine (DCL5) and Lake Wildwood inlet (DCL6). See Appendix A for detailed sediment sampling locations.

Storm sampling sites were selected to include sites above and below known mine sites, along major tributaries, an upper watershed site above mining impacts, and a lower watershed site, and near the Yuba confluence. The upper watershed site that we selected was at the outflow of Scotts Flat Reservoir. Scotts Flat was the site of a large hydraulic mine, and the reservoir has been 303(d) listed for mercury. USGS data indicates at least one major mercury source above the reservoir. However, our first several storms showed the discharge from this site had some of the lowest mercury concentrations in the watershed, suggesting that the reservoir is effectively preventing most of the mercury from being transported down the watershed, and we therefore chose to focus our sampling efforts below this site. There were eight storm sampling sites. Moving downstream the sampling sites are as follows: Deer Creek main stem sites Scotts Flat Reservoir (DCL1) and Willow Valley Road (DCL2), the first tributary to enter on river left is Little Deer Creek (DCL3), the second tributary to enter on river left near the Pine St. Bridge is called Gold Run (DCL4), the main stem Deer Creek sampling site bellow these tributaries is the Champion Mine site (DCL5) and below that is the Lake Wildwood site (DCL6), below Lake Wildwood, Squirrel Creek (DCL7) enters on river left, and the most downstream site is near the confluence with the Yuba is at Mooney Flat (DCL8).

Table 1: Deer Creek Mercury Storm Sampling Sites 2005-2006
Total mercury in water and total suspended solids samples were collected at the following sites:

DCL1. Scotts Flat: Deer Creek between Upper and Lower Scotts Flat Reservoirs via Scotts Flat Dam Rd. First trail on right above NID gate.

DCL2. Willow Valley: Deer Creek 20 m below Boulder St. ford on Willow Valley Rd.

DCL3. Little Deer Creek: Culvert entrance above Stonehouse parking lot.

DCL4. Gold Run Creek: Gold Run Creek above confluence via trail on fwy easement.

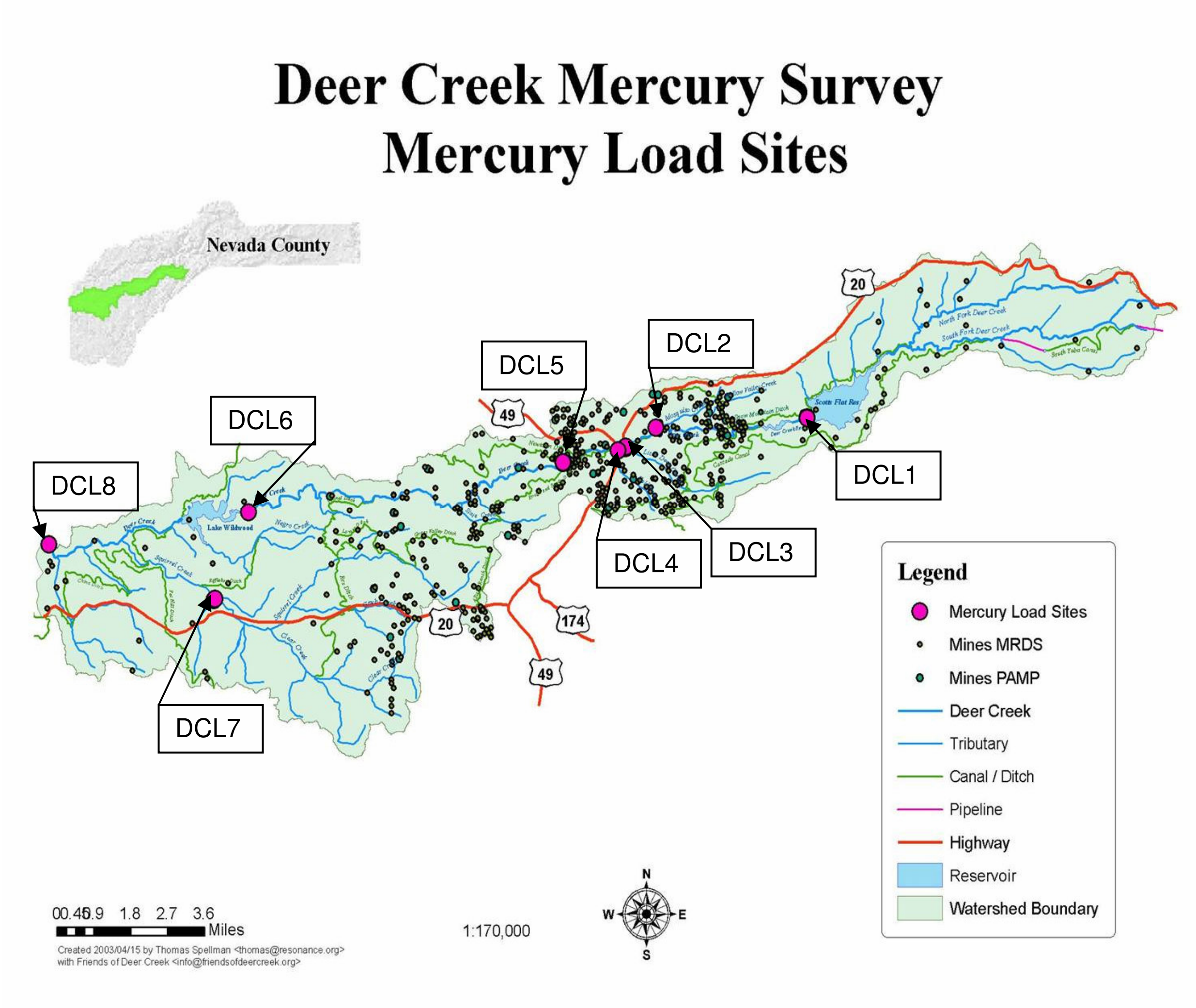
DCL5. Champion Mine: Deer Creek 1 mile below Champion mine on Rothert property

DCL6. Lake Wildwood: Deer Creek inlet at Lake Wildwood Dr. bridge.

DCL7. Squirrel Creek: Pleasant Valley Rd bridge over Squirrel Creek.

DCL8. Mooney Flat: Mooney Flat Rd. bridge over Deer Creek near Smartville.

The following map shows the Deer Creek watershed with the location of load sampling sites and historic mines:



Additional sites were sampled in between the eight loading sites (DCL1-8) to try and locate source areas for mercury. Each additional site was labeled in chronological order from when it was sampled. These additional sites were only sampled during one storm event, except DCL11 which was sampled twice.

Table 2: Deer Creek Mercury Additional Storm Sampling Sites 2005-2006

Total mercury in water and total suspended solids samples were collected at the following sites:

DCL9. Woods Ravine: Woods Ravine 200 m above confluence (off Champion Rd).

DCL10. Slack's Ravine: Slack's Ravine 200 m above confluence, from Mooney Flat Rd.

DCL11. Nevada St: Nevada St. bridge crossing Deer Creek.

DCL12. Little Deer Ln: Little Deer Creek Ln bridge over Deer Creek (off Slate Creek Rd)

DCL13. Bitney: Bitney Springs Rd crossing Deer Creek.

DCL14. Banner Mtn Trail: Little Deer Creek, upstream side of Banner Mtn Trail crossing.

DCL15. Northern Queen: Gold Run Creek at Northern Queen Inn, just before it goes under fwy.

DCL16. GR Railroad Ave fork: Gold Run river right tributary off Railroad Ave.

DCL17. GR Mowhawk fork: Gold Run river left fork below marsh off Railroad Ave.

DCL18. Eagle Ravine: Eagle Ravine crossing Willow Valley Rd, just past HEW.

DCL19. Manzanita drain: Drainage from Manzanita Diggins discharging below Deer Creek Inn.

Sediment Sampling Methods

Sediment samples for total mercury collected prior to the storm season were of in-stream fines and bank/floodplain sediments. We found it important to differentiate in-stream versus bank samples from the same site as the material was often a different composition with different mercury concentrations. The creek banks at some of our sites appeared to be deposition of historic tailings that are now re-eroding into the creek, while in-stream fines at the same site were a combination of sediments eroded from upstream sites. These two types of sediment represent different source material for mercury, and after observing this phenomenon at several sites, we decided to consider them as different rather than duplicate samples. We noted their origin in our sample descriptions to help determine more specifically where the elevated mercury was coming from. See Appendix A for detailed sediment sampling locations.

A polycarbonate scoop was rinsed with ambient water and used to collect a composite of 5-10 sub-samples of the top 2 cm of fines. The sediments were sieved through a coarse 2 mm screen into a plastic sample bag, and then re-sieved with a clean piece of 62 micron mesh, allowed to evaporate until lightly moist in labeled glass sample jars, before sealing and shipping. Samples were analyzed by California Laboratory Services using EPA 6000/7000 Series Methods. A copy of the full sampling protocol is included in Appendix B.

Storm Sampling Methods:

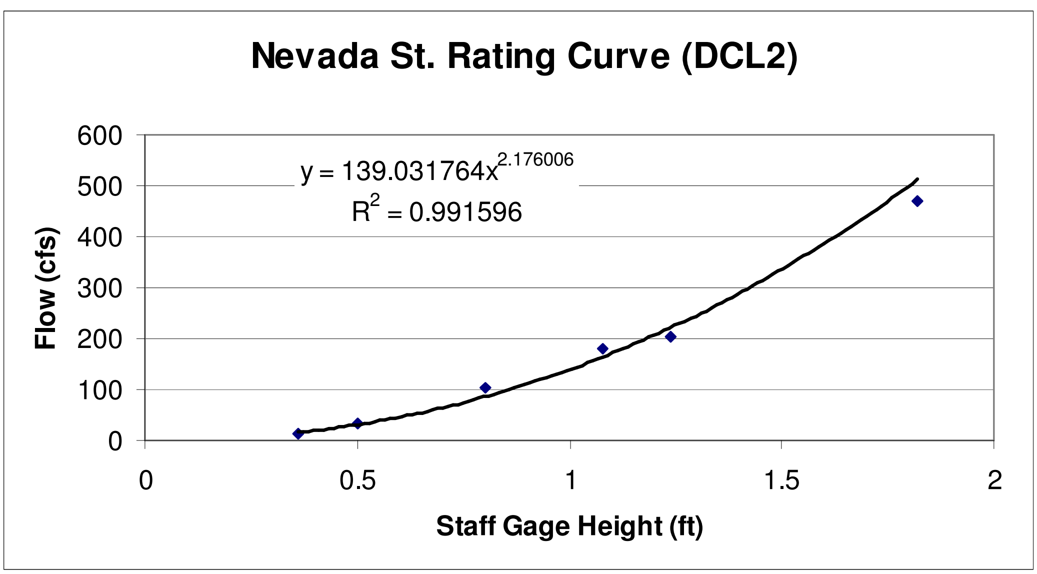
Storm samples were taken approximately 1 hour after the local rain gauge reached peak rainfall rate. Our goal was to sample during peak flows for each storm event. Samples were collected using ultra-clean sample handing methods, in triple rinsed 250 mL glass bottles that had been double bagged and filled with acidified ultra-clean water by Moss Landing Marine Laboratory (Modified EPA 1631e). A copy of the full sampling protocol is included in Appendix B.

Low flow samples were collected directly by wading into the stream or filling the bottle on the end of a sampling pole in the fastest moving water. High flow samples were taken from the downstream side of a bridge, where possible, in a specialized bucket, or from shore on the end of a pole, from fast-moving, well-mixed water. Storm water samples at bridge sites were initially collected in a triple rinsed, weighted, acid-washed one gallon glass bottle which was then decanted into the 250 mL bottles. However, the steep gradient and high velocities of Deer Creek made collection with the larger bottle difficult, and after losing one of the large bottles at high flow, a smaller sampling bucket was designed to fit the 250 mL bottle which allowed bridge samples to be collected directly. Samples were stored on ice and shipped within 4 days to Moss Landing Marine Laboratory for analysis by modified EPA Method 1631e.

Total suspended solids (TSS) samples were taken in the same manner (hand, pole or bridge bucket sampling), from the same locations and at the same time as the mercury samples, but without ultra-clean handling, and processed in the FODC lab, using 2540D standard methods for TSS.

Stream Discharge Methods:
Long-term, accurate flow gauging stations are located at Scotts Flat Reservoir (powerhouse and spillway, just above DCL1), and at the USGS gauging station # 11418500 on Deer Creek near Smartville (http://waterdata.usgs.gov/ca/nwis/uv?11418500), (site DCL8). Flow data for sites DCL1, the most upstream site, and DCL8, the most downstream site, were collected by Nevada Irrigation District and USGS/California Data Exchange, respectively.

When we began this study, DCL1 and DCL8 and one staff gauge at DCL5 were the only sources of flow data for Deer Creek. After selecting the sites for repeated water sampling, we installed additional staff gauges at DCL3, 4, and 7, and later 1 mile above DCL6 and 0.3 miles below DCL2. We collected staff gage readings during sampling events and as regularly as possible during the winter and spring. To generate stage discharge relationship we measured discharge using the velocity area method. We generated flow profiles at DCL2, 3, 4, 6, and 7 under a range of flow conditions to develop rating curves for each site. The rating curves allowed us to estimate discharge for stage reading within the range of the measured values. One of our rating curves for DCL2 is shown here:



For high flows that were outside the range of measured discharge values, we estimated discharge using the water balance method between mainstem sites and tributaries. Summer flows were calculated using a water balance by subtracting water diversions based on data from Nevada Irrigation District. Since we had flow data for a starting point (DCL1) and end point (DCL8), we calculated the flows at the sites in between based on a combination of flow profiles, rating curve calculations, and water balance.

Load Calculations:

A load is a measure of the total quantity of mercury transported past or into a site over a set time period. In order to calculate loads, mercury concentrations (ng/L) were multiplied by flow (cfs) and a unit conversion factor to determine in an estimate of grams of mercury/day transported:

$$\text{Load (g/day)} = (\text{Hg concentration ng/L})(0.002445)(\text{Flow cfs})$$

Load estimates were calculated for all storm events. Load calculations were based on flow estimates and therefore reflect a margin of error because of the lack of our ability to measure discharge at high flows for all sites, except DCL1 and DCL8.

Macroinvertebrate Sampling Methods:

Aquatic macroinvertebrates were collected at 4 stream sites with kick nets and stored in labeled plastic bags on ice. After 4-24 hours of depurating, they were rinsed, sorted and weighed in the laboratory, frozen in certified cleaned glass jars and shipped on dry ice to the Trace Element Research Laboratory at Texas A&M University. A copy of the full sampling protocol is included in Appendix B.

Twelve samples were collected at three sites by Friends of Deer Creek. USGS collected an additional 25 macroinvertebrate samples in the Deer Creek watershed during the same week, which will provide an interesting comparison and broader picture of mercury in Deer Creek biota when the data are available. All samples were analyzed for methyl mercury, EPA Method 1630 Modified.

Quality Assurance:

At least 10 percent of the water and sediment samples were dedicated to quality assurance. The field component consisted of collection of duplicate samples and method blanks processed through field protocols, as well as submission of known concentration sediment samples. These field quality control samples were randomly distributed among sampling sites and events. Out of 100 water samples, 7 field duplicates and 4 field blank samples were collected, with corresponding TSS samples for all but the blanks. For blank water samples, MilliQ water was transported into the field and handled with ultra-clean techniques, uncapped, lowered over the creek or allowed to sit on shore for 1 minute, used to rinse the 250 mL bottle 3 times and then decanted into the bottle, which was shipped with the regular samples. Of the 93 sediment samples, 11 field duplicates were collected, and 6 samples of certified reference material processed.

The laboratory quality assurance component consisted of the following analyses for each batch of water samples (each sampling event): three method blanks, one pair of analytical duplicates, one matrix spike/matrix spike duplicate pair, and one standard reference material (SRM NIST-1641d). The sediment laboratory quality control included analysis (per batch, 6 batches total) of one blank, one LCS/LCS duplicate pair, and one Matrix Spike/Matrix Spike Duplicate pair. The results of the quality assurance measures are shown in Appendix C.

In brief, all detection limits were achieved, all blanks were below the detection limit, the replicate RPD was within the DQO of 25%, the matrix spike recoveries were within the DQO of 75-125%, and the standard reference material recoveries were within the DQO of 75-125%. The QC sediment samples were all within the %REC limits (<0.1 mg/kg for blanks, 75-125% for LCS and Matrix Spikes), except for 3 of the Matrix Spikes and 2 of the Matrix Spike Duplicates.

RESULTS

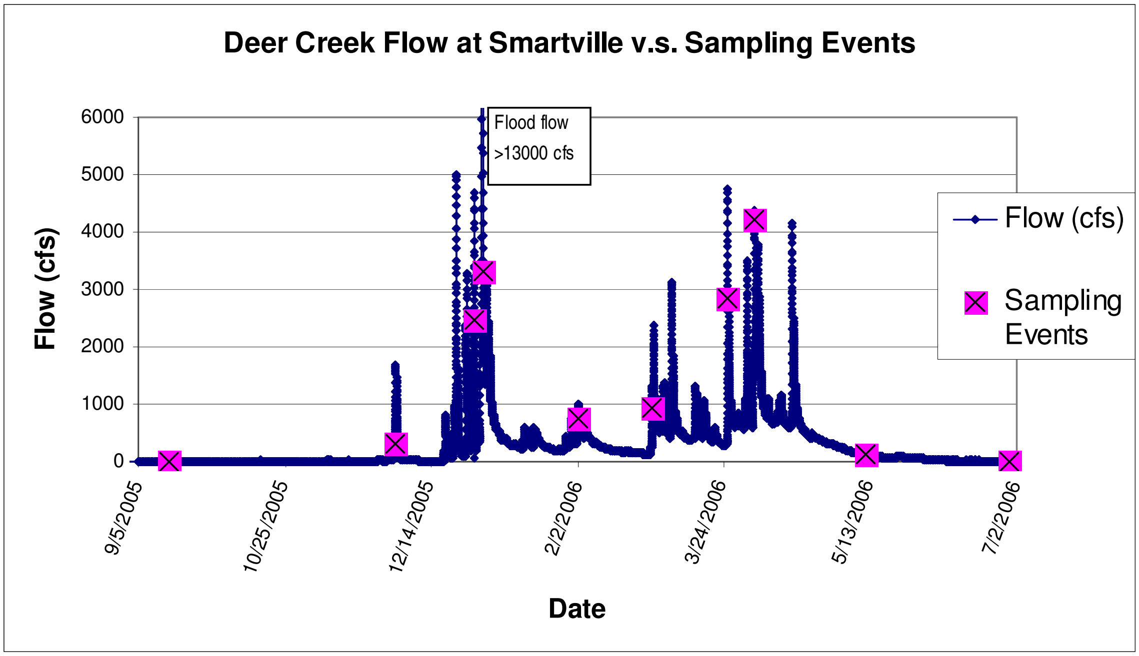
Of the storm water samples collected 58% exceeded the USEPA Criterion (CA Toxics Rule) of 50 ng/L. The following trends were discerned from the data:

- Mercury concentrations increased in the downstream direction during storm events
- There were elevated mercury concentrations in the tributaries Little Deer Creek (DCL3) and Gold Run Creek (DCL4)
- Mercury concentrations were low below the reservoirs, Scotts Flat Reservoir (above DCL1) and Lake Wildwood Reservoir below (DCL6).
- Large storm events generally had higher mercury and TSS concentrations (i.e. high flow events on 12.31.05 and 12.28.05)
- Mainstem mercury concentrations in water were very highly correlated with TSS concentrations, (R^2 value of 0.9).

<u>Sampling events</u>

Twenty-four initial sediment samples were collected throughout the watershed in August and September of 2005. Storm samples were collected during 10 sampling events representing a range of flow conditions, including 2 low-flow irrigation season events, 4 high-flow storms, and 4 intermediate flow winter and spring events. At each storm sampling site total mercury, total suspended solids and discharge were measured. Sixty four post storm season sediment samples were collected in June 2006, to determine the locations of potential source regions identified by the storm sampling.

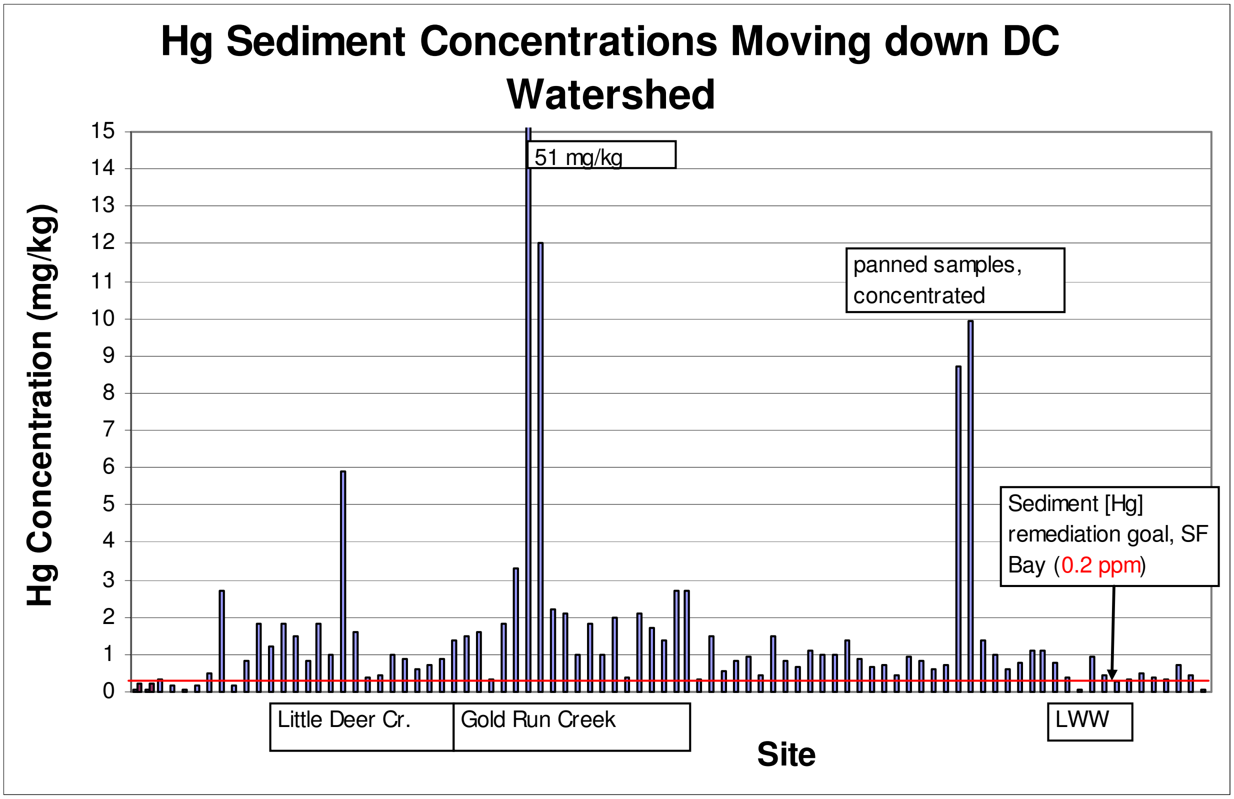
A graph of flow for the 2005-2006 sampling season with the dates and times of our sampling events are shown below. The flow data is from USGS gauge # 11418500, Deer Creek near Smartville (located at Site DCL8, near the Yuba confluence).



<u>Sediment sampling</u>
Mercury in sediment samples collected in the Deer Creek watershed varied from non-detect (Method detection limit of 0.1 mg/kg) to 51 mg/kg. The mean sediment mercury concentration from our samples was 1.92 mg/kg. The median sediment mercury concentration was 0.89 mg/kg. The EPA preliminary remediation goal for soil is less than 2.3 mg/kg. (mg/kg is interchangeable with ppm)

Deer Creek Mercury in Sediment				
Mean	**Median**	**Percent samples >0.08ppm**	**Percent samples >0.2ppm**	**Percent samples >2.3ppm**
mg/kg	mg/kg	(Global Background)	(SF Bay remediation goal	(EPA PRG for Soil)
1.92	0.89	94%	91%	10%

The graph below shows mercury sediment concentrations at sites moving downstream, including sections moving down tributaries.



One site on Gold Run Creek had bank sediments with a mercury concentration of 51 mg/kg, more than 2.5 x RCRA hazardous waste limit. This sediment was very close to the site of a historic ore processing facility, and more sampling should be conducted there to define the area of significant contamination. The second highest sample (12mg/kg) was located a short distance downstream from the 51 mg/kg sample. Another potential hotspot was located on one of the tributary streams to Little Deer Creek.

Storm Sampling: Mercury

Mercury concentration in the water measured during storm events from all water bodies ranged from 0.34 ng/L to 1033 ng/L across all sites and under a range of discharges. The average mercury concentrations for the Deer Creek mainstem sites combined was 60.02 ng/L (DCL 1, 2, 5, 6 and 8,). The tributaries, Little Deer Creek and Gold Run, were found to have elevated levels of mercury. The average mercury concentration for Little Deer Creek, (DCL3) was 206.97 ng/L and the average mercury concentration for Gold Run (DCL4) was 275.95ng/L, across all storm events.

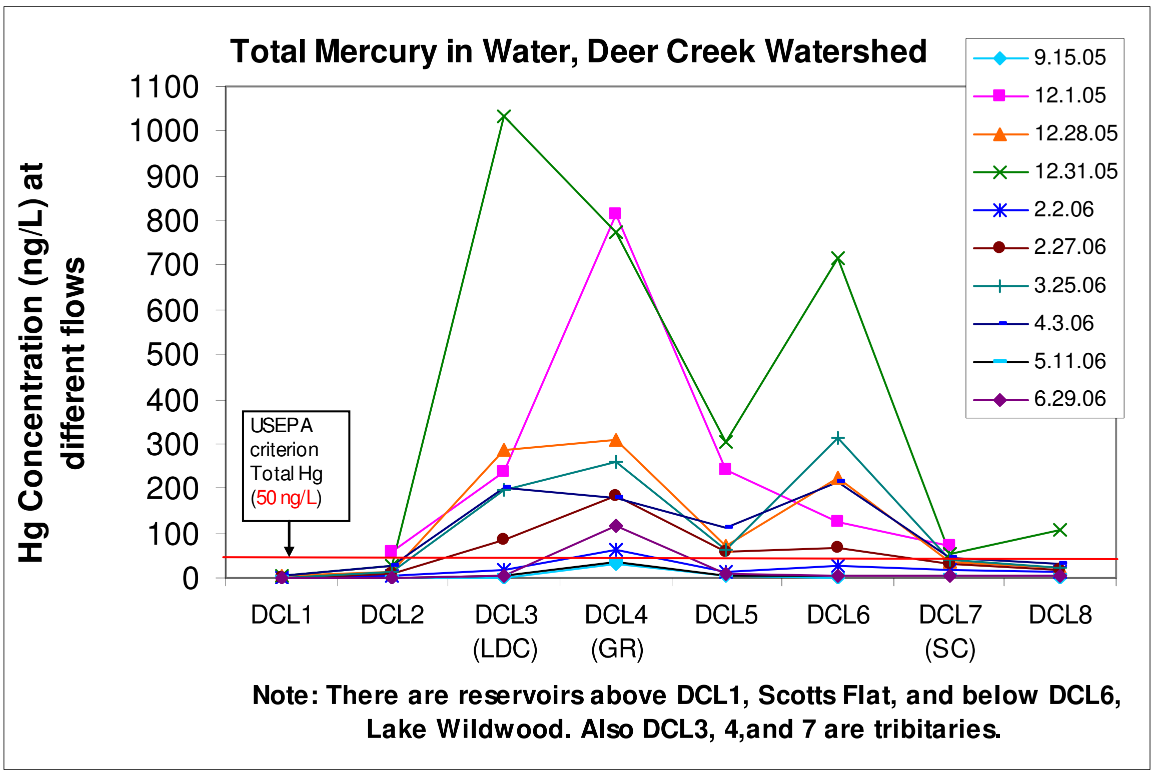
Total Mercury in Water (ng/L)

Site #	9.15.05	12.1.05	12.28.05	12.31.05	2.2.06	2.27.06	3.25.06	4.3.06	5.11.06	6.29.06	Average	Stdev
DCL1	0.34		2.92	5.97	1.53	1.75	1.36	2.37	1.20	1.37	2.09	1.63
DCL2	0.76	57.8	11.73	27.18	5.89	9.64	15.20	25.33	1.74	1.72	15.70	17.52
DCL3 (LDC)	1.06	238	287	1033	16.58	86.96	196	201	5.29	4.43	206.97	309.93
DCL4 (GR)	31.27	813	307	772	63.73	183	260	177	37.04	116	275.95	286.98
DCL5	2.41	242	70.78	303	11.48	58.07	63.03	114	5.11	9.81	87.95	104.69
DCL6	1.69	126	223	716	27.80	65.86	311	213	5.35	3.79	169.40	220.69
DCL7 (SC)		71.6	34.32	54.24	18.26	31.86	38.84	46.44	3.65	4.36	33.73	22.51
DCL8	1.10		24.26	109	11.26	16.86	22.97	29.95	5.55	3.90	24.97	32.99

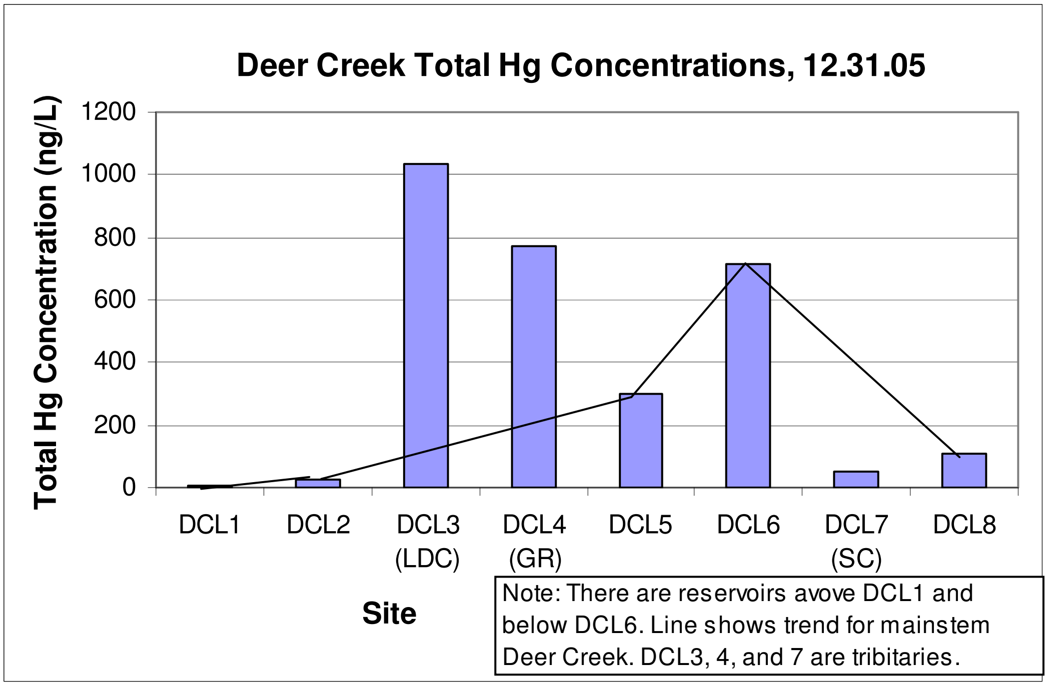
Additional water samples were collected at intervals between the eight loading sites (DCL1-8) in an attempt to determine which section of Deer Creek had the greatest jump in mercury concentrations, and should be the focus of more intensive sediment sampling to locate input sources. Data from theses additional sites and the storm event when they were sampled are shown in the table below.

Additional Sample Sites (ng/L)											
DCL9	DCL10	DCL11		DCL12	DCL13	DCL14	DCL15	DCL16	DCL17	DCL18	DCL19
12.28.05	12.31.05	2.27.06	4.3.06	3.25.06	3.25.06	4.3.06	4.3.06	4.3.06	4.3.06	4.3.06	4.3.06
87.97	19.79	22.56	53.31	91.36	128	358	151	94.82	276	86.84	137

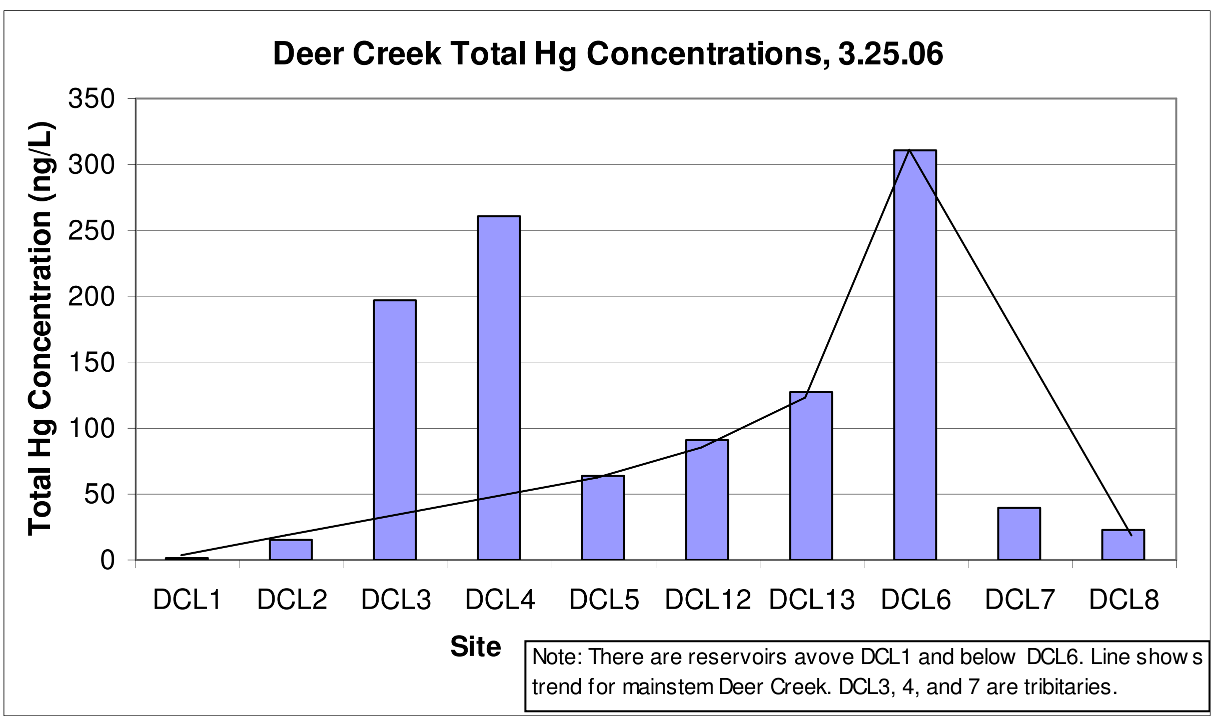
Of the 100 water samples collected, 77 were collected during 10 different flow events at 8 core sites, 12 were collected at additional sites, and 11 were collected as Quality Assurance samples (7 were field duplicate samples, and 4 were field blank samples, see Appendix C). Mercury concentrations moving down the watershed at each sampling event are shown graphically below:



The following graph shows mercury concentrations during the 12.31.05 flood at sites moving down the watershed:



Large increases in mercury concentration were observed between DCL5 (Champion Mine) and DCL6 (Lake Wildwood). Additional samples were taken between these two sites at Little Deer Creek Lane (DCL12) and at Bitney Springs Road crossing (DCL13) to try and locate the source area of mercury.

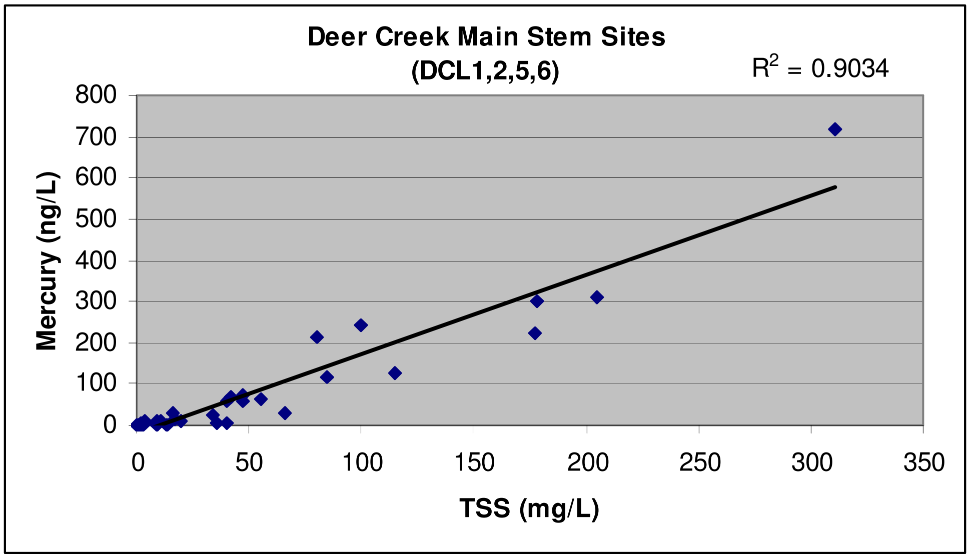


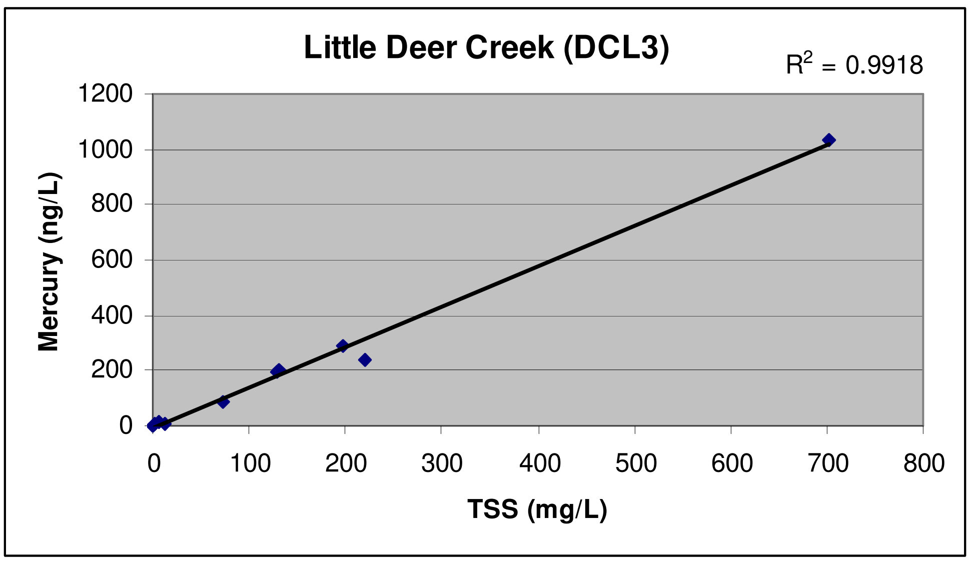
Mercury concentrations entering Lake Wildwood (DCL6) are generally much higher for a given flow than those at the Yuba confluence (DCL8), downstream of the Lake Wildwood dam, indicating that Lake Wildwood is trapping a large portion of the mercury and sediment moving down Deer Creek.

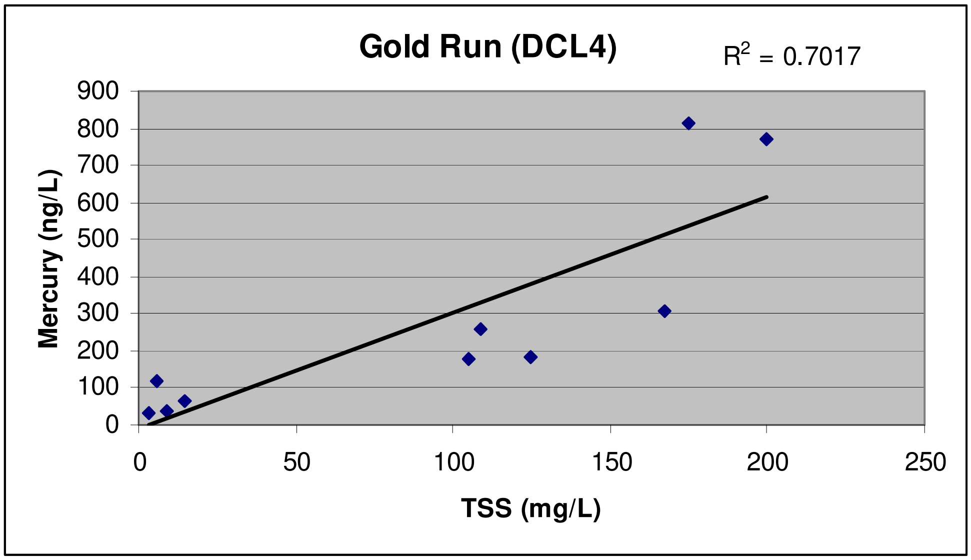
<u>Storm Sampling: Total Suspended Solids</u>
Total Suspended Solids (TSS) samples were taken concurrently with each storm water sample for mercury to help determine the relationship of mercury concentrations in water to sediment mobilization. The amount of total suspended solids during storm events ranged from undetectable to 204.5mg/L in Deer Creek. Little Deer Creek tributary had the highest TSS concentration of 703.2mg/L. The concentration of TSS follows the same increasing downstream trend as mercury concentration showed, with significant tributary inputs. A table of TSS concentrations at each site and sampling event is shown below:

Total Suspended Solids (TSS, mg/L)								
Date	*DCL1*	*DCL2*	*DCL3*	*DCL4*	*DCL5*	*DCL6*	*DCL7*	*DCL8*
9/15/05	0.3	0.5	0.7	2.9	0.7	0	0.3	0.7
12/1/05	2.5	47.5	220	175	100	115	100	75
12/28/05	3.6	8.6	198	167.3	46.9	177.5	74	42.1
12/31/05	35.9	65.9	703.2	199.5	178	310.5	128	117
2/2/06	3.1	3.7	6	14.8	4	16.3	15.5	9.9
2/27/06	2.9	19.8	71.7	124.8	40	42.3	29.3	18.8
3/25/06		16.8	128	109	54.8	204.5	143.5	61
4/3/06	9.1	34	130	105	84.5	80	129	168
5/11/06	2.1	1.7	1.9	8.8	2.1	2.6	0.8	3
6/29/06	13	13.5	12.2	5.8	10.3	10.7	10.6	8.4
Average	8.1	21.2	147.2	91.3	52.1	95.9	63.1	50.4
Stdev	11.2	21.6	211.9	77.4	56.4	105.1	58.2	55.9

A regression of TSS and mercury concentrations for the mainstem Deer Creek sites down to Lake Wildwood (DCL1,2,5,and 6) had an R^2 value of 0.9. Similar regressions were made for each one of the tributaries. Little Deer Creek (DCL3) had an R^2 value was 0.99 and Gold Run (DCL4) had a R^2 value of 0.7.


Deer Creek Main Stem Sites
(DCL1,2,5,6)
R^2 = 0.9034
Mercury (ng/L)
TSS (mg/L)
0
100
200
300
400
500
600
700
800
0
50
100
150
200
250
300
350


Little Deer Creek (DCL3)
R^2 = 0.9918
Mercury (ng/L)
TSS (mg/L)
0
200
400
600
800
1000
1200
0
100
200
300
400
500
600
700
800

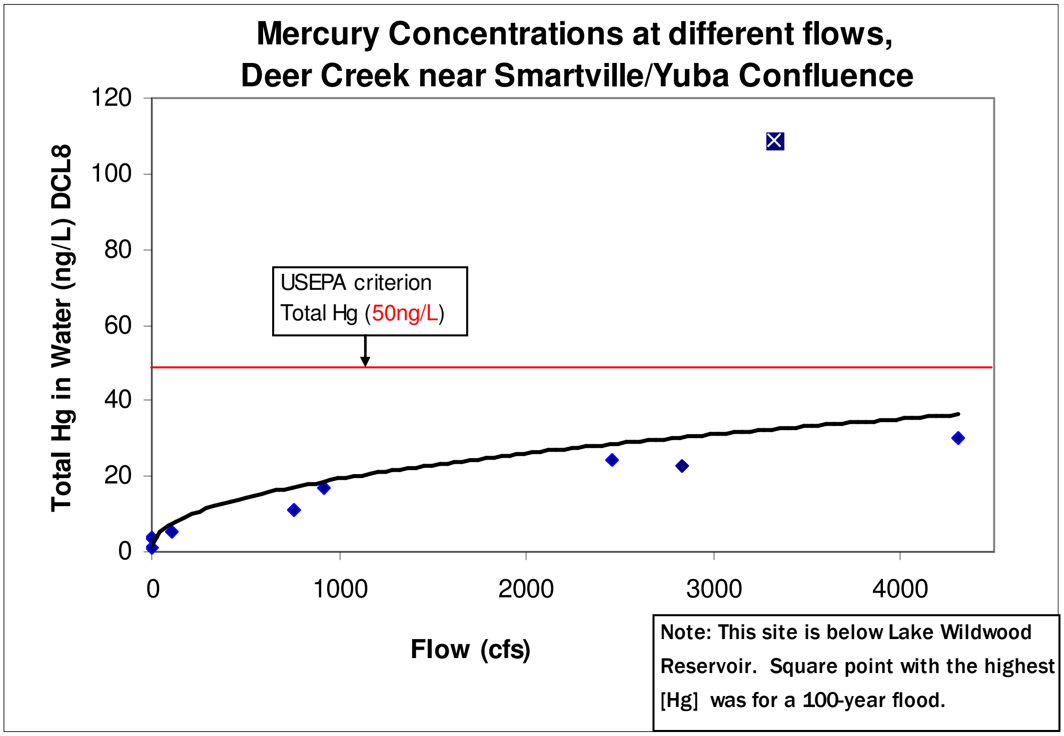


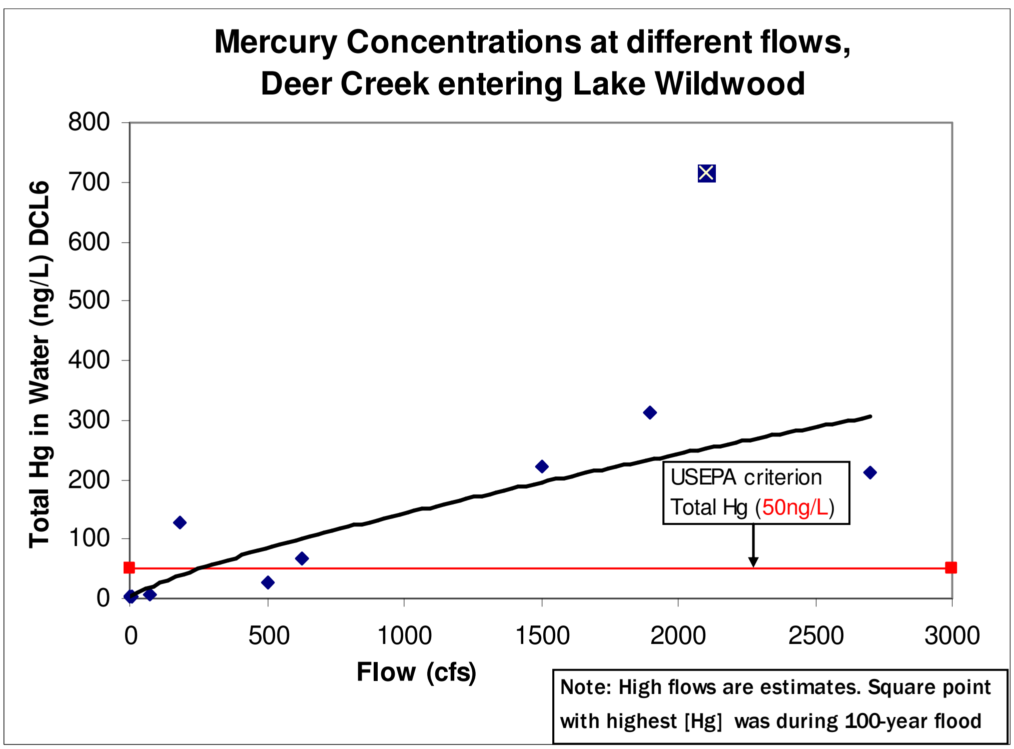
Macroinvertebrates

Results in progress. We are waiting for Texas A&M University to return the data.

Hydrology

Storm-based flow measurements were conducted at mid and high flows for 7 of the 10 sampling events capturing a range of flows. The following graphs display the relationship of mercury concentrations to flow at two of our sites, DCL8 and DCL6. Flow was analyzed with respect to mercury concentration at DCL8 because of the USGS gauge at Smartsville. These data show an increase in mercury concentration with increased discharge. Flow was also analyzed with respect to mercury concentration at DCL6 at the inlet to Lake Wildwood. These data show a similar increasing trend with discharge and also indicate that the concentration of mercury is above the USEPA criteria of 50ng/L.


Mercury Concentrations at different flows,
Deer Creek near Smartville/Yuba Confluence
Total Hg in Water (ng/L) DCL8
120
100
80
60
40
20
0
0
1000
2000
3000
4000
Flow (cfs)
USEPA criterion
Total Hg (50ng/L)
Note: This site is below Lake Wildwood Reservoir. Square point with the highest [Hg] was for a 100-year flood.


Mercury Concentrations at different flows,
Deer Creek entering Lake Wildwood
Total Hg in Water (ng/L) DCL6
800
700
600
500
400
300
200
100
0
0
500
1000
1500
2000
2500
3000
Flow (cfs)
USEPA criterion
Total Hg (50ng/L)
Note: High flows are estimates. Square point with highest [Hg] was during 100-year flood

Load Calculations

Mercury Load Estimates for the eight principal water sampling sites are shown below. The location of the highest load for each sampling event is shown in bold. The locations of these non-additive jumps in mercury loads are highlighted below, indicating unknown mercury sources upstream from those sites.

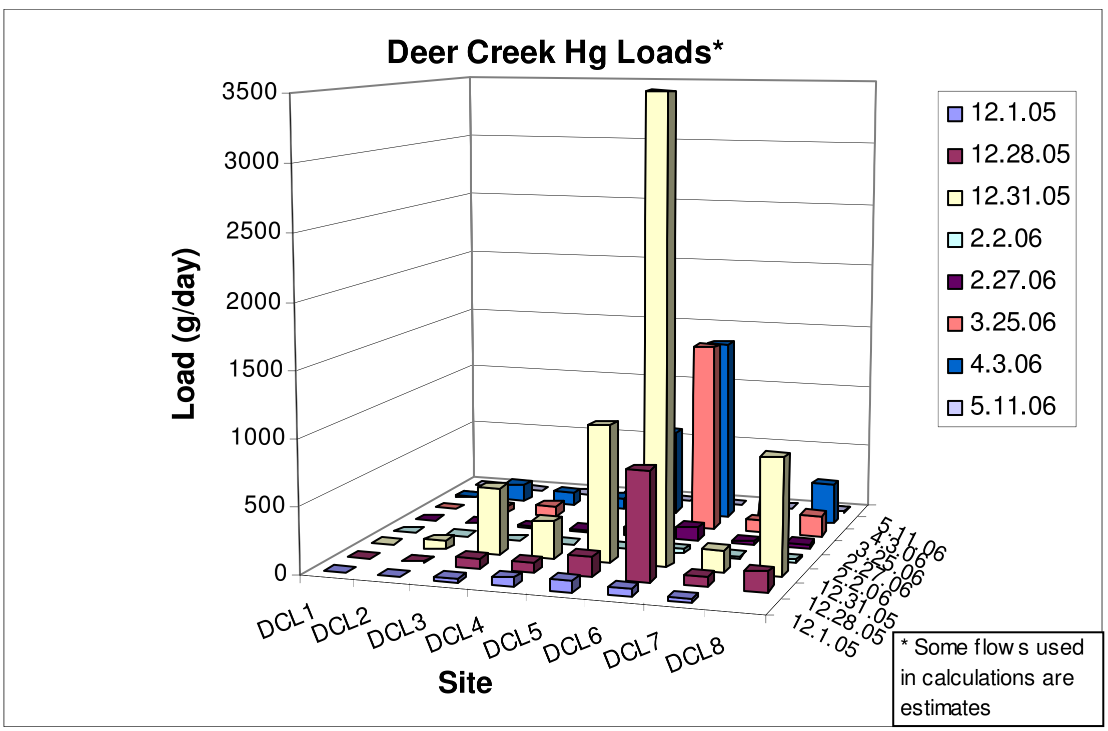
Deer Creek Mercury Load Estimates (grams Hg/day)

	9.15.05	12.1.05	12.28.05	12.31.05	2.2.06	2.27.06	3.25.06	4.3.06	5.11.06	6.29.06
DCL1	0.07	0.00	0.64	11.97	0.97	0.43	3.33	11.60	0.28	0.26
DCL2	0.04	7.07	11.48	69.11	5.04	7.03	44.61	136.23	0.36	0.08
DCL3	0.01	21.27	69.61	505.11	0.89	8.86	82.50	98.33	0.06	0.03
DCL4	**0.26**	69.56	75.04	282.99	3.12	17.87	95.36	86.77	0.45	**0.85**
DCL5	0.14	**76.74**	155.74	1037.62	11.23	56.79	231.18	667.15	1.09	0.48
DCL6	0.01	57.10	**818.44**	**3674.10**	**33.99**	**100.65**	**1445.61**	**1408.37**	0.98	0.04
DCL7		20.43	75.53	159.14	11.61	23.13	89.63	181.67	0.32	0.11
DCL8	0.01		145.92	883.41	21.03	38.06	158.95	315.62	**1.51**	0.04

Bold= highest load for sampling event

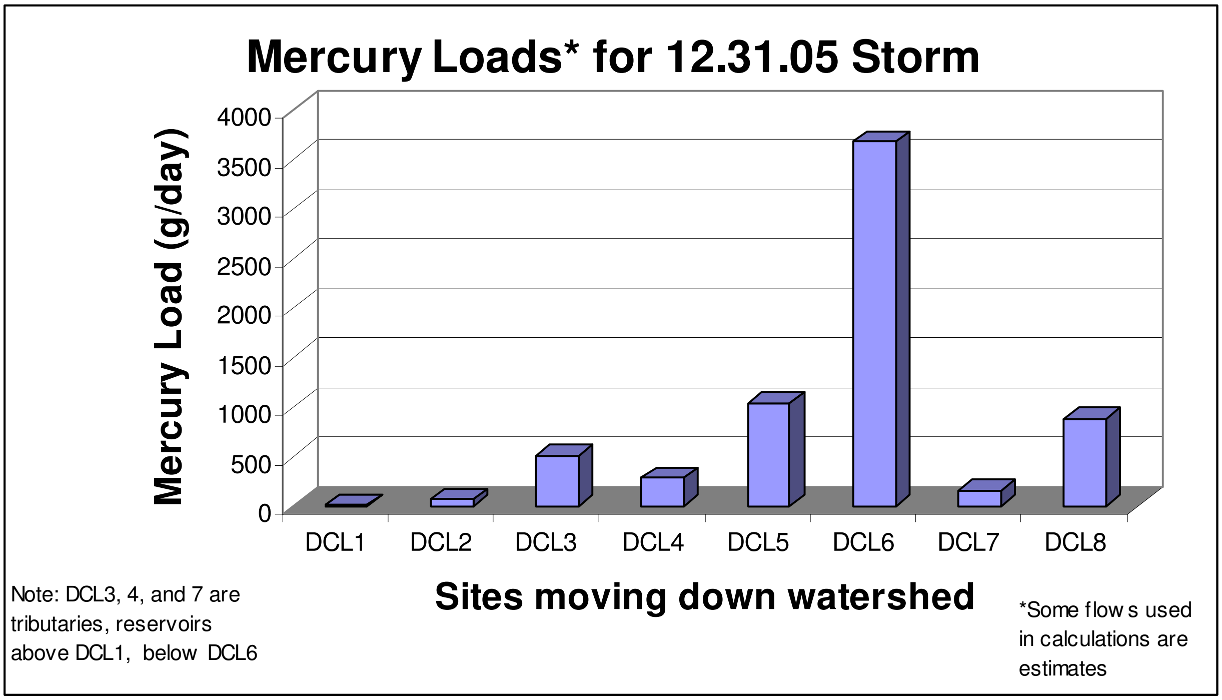
Highlighted = site where the load increases with an unaccounted source

The graph below shows how mercury loads vary greatly between storms, and loads can increase dramatically at the highest flows, as during the 12.31.05 flood.

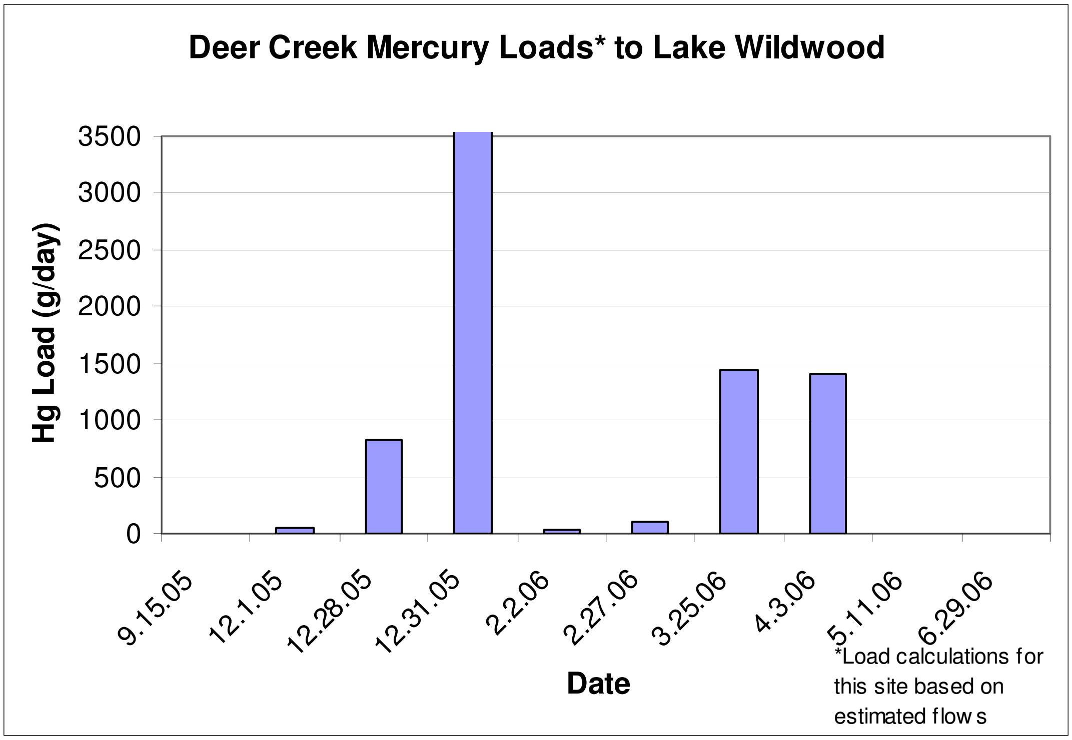


During low flow events, such as 9.15.05 and 6.29.06 (irrigation season), canal diversions between DCL1 and 2, DCL2 and 5, and DCL5 and DCL 6 dominate the load trend, with many downstream sites showing lower loads because of diversion of water and the mercury it carries. High flow storms clearly mobilize much greater loads of mercury, often several orders of magnitude greater than low flows, but the high flows also last for shorter intervals.

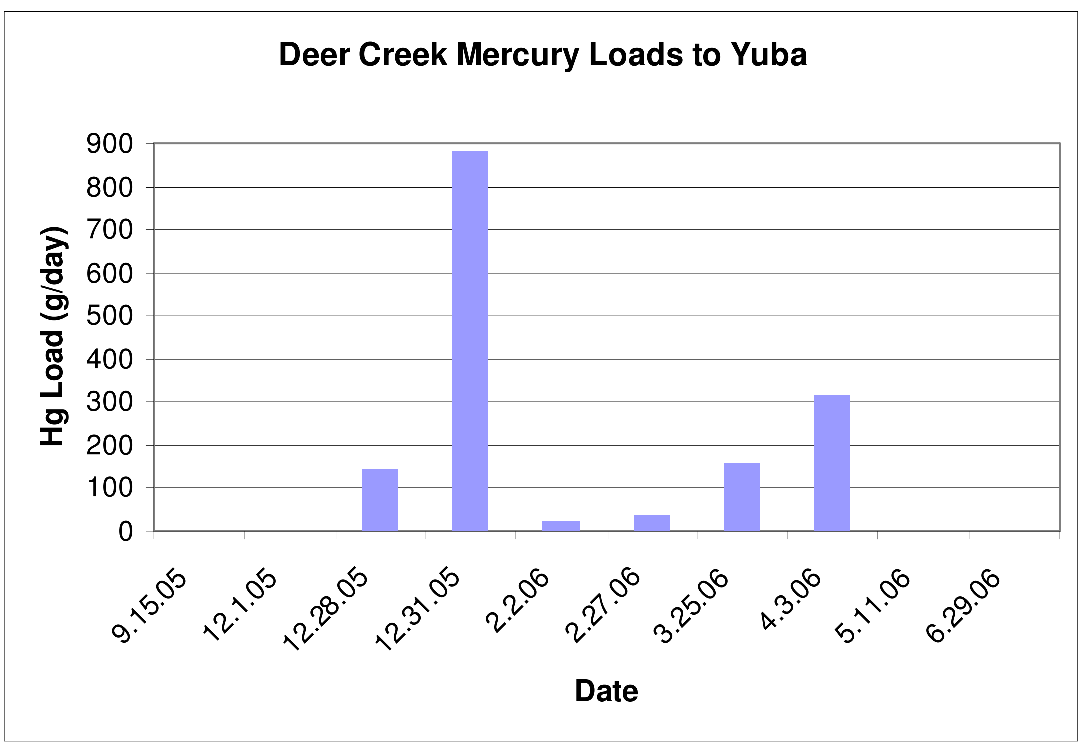
The load for all sites during the 12.13.05 flood indicate an increasing mercury loading trend moving down the watershed to Lake Wildwood reservoir, below DCL6, where load concentrations drop below the dam. The relative significance of tributary loads can be seen for sites DCL3 (Little Deer Creek), DCL4 (Gold Run), and DCL7 (Squirrel Creek) can be seen in the graph below.



Our data indicate consistently high loads of mercury entering Lake Wildwood (below DCL6), with much lower loads at the output of the reservoir, indicating that Lake Wildwood is effectively trapping a significant portion of the mercury load coming down Deer Creek. Because of uncertainties in our current estimates of flow entering Lake Wildwood, we do not attempt to estimate an annual mercury load to Lake Wildwood. Estimated daily mercury loads to Lake Wildwood for different sampling events are indicated below.



Deer Creek's mercury loads to the Yuba River, shown below, were calculated based on flows from the USGS gauging station # 11418500 and mercury concentrations measured at DCL8 (Mooney Flat bridge), less than 1 mile upstream of Deer Creek's confluence with the lower Yuba River.



Mercury concentrations delivered to the Yuba River (approximated from DCL8) only once exceeded the 50 ng/L criterion during our sampling events. This exceedence occurred during the 12.31.05 flood. It appears that Deer Creek's transport of very high levels of mercury to the Yuba River and downstream areas is mitigated by Lake Wildwood Reservoir. Deer Creek's mercury loads to the Yuba River provide an indication of how much mercury from Deer Creek is impacting downstream areas. As the mercury in water and sediment data suggests, Lake Wildwood traps an appreciable amount of mercury traveling down Deer Creek lowering the impact of mercury input into the Yuba River.

DISCUSSION

I. Mercury Sources in the Deer Creek Watershed

The primary objective of this study was to identify major mercury sources in the Deer Creek watershed. Our data clearly show that mercury in the watershed is bound to sediment and as such is transported with high flows that mobilize sediment. The sources of mercury bound sediment in the Deer Creek watershed are likely to be 1) historic tailings near mine or mill sites or 2) streambank and floodplain sediments high in mercury located in areas were mercury washed downstream from mining/processing sites and these sediments are now actively re-eroding or are mobilized during high flows. We analyzed trends in both mercury concentrations in water and mercury loads to evaluate where mercury was entering Deer Creek.

Mercury concentrations in Deer Creek at the eight load sites increased in measured intervals in the downstream direction. Flow measurements on the tributaries were conducted to determine their role in mercury loading. While mercury concentration data helped identify sources, mercury load analysis helped determine which source areas were the greatest contributors to elevated mercury on the mainstem.

We found that Squirrel Creek (DCL7), the largest tributary, had much lower concentrations of mercury than the smaller tributaries Little Deer Creek (DCL3) and Gold Run Creek (DCL4), which allowed us to skip detailed sampling in the Squirrel Creek watershed and focus additional samples in the Little Deer and Gold Run watersheds. Little Deer Creek and Gold Run Creek collectively contributed 15-20% on average of the total load of mercury entering Lake Wildwood because they were small watersheds with low flows. This approach allowed us to prioritize additional sampling and gave us a better chance of identifying hotspots that might be feasible targets for remediation. However, more fine scale sampling in these sub-watersheds is needed to identify point sources for cleanup.

According to a mass balance model, mercury loads moving down a watershed should be roughly additive, meaning that the load at a downstream site should be the approximate sum of the load measured upstream and any tributary or in-stream inputs in between, minus any deposition or diversion (reservoirs, canals, wetlands, etc), by the principle of conservation of mass. Mercury loads during high flows at DCL5, for example, should be the approximate sum of DCL2 (upstream site) and DCL3 and 4 (tributaries), as in the 12.28.05 storm, unless there are other unmeasured sources in between.

The mercury load more than triples between DCL5 and DCL6 during the high flow sampling events, suggesting input sources in this section. We further identified that the source location was greatest between the Bitney Springs Rd. crossing (DCL13) and the Lake Wildwood inlet (DCL6). We need repeated storm sampling at DCL5, 12, 13 and 6 to draw any conclusions about where the majority of the load is entering the system between these sites. We also need additional sites below DCL13.

The fact that mercury load tripled between DCL5 and 6 is surprising because there are not very many known mine sites between DCL5 and DCL6 section, according to historic maps and records or GIS data sources (MRDS (Mineral Resources Data System) and PAMP (Principal Areas of Mine Pollution). We focused some of the sediment sampling in this region, but did not find any major spikes in mercury concentration. Further sampling should be conducted in this region to locate potential point sources.

One hypothesis is that the mercury sources in this DCL5-6 reach are not coming from specific mines, but are floodplain and bank sediments re-mobilized during high flows. The gradient of Deer Creek becomes gentler for much of this section, and historic maps and photographs show large areas below DCL5 filled with hydraulic mine tailings. Terraces of hydraulic tailings can be seen in areas below DCL5. However, the reach between DCL13 and DCL6 has many steeper, bedrock canyon sections and less floodplain than the sections between DCL5 and 13.

We attempted to locate hotspot source areas of mercury by sampling sediments between load sites and along tributary sub-watersheds. For effective remediation, it is ideal to target the largest mercury load sources to the watershed. However, if the mercury source is widespread and not sufficiently concentrated, remediation (removal, capping, stabilization, etc) will not be feasible.

We focused some of our detailed sediment sampling upstream of DCL4 along Gold Run because it was the area with the highest mercury concentration. One of the challenges of locating hotspots more exactly in the Deer Creek watershed is the private ownership of most of the watershed. Although some landowners have graciously given permission for sampling on their properties and some public lands and roads provide access for sampling, it is often difficult to track upstream sources because even the small creeks cross many different private parcels.

Important findings with respect to the mercury sources in the Deer Creek Watershed are:

1) Mercury in the Deer Creek mainstem is closely assosciated to sediment and as such is transported with high flows that mobilize sediment, R^2 value of 0.9.

2) The tributaries Little Deer Creek (DCL3) and Gold Run (DCL4) have elevated mercury concentrations from unknown sources in their sub-watersheds.

3) The data suggest that there are unknown sources of mercury between Willow Valley Rd (DCL2) and Champion Mine (DCL5). This stretch of the creek is where most of the major Nevada City district mines including numerous hydraulic mines were historically located.

4) The data suggests that there are unknown sources of mercury between the Champion Mine site (DCL5) and Lake Wildwood inlet (DCL6) on the mainstem of Deer Creek.

II. Extent and magnitude of Mercury in the Deer Creek Watershed.

In examining whether Deer Creek's mercury levels pose a serious concern for human and aquatic health, the USEPA Criterion for total mercury in water (CA Toxics Rule) of 50 ng/L provides some standard for toxicity. However, 50 ng/L may also be too high to adequately protect aquatic life, as its derivation did not consider mercury bioaccumulation (Foe, 1998). As discussed above, 44% of the total water samples and 58% of the storm samples exceeded the 50 ng/L criterion. Evaluation of mercury levels in Deer Creek's biota and comparison to adjacent, heavily mined watersheds provides a more direct indication of the threat posed by mercury in the Deer Creek watershed.

<u>Mercury in Sediment</u>
Global background concentrations for Deer Creek watershed are estimated to be (0.05-0.08 ppm, Foe, pers. communication). Almost all of the sediment samples in Deer Creek (94%) were above background levels (mean 1.92 mg/kg (ppm)). The remediation goal for sediments currently proposed by San Francisco (Region 2) mercury TMDL is 0.2 ppm (CA Regional Water Quality Control Board). The U.S. EPA Preliminary Remediation Goal (PRG) for mercury in soil is 2.3 ppm.

For comparison the mean total mercury concentration found at Englebright Reservoir shallow sediment samples collected by USGS (South Yuba River) was 0.288 ppm (dry) (Alpers et al, in press) and the sediments measured directly in the Greenhorn Creek (a tributary to the Bear River) ranged from 0.0044 to 12 ppm of mercury (Alpers et al, 2005).

While upland soils are different than in-stream sediments in terms of their contribution to water contamination, each of these levels provide some reference for comparing mercury concentrations in sediment from the Deer Creek watershed. The Deer Creek watershed samples exceeded the San Francico Bay TMDL (0.2ppm), the USEPA PRG (2.3ppm) and the Englebright Reservoir average (0.288ppm), suggesting that Deer Creek is a highly impacted watershed.

<u>Mercury in the Water</u>

USGS conducted an in-depth study on Greenhorn Creek, a tributary of the Bear River with similarities in elevation and size to Deer Creek, and the site of some of the most intensive hydraulic mining in California. USGS measured total mercury concentrations in water ranging from 0.8 to 153,000 ng/L, with a median value of 9.6 ng/L (Alpers et al, 2005), compared to the Deer Creek range of 0.34 ng/L to 1033 ng/L. The highest concentrations from the Greenhorn Creek study were from known mine discharge sites, so they could be expected to be higher than the Deer Creek water samples which were collected mostly on the main stem and tributaries rather than at specific mine sites. However, the median total mercury water concentration in Deer Creek, 31.56 ng/L, was higher than the Greenhorn Creek median (9.6ng/L).

Mercury in the Food Chain

Measuring mercury concentrations in biota provides a more tangible measure of how mercury in the watershed is affecting ecosystem health and potentially human health. This study did not include sampling fish tissue, but we were able to sample macroinvertebrates, an important food source for fish in Deer Creek that have been used in other mercury studies as "biosentinels" or indicators of mercury bioaccumulation in aquatic food chains (Slotton et al, 1997).

Insert FODC [MeHg] in macroinvertebrate data when received from analytical lab.

These samples are of five taxa (Gomphidae (Dragonfly), Aeshnidae (Dragonfly), Gerridae (Water Strider), Hydropyschidae, and Perlidae (Stonefly)), selected for abundance and comparability with USGS data.

In a previous study from 1999-2001, USGS collected macroinvertebrate samples on Deer Creek at Little Deer Creek, Deer Creek at Willow Valley Rd, above Scotts Flat Reservoir and below Deer Creek Falls. The ranges of methyl mercury in wet tissue that they sampled are listed here for comparison (data unpublished):

Common Name	**Invertebrate Family**	**MeHg Range (ppm wet)**
Dragonfly	Aeshnidae	0.0547 - 0.0625
Dragonfly	Gomphidae	0.1059 - 0.1443
Stonefly	Perlidae	0.0396 - 0.1746
Water Strider	Gerridae	0.0558 - 0.2147
Dobsonfly	Corydalidae	0.0263 - 0.1460

Data on mercury levels in fish for a number of sites on Deer Creek as well as data on adjacent watersheds is available from studies done by the U.S. Geological Survey (1999) and the State Water Resources Control Board Toxic Substance Monitoring Program 1978-2000. These data provide an important indication of the impacts of Deer Creek's mercury contamination on local biota and of potential risk to humans consuming fish.

The USGS data indicated that Little Deer Creek had relatively high levels of mercury in trout compared to samples from the Yuba and Bear River watersheds. The majority of the trout collected on Little Deer Creek and the largemouth bass from Scotts Flat Reservoir were above the California Office of Environmental Health Hazard Assessment (OEHHA) screening value of 0.3 ppm, leading to 303(d) listing of Little Deer Creek and Scotts Flat Reservoir. The following two graphs of fish data collected by USGS are from May et al, 1999.

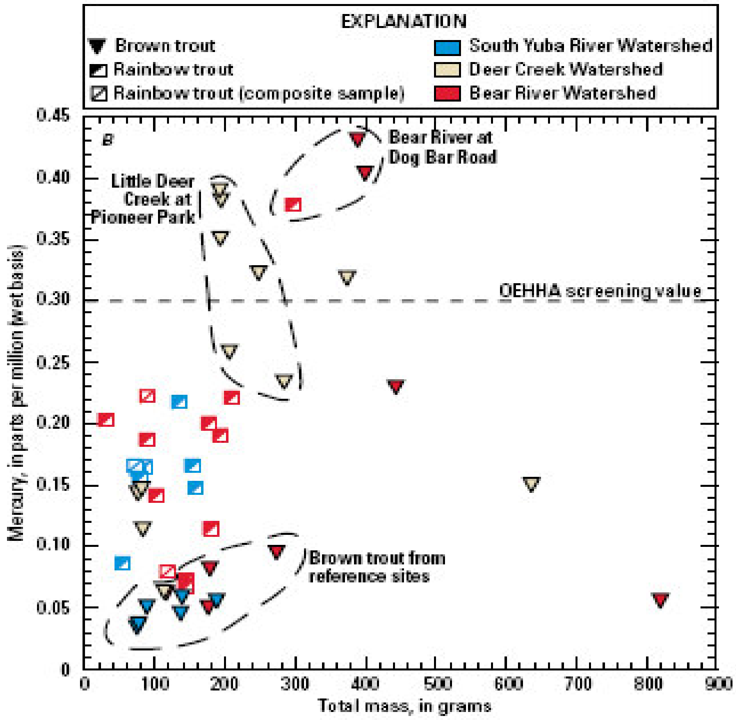


Figure 9. Mercury concentration for stream fish samples ollected from the South Yuba River, Deer Creek, and Bear River watersheds, California, 1999. *A*, In relation to total length. *B*, In relation to total mass. Dashed horizontal line at mercury concentration of 0.3 ppm represents a screening value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

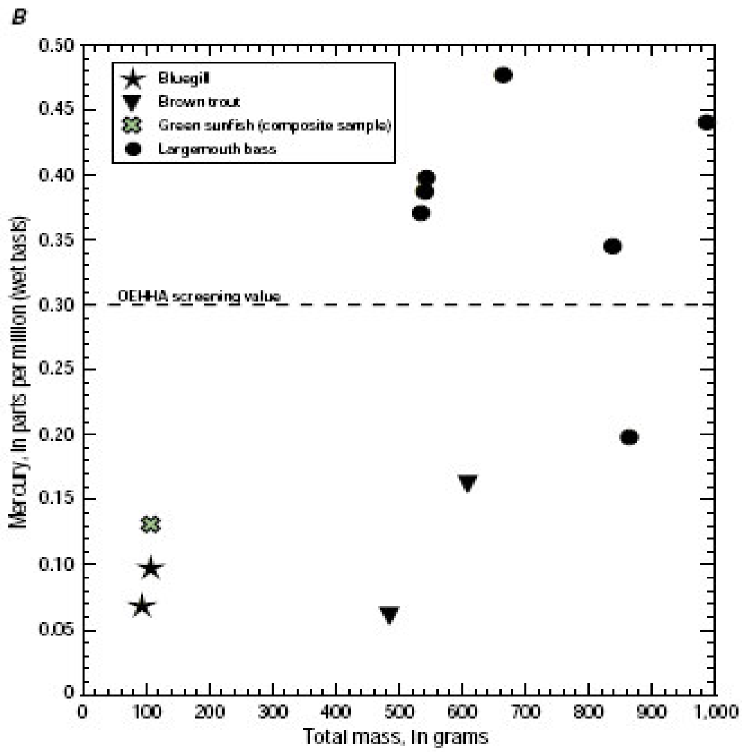


Figure 5. Mercury concentration for fish collected from Scotts Flat Reservoir, California, 1999. *A*, In relation to total length. *B*, In relation to total mass. Dashed horizontal line at mercury concentration of 0.3 ppm represents a screening value provided by the Office of Environmental Health Hazard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

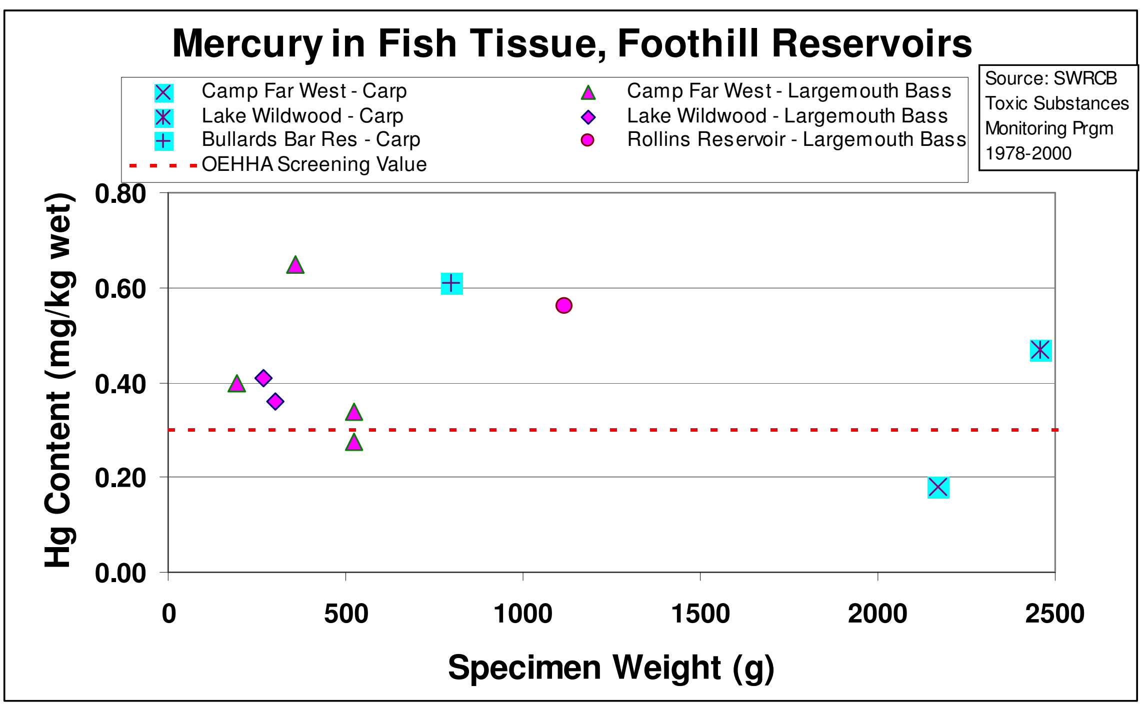
Little Deer Creek and Scotts Flat Reservoir are located in the upper half of the Deer Creek watershed. Further down the watershed, additional mine sites and higher temperatures may increase the levels of methyl mercury. Samples collected in Lake Wildwood Reservoir by the State Water Resources Control Board (SWRCB), Toxic Substances Monitoring Program 1978-2000 indicate that they levels of mercury in fish tissue from Lake Wildwood is greater than the OEHHA screening value (0.3 ppm). The following data from the online dataset show mercury concentrations in fish tissue from Lake Wildwood and reservoirs in adjacent, heavily-mined watersheds.

Mercury in fish from Foothill Reservoirs

SWRCB, 1978-2000 (http://www.waterboards.ca.gov/programs/smw/index.html)

SITE	HG (mg/kg)	COMMON NAME	GENUS	SPECIES	DATE	AGE	WEIGHT (g)
Bullards Bar Res	0.610	Carp	Cyprinus	carpio	10/26/1990	2	799.4
Camp Far West	0.180	Carp	Cyprinus	carpio	8/27/1987	3-4	2170.0
Lake Wildwood	0.470	Carp	Cyprinus	carpio	10/2/1987	4	2456.0
Camp Far West	0.400	Largemouth Bass	Micropterus	salmoides	8/27/1987	1	192.5
Camp Far West	0.650	Largemouth Bass	Micropterus	salmoides	9/21/1990	2-3	358.2
Camp Far West	0.338	Largemouth Bass	Micropterus	salmoides	10/28/1998	3	521.5
Camp Far West	0.275	Largemouth Bass	Micropterus	salmoides	10/28/1998	3	521.5
Lake Wildwood	0.360	Largemouth Bass	Micropterus	salmoides	10/2/1987	1-2	301.6
Lake Wildwood	0.410	Largemouth Bass	Micropterus	salmoides	8/22/1990	1-2	270.0
Rollins Reservoir	0.560	Largemouth Bass	Micropterus	salmoides	7/29/1985	3-5	1115.9

In the graph of the above data the relationship of mercury tissue concentrations to the weight of the fish can be seen. Weight can be used as an approximation of fish age. Older fish are more likely to have accumulated more mercury. The Largemouth Bass from Lake Wildwood had similar mercury concentrations to those in Scotts Flat (a listed 303d water body for mercury), but were roughly half the size of the Scotts Flat Bass. This is significant because mercury concentrations in fish generally increase with size and weight and one could expect that the methyl mercury concentrations in the food chain at Lake Wildwood is at least as significant if not greater than Scotts Flat. It is likely that Lake Wildwood Reservoir is a site for mercury methylation due to the warm temperatures and accumulative trapping of mercury-laden sediment.



Camp Far West and Rollins Reservoir are in the Bear River watershed, downstream of extensive historic hydraulic mining, and provide a good reference for foothill reservoirs heavily impacted by mercury. The Lake Wildwood fish show a similar range of mercury to these heavily impacted areas.
In order to draw further conclusions about the impacts of Deer Creek mercury contamination to human health, more fish data would be needed, as well as information on who is eating fish from watershed, how much, and where the fish were caught.

Important findings relevant to the extent and magnitude of mercury in the Deer Creek Watershed are:

1) 58% of the storm samples exceeded the 50 ng/L criterion.

2) 94% of the sediment samples in Deer Creek were above background levels (mean 1.92 mg/kg (ppm)).

3) The Deer Creek watershed sediment samples exceeded the San Francico Bay TMDL (0.2ppm), the USEPA PRG (2.3ppm) and the Englebright Reservoir average (0.288ppm), suggesting that Deer Creek is a highly impacted watershed.

4) The median total mercury concentration in Deer Creek water samples was 31.56 ng/L, which exceeded the Greenhorn Creek median value (9.6ng/L).

5) Mercury concentrations in fish tissue from Lake Wildwood was greater than the OEHHA screening value (0.3 ppm). The Largemouth Bass from Lake Wildwood had similar mercury concentrations to those in Scotts Flat (a listed 303d water body for mercury), but were roughly half the size of the Scotts Flat Bass. This is significant because mercury concentrations in a fish generally increase with size and weight and one could expect that the methyl mercury concentrations in the food chain at Lake Wildwood is at least as significant if not greater than Scotts Flat.

ACKNOWLEDGEMENTS
Friends of Deer Creek would like to thank the CALFED Bay-Delta program, and the U.S. Environmental Protection Agency for providing funding for this project through the Regional Water Quality Control Board, the Department of Conservation Watershed Coordinator Program, and the Delta Tributaries Mercury Council (DTMC)/Sacramento County Regional Sanitation District. We are very grateful for training, advice and assistance from Chris Foe of the Regional Water Quality Control Board, David Lawler from BLM, Roger Hothem from USGS, Rick Humphreys from the State Water Resources Control Board, Rick Weaver from the USDA Forest Service, members of the DTMC, staff of the Nevada Irrigation District and the City of Nevada City, Jerry Bloom and High Sierra Electronics, and the numerous volunteers, private landowners, and members of Friends of Deer Creek who helped with this study.

REFERENCES CITED

Alpers, C.N., Hunerlach, M.P., May, J.T., Hothem, R.L., Taylor, H.E., Antweiler, R.C., De Wild, J.F., and Lawler, D.A., 2005, Geochemical characterization of water, sediment, and biota affected by mercury contamination and acidic drainage from historical gold mining, Greenhorn Creek, Nevada County, California, 1999-2001: U.S. Geological Survey Scientific Investigations Report 2004-5251, 278 p. Available at http://pubs.usgs.gov/sir/2004-5251/

Alpers, C.N., Hunerlach, M.P., May, J.T., and Hothem, R.L., 2005, Mercury Contamination from Historical Gold Mining in California: U.S. Geological Survey Fact Sheet 2005-3014, 6 p. http://pubs.usgs.gov/fs2005-3014

Alpers, C.N., Hunerlach, M.P., Marvin-DiPasquale, M.C., Antweiler, R.C., and Snyder, N.P., in press,
Geochemical data for mercury, methylmercury, and other constituents in sediments from Englebright Lake, California, 2002, U.S. Geological Survey Data Series Report 05-151

Alpers, C.N., Antweiler, R.A., Snyder, N.P., Curtis, J.A., and Hunerlach, M.P., in review, Mercury transport and deposition in a watershed affected by historical gold mining: the upper Yuba River, California. Draft journal article to be submitted to Water Resources Research.

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

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

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

Churchill, R.K., 2000, Contributions of mercury to California's environment from mercury and gold mining activities; Insights from the historical record, *in* Extended abstracts for the U.S. EPA sponsored meeting, Assessing and Managing Mercury from Historic and Current Mining Activities, November 28-30, 2000, San Francisco, Calif., p. 33-36 and S35-S48.

Foe, C., and Croyle, W., 1998. Mercury Concentrations and Loads from the Sacramento River and from Cache Creek to the Sacramento-San Joaquin Delta Estuary. California Regional Water Quality Control Board, Central Valley Region. 101p.

Hunerlach, M.P., Alpers, C.N., Marvin-DiPasquale, M., Taylor, H.E., and De Wild, J.F., 2004, Geochemistry of mercury and other trace elements in fluvial tailings upstream of Daguerre Point Dam, Yuba River, California, August 2001: U.S. Geological Survey Scientific Investigations Report 2004-5165, 66 p. Available at http://pubs.water.usgs.gov/sir2004-5165/

Klasing, Susan, and Brodberg, Robert, 2003, Evaluation of potential health effects of eating fish from selected water bodies in the northern Sierra Nevada Foothills (Nevada, Placer, and Yuba Counties): Guidelines for sport fish consumption: California Office of Environmental Health

Hazard Assessment, 48 p. Available at http://www.oehha.ca.gov/fish/pdf/SierraLakesAdvisoryfinal.pdf

May, J.T., Hothem, R.L., Alpers, C.N., and Law, M.A., 2000, Mercury bioaccumulation in fish in a region affected by historic gold mining: The South Yuba River, Deer Creek, and Bear River watersheds, California, 1999: U.S. Geological Survey Open-File Report 00-367, 30 p. http://pubs.water.usgs.gov/ofr00-367/

MRDS spatial mine data: http://tin.er.usgs.gov/mrds/

PAMP spatial mine data: http://www.consrv.ca.gov/omr/abandoned_mine_lands/pamp/index.htm

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

State Water Resources Control Board, Toxic Substances Monitoring Program data base for years 1978-2000, available at http://www.waterboards.ca.gov/programs/smw/index.html

U.S. Environmental Protection Agency, 2001, Water quality criterion for the protection of human health: Methylmercury: EPA-823-R-01-001, 16 p. Available at http://www.epa.gov/waterscience/criteria/methylmercury/merctitl.pdf

White, R.F, Grandjean, P.A., and Weihe, P, 1995. An overview of human studies on CNS effects of methylmercury. *In* National forum on Mercury in Fish. U.S. EPA Office of Water. EPA 823-R-95-002.