Summary
Putah Creek Mercury Water Quality Issues

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Putah Creek is a tributary of the Yolo Bypass which in turn is a tributary of the Sacramento San Joaquin Delta. Some of the fish in the Delta, Yolo Bypass as well as Putah Creek and many other Delta tributaries contain sufficient concentrations of mercury to be hazardous to those who use the fish as food. The elevated concentration of mercury in fish is the result of a bioaccumulation process where through the aquatic food web mercury in its various chemical forms is converted into methyl mercury that bioaccumulates in fish tissue. The excessive bioaccumulation of mercury in edible fish is one the most significant causes of public health related water quality impairment in the Delta and many of its tributaries. There is also concern about the impact on reproduction by mercury in small fish that are used as food by fish eating birds. Information on the excessive mercury bioaccumulation of mercury in Central Valley fish is available at the Central Valley Regional Water Quality Board (CVRWQCB) at,
http://www.swrcb.ca.gov/centralvalley/water_issues/tmdl/central_valley_projects/index.shtml

In an effort to work toward controlling the bioaccumulation of mercury in edible fish there is need to understand the sources of mercury that bioaccumulate in fish and other aquatic life. As a result there is considerable interest in the understanding the sources of mercury to and within a waterbody that lead to excessive mercury concentrations in edible fish.

The headwaters of Putah Creek located upstream of Lake Berryessa in the Vaca Hills (see Figures 1 and 2) contain several abandoned mercury mines that contribute mercury to Putah Creek and its upstream tributaries. These mines are the source of mercury that has polluted Putah Creek, Yolo Bypass and the Delta associated fish.

Beginning in the mid 1990s studies have been conducted on the occurrence of excessive mercury Putah Creek fish. Since then there have several studies on mercury water quality issues in Putah Creek. Drs. G. Fred Lee and Anne Jones-Lee have developed a presentation on the information on Putah Creek fish and water. This information has been presented at the December 2, 2008 meeting of the Delta Tributaries Mercury Council. The PowerPoint slides used in this presentation are available at,
http://www.gfredlee.com/DSCSOC/2008/PutahCrHgLEHRsli.pdf. A summary of the information presented on these slides is discussed below. A map of the location of the LEHR Superfund site is presented in Figure 3.

Figure 1 Map of Putah Creek Watershed
Adapted from UCD Putah-Cache Bioregion Project: UCD Davis
http://bioregion.ucdavis.edu/where/featrmap.html

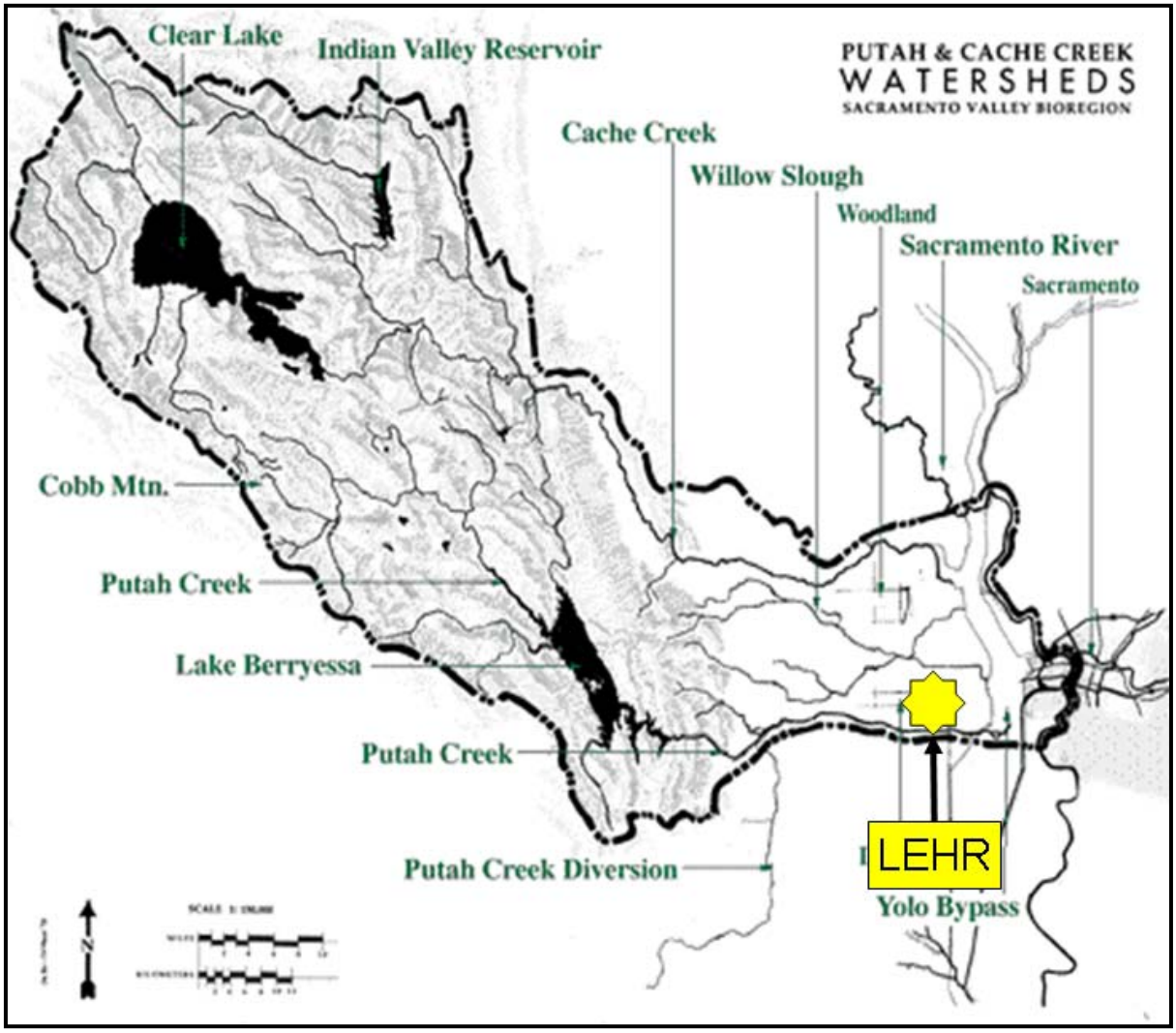
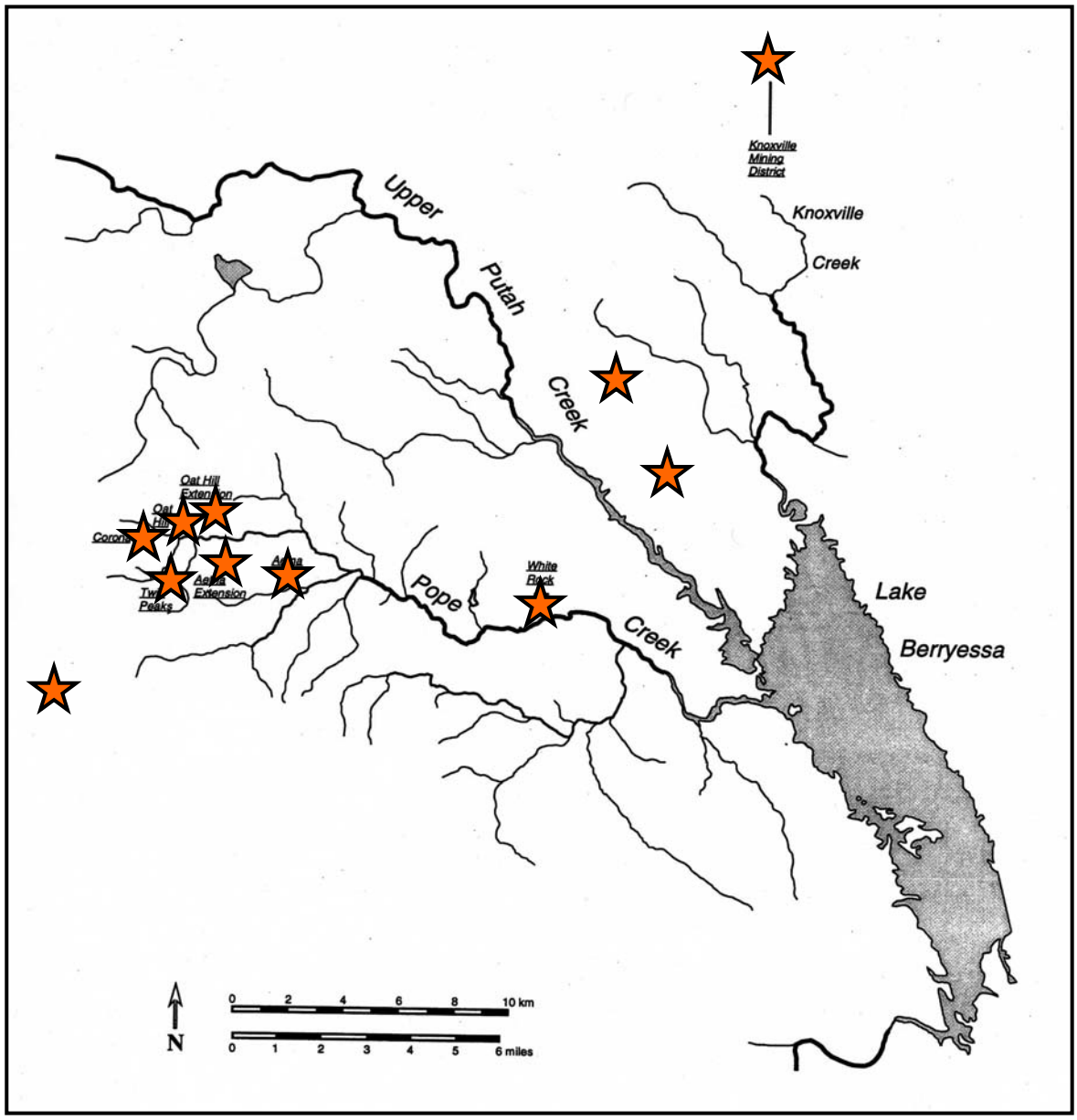
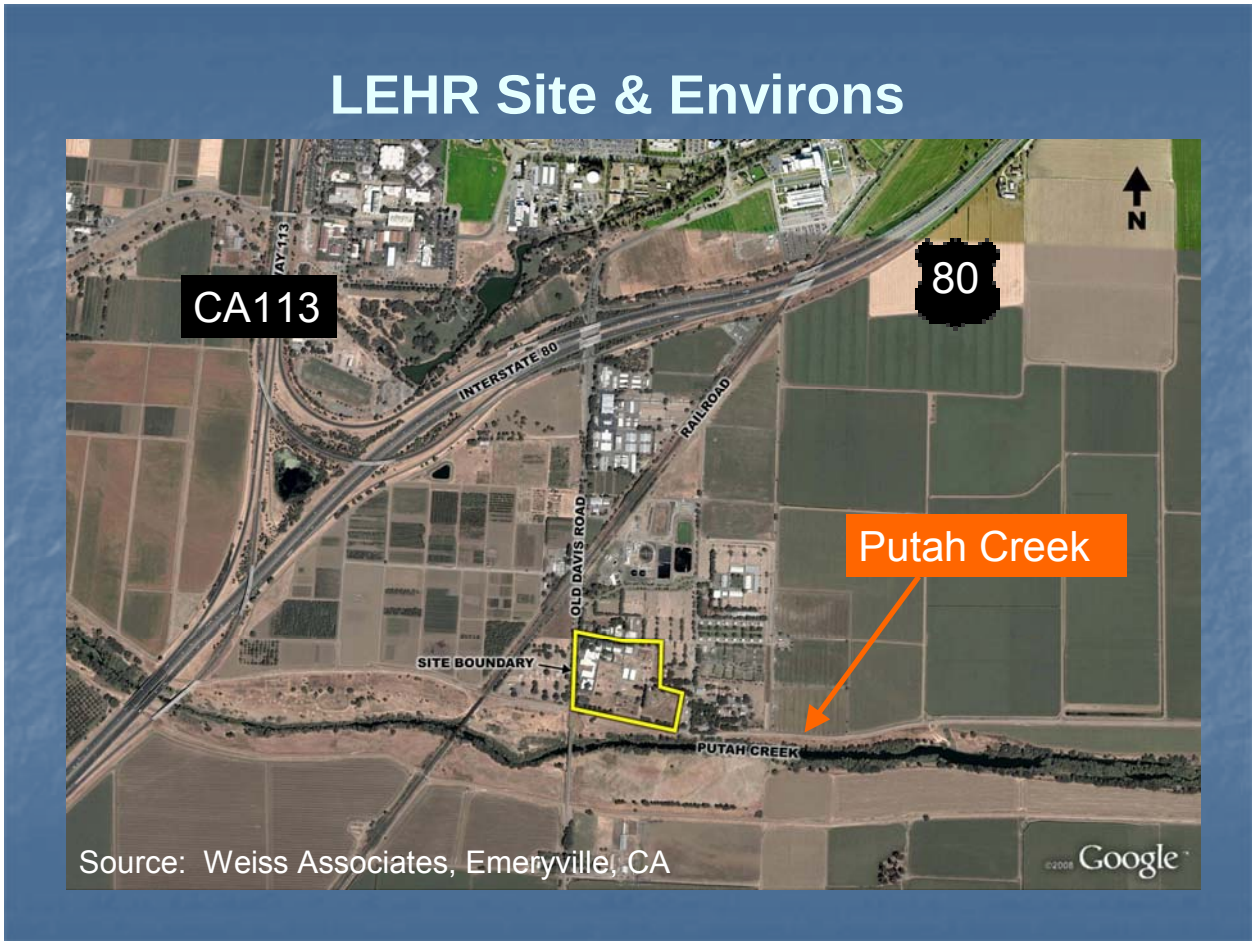


Figure 2. Portions of Upper Putah Creek Watershed Showing Primary Abandoned Mercury Mines (Slotton et al. (1999)



Drs. G. Fred Lee and Anne Jones-Lee interest in bioaccumulation of mercury in Putah Creek fish arises through their serving as US EPA Superfund Technical Assistant Grant (TAG) technical advisors to the Davis South Campus Superfund Oversight Committee (DSCSOC) on the adequacy of the investigation/remediation of the University of California Davis/Department of Energy (UCD/DOE) LEHR national Superfund site located on the UCD campus in Davis, CA. Information on the LEHR Superfund site and DSCSOC is available at, http://www.gfredlee.com/DSCSOC/DSCSOC.htm.

Figure 3 Map of the Location of the LEHR Superfund Site



Upon their appointment to the TAG advisory positions in 1995 they found that inadequate evaluation of the potential for wastes derived from the LEHR Superfund site could be present in stormwater runoff to bioaccumulate in Putah Creek fish and thereby create a condition that is hazard to those who use Putah Creek fish as food. Lee and Jones-Lee (1998) discussed the deficiencies in hazardous chemical site impact investigation, In 1995 DSCSOC requested that Agency for Toxic Substances and Disease Registry (ATSDR) as part of its Public Health Assessment for the LEHR Superfund site determine whether the fish near LEHR contained concentrations of hazardous chemicals that would be a threat to those who use Putah Creek fish. The initial 1996 ATSDR/US EPA fish sampling of Putah Creek fish found Hg in fish (largemouth bass) taken from near LEHR ranged 0.11 to 0.81 mg/kg Hg (wet weight). A summary of the ATSDR/USEPA data for mercury in Putah Creek fish is presented in Table 1. The ATSDR/USEPA 1996 and 1997 (ATSDR 1997, 1998) studies demonstrated that some fish in Putah Creek near Davis, CA contained mercury at that are a threat human health when used as food. Lee (1998a.b, 1999) has issued several reports on this issue.

Table 1. Mercury Concentration in Largemouth Bass from Putah Creek – Oct/Nov 1997

Fish Size	Mean ± SD (mg Hg/kg)
Small (< 415 g)	0.17 ± 0.06
Medium (540 – 730 g)	0.32 ± 0.14

In the late 1990s, subsequent studies Slotten and Ayers (1999) found that some Putah Creek fish taken through out Putah Creek below Lake Berryessa contain excessive mercury. Slotten et al. (1999) also found elevated concentrations of mercury in small fish taken in tributaries of Lake Berryessa in the mercury mine area . A summary of the Slotten data on Putah Creek fish mercury concentrations is presented in Table 2.

These mid to late 1990s studies on mercury on mercury in Putah Creek fish demonstrated that mercury in Putah Creek fish is derived from Putah Creek water/sediments. It is also possible that the UCD/DOE LEHR Superfund site stormwater runoff and campus wastewater discharges to Putah Creek were contributing to the excessive mercury in Putah Creek fish. As discussed below LEHR Superfund site stormwater runoff contains sufficient mercury to contribute to the excessive bioaccumulation of mercury in Putah Creek fish near and downstream of LEHR.

The studies on mercury in fish from Putah Creek caused DSCSOC to request that the Central Valley Regional Water Quality Board to list Putah Creek as a Clean Water Act section 303(d) limited due to excessive bioaccumulation of mercury of edible fish.

Table 3 Mercury Concentrations in Putah Creek Fish 1998—1999
(Slotton & Ayers, 1999)

Fish Type & Location	Mean ± SD (mg Hg/kg) [no. fish]
Trout – near Lake Berryessa	0.85 ± 0.03 [11]
Bluegill – Upstream of UCD	0.21 ± 0.06 [7]
Bluegill – Downstream of UCD	0.2 ± 0.08 [5]
Largemouth Bass – Downstream of UCD	0.46 ± 0.23 [6]
Roach – Upstream of Lake Berryessa (only small fish)	Range: 0.08 – 0.17

This listing occurred in 2003 by the CVRWQCB/SWRCB/US EPA. This listing requires that all NPDES permitted discharges of wastewaters and some stormwaters not exceed the water standard/objective for mercury.

Regulatory Standard for Mercury

The current mercury standard is the California Toxics Rule (CTR) criterion of 50 ng/L (nanograms/liter) as total recoverable mercury. As discussed by the US EPA at the time of promulgation of the CTR criteria the 50 ng/L is a value that was developed to make the approach for regulating bioaccumulation of chemicals in fish consistent amount chemicals. It was acknowledged that that value was not protective against excessive bioaccumulation of mercury in fish. The protective concentration of total recoverable mercury in a waterbody is about 5 ng/L.

As discussed in DSCSOC reports, presented at, http://www.gfredlee.com/dscsoc/doc.htm devoted to stormwater runoff from the LEHR Superfund site has been repeatedly found to contain total recoverable mercury at over 500 ng/L. This situation caused the CVRWQCB to require that UCD develop stormwater runoff programs that will prevent mercury in LEHR site runoff to be less than the CTR criterion of 50 ng/L. Ultimately this value will need to be adjusted to about 5 ng/L when the CTR criterion is properly adjusted to prevent excessive bioaccumulation of mercury in fish. At this time UCD is attempting to prevent stormwater runoff from the LEHR site to prevent excessive discharge of mercury to Putah Creek. It is our experience that placing straw bails/rolls in front of stormwater inlets for discharge locations will not be adequate to prevent violations of excessive mercury discharges in stormwater runoff from the LEHR site.

Fish Consumption Guidance

In 2006 the California Office of Environmental Health Assessment (OEHHA 2006) issued fish consumption guidance for Putah Creek upstream of Lake Berryessa, within Lake Berryessa and downstream of this lake,
(http://oehha.ca.gov/fish/so_cal/putahcreek.html) This guidance (see Tables 4 and 5 and Figures 4 and 5) included information on the existing fish mercury concentrations and establishes the guidance on the amount of various types fish that may be consumed per week and be considered to be a significant threat to human health.

CALFED Mercury Studies

In August 2008 the final reports from the CALFED (Stephenson et al. 2008) supported multiyear project mercury project. This project included monitoring of Putah Creek water for total recoverable mercury and methyl mercury. As presented in Table 6 the total recoverable mercury in Putah Creek average 24 ng/L with some high flow values exceeding 100 ng/L. The methyl mercury concentration in Putah Creek was found to be about 0.15 ng/L.

Table 4. Summary Mean Hg Concentrations for Legal &/or Edible-Size Fish & Shellfish from Putah Creek (OEHHA, 2006)

Species	Hg (ppm)*
Channel Catfish	**0.15**
White Catfish	**0.14**
Catfish	**0.14**
Largemouth Bass	**0.46**
Sacramento Blackfish	**0.09**
Sacramento Sucker	**0.16**
Bluegill	**0.14**
Green Sunfish	0.17
Redear Sunfish	0.15
Hybrid Sunfish	0.19
Sunfish	**0.14**
Carp	**0.18**
Rainbow Trout	0.08
Brown Trout	0.06
Trout	**0.07**
White Crappie	0.28
Black Crappie	0.33
Crappie	0.29
Hitch	0.09
Sacramento Pikeminnow	0.50
Crayfish	0.21
* **BOLD:** Samples with Sufficient Numbers	

Table 5. Summary Mean Hg Concentrations for Legal &/or Edible-Size Fish from Lake Berryessa (OEHHA, 2006)

Species	Hg (ppm)*
Channel Catfish	**0.52**
White Catfish	**0.77**
Catfish	**0.56**
Largemouth Bass	**0.75**
Smallmouth Bass	**0.93**
Black Bass	**0.76**
Rainbow Trout	**0.17**
Chinook (King) Salmon	**0.48**
Bluegill	**0.39**
Carp	**0.54**
*** BOLD: Samples with Sufficient Numbers**	

Figure 4. Safe Eating Guidelines Fish Consumption from Putah Creek (Source: OEHHA, 2006)

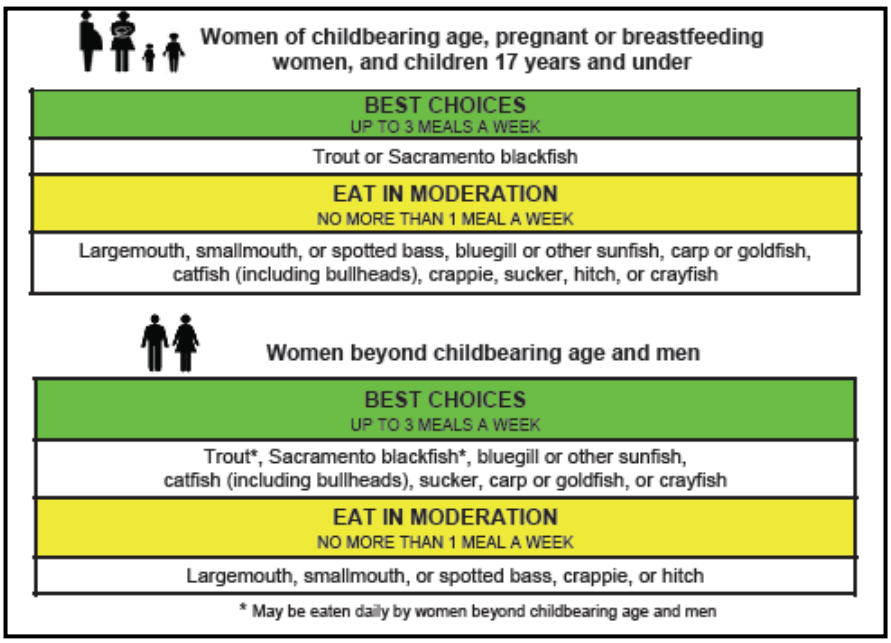


Figure 5. Safe Eating Guidelines Fish Consumption from Lake Berryessa (Source: OEHHA, 2006)

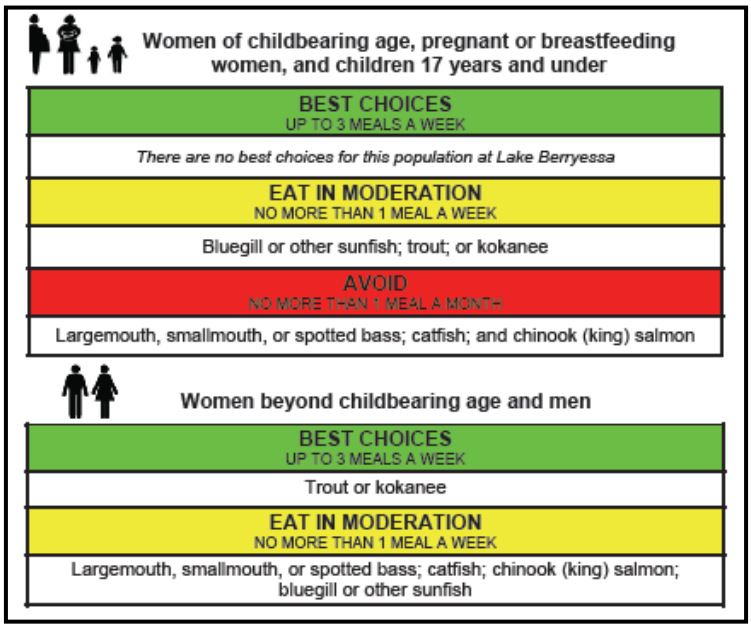


Table 6. CALFED Mercury Project Concentrations of Hg in Water
(Based on data in Stephenson et al. 2008)

Location	Concentration or Mean ± SD (ng Hg/L)
Putah Creek at Mace Blvd (63 samples 2003 – 2006)	23.82 ± 16.64
Creek during Some High Creek Flows	100
MeHg in Putah Creek	0.15 ± 0.03
MeHg in Cache Creek	0.26 ± 0.09

Foe (2008) has indicated that the CVRWQCB staff will propose a Basin Plan amendment of ,

- "*our proposed basin plan amendment tissue objective for large trophic level 3 and 4 fish are 0.08 and 0.24 ppm wet weight. This will allow people to safely eat a meal a week.*
- *We are also proposing a small fish (up to 50 mm length) tissue objective of 0.03 ppm wet weight. This is to protect fish eating wildlife. The small fish number*

comes from recommendations by the US FWS to protect, among other animals, least terns. There is a least tern nest colony near Antioch.

- *You can read the details in our TMDL report to the US EPA. The unfiltered methyl mercury concentration needed to met these tissue numbers are site specific. The value for the Delta appears to be around 0.06 ng/l.*"

Information on the CVRWQCB proposed TMDL for the Delta is located at, http://www.swrcb.ca.gov/centralvalley/water_issues/tmdl/central_valley_projects/delta_hg/index.shtml. Comparison between these means that some fish in Putah Creek would be expected to contain excessive mercury in edible tissue since the mercury concentrations in Putah Creek are well above the proposed Basin Plan water quality objective for mercury.

LEHR Site and Area Surface Soil Mercury

Studies on mercury in the surface soils near the LEHR site (see Figure 6 and Table 7 shows that typically these soils contain from 1 to 5 mg/kg.

Figure 6 Map of the Mercury Near LEHR Surface Soil Sampling Locations

Dashed area is the LEHR site (Source: Weiss Assoc., 2008)

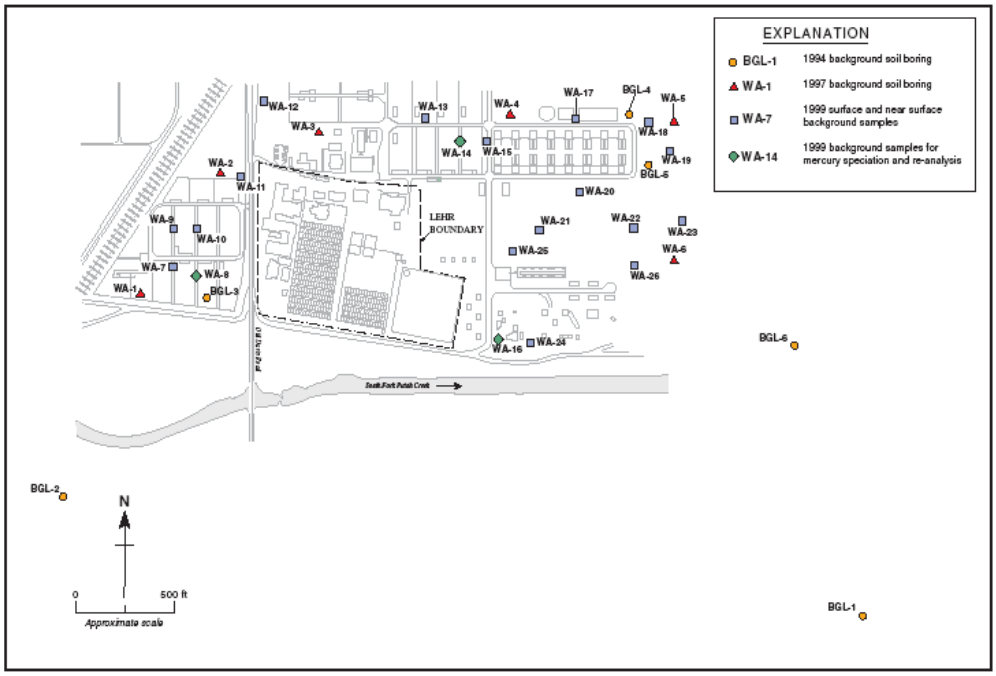


Table 7. Hg Concentrations in near LEHR Area Soils
(Source: Weiss Assoc., 2008)

Sample Depth	Mean ± SD (mg/kg Hg)
Surface	1.3 ± 1.1
2 ft	1.9 ± 1.3
3 – 4 ft	0.25 ± 1.7
8 – 22 ft	0.16 ± 0.16
30 – 40 ft	0.19 ± 0.09

The mercury concentrations in the LEHR and near LEHR soils were typically a factor of 5 to 10 times less than the surface soils. A similar of elevated surface soils mercury is found at LEHR (see Table 8) site.

Table 8. Average Concentrations of Hg in Soil at Selected Locations at LEHR Site (Source: Weiss Assoc., 2008)

Area	Soil Depth: ≤ 2 ft			Soil Depth: >2 - 4 ft		
	No. Samples	Hg Concentration (mg/kg Hg)		No. Samples	Hg Concentration (mg/kg Hg)	
		Mean	SD		Mean	SD
Eastern Dog Pens	25	1.7	3.1	19	1.7	2.5
Western Dog Pens	163	1.1	0.92	28	1.1	1.1
Landfill No. 1	11	1.4	0.81	2	0.6	0.57
Landfill No. 2	11	0.5	0.29	5	0.93	0.69
Landfill No. 3	9*	1.1	0.8	1	0.75	n/a
Non OU Area	71	0.89	0.77	18	1.2	0.72
Old Davis Road Stormwater Runoff Ditch	5	0.8	0.59	0		

* One anomalous sample (49.5 mg/kg) excluded

These elevated surface soil mercury concentrations compared to soils below this level are likely due to the situation that from the mid 1800s until the mid 1940s and the completion of the Corps of Engineers Putah Creek project when high levees were constructed on Putah Creek Putah Creek used to flood the area lands near the channel. Further in 1957 with the completion of the Lake Berryessa Morrison Dam Putah Creek the downstream transport of mercury from the tailings piles from the abandon mercury mines located upstream of Lake Berryessa. Since the closure of the Lake Berryessa dam essentially all the upstream mercury derived from the mercury mines is trapped in Lake Berryessa.

This lake is estimated to have a hydraulic residence time (filling time) of about 5 to 10 years. This means that the particulate mercury which is the primary form of mercury

derived from the erosion of mercury mine tailings is settled out in the lake. At this time the source of mercury that is the source of mercury that is bioaccumulating to excessive levels in Putah Creek fish is mercury that was originally derived from the mines upstream of Lake Berryessa prior to the construction of the Lake that has accumulated in the Putah Creek stream sediments and banks as well as mercury that is added to the creek from runoff from the near creek areas.

Control of Mercury in Putah Creek Fish

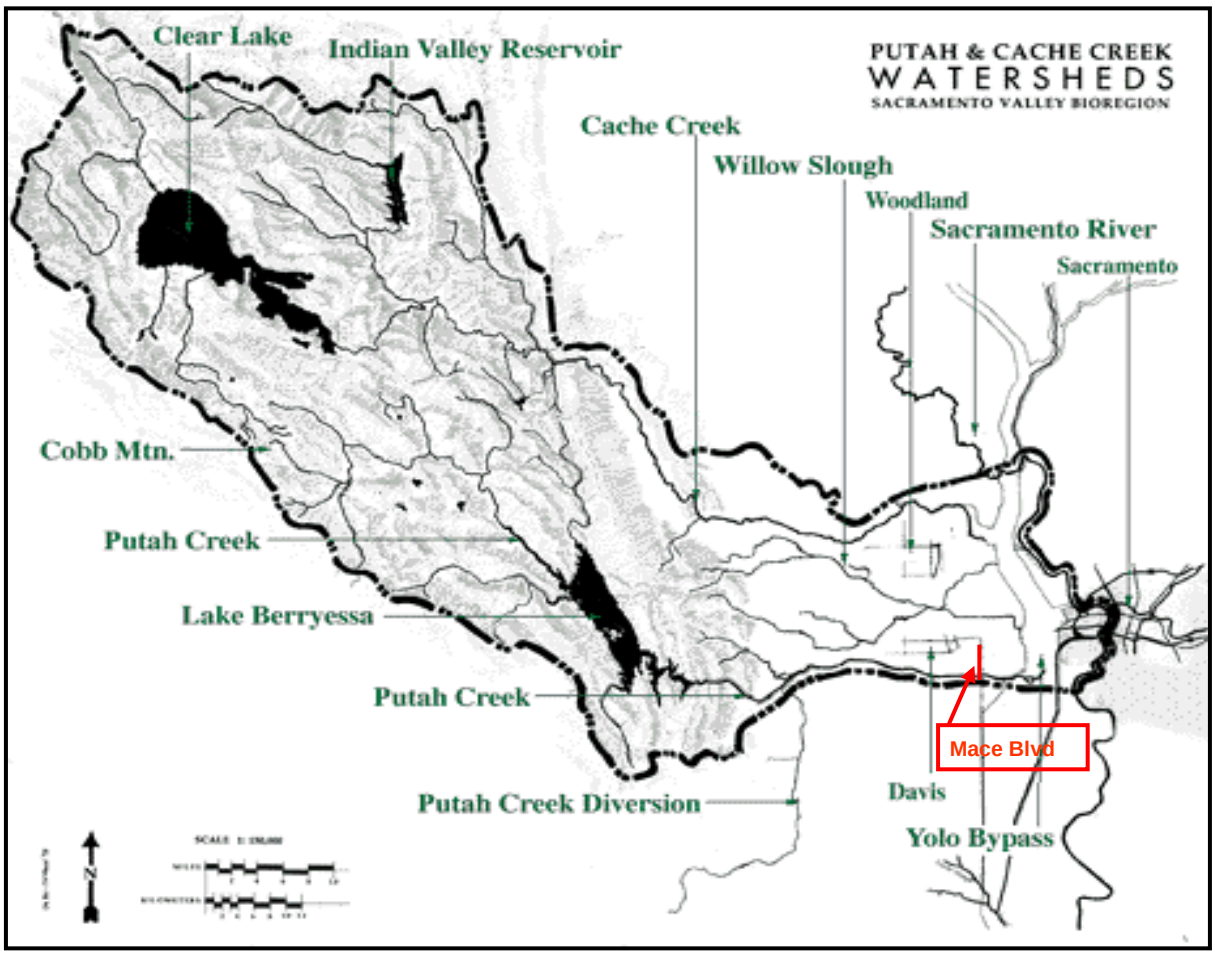
The CVRWQCB has scheduled a TMDL for mercury control for 2015. As part of implementing this TMDL it will be necessary to conduct studies to determine if these are location along Putah Creek that serve as a major current source of mercury for the current levels of total recoverable and methyl mercury in the Creek. Similarly studies need to be conducted of the surface soils along Putah Creek such as at LEHR and near LEHR and within the city of Davis that contribute mercury in stormwater runoff at concentrations above about 5 ng/L that enter Putah Creek. These studies could define hot spots that need attention for mercury control as part of implementing the TMDL.

Fate of Mercury in Putah Creek

An issue of concern is the fate of the mercury that is transported all the way down Putah Creek to the areas near the Yolo Bypass. The mercury data presented in Table 6 is based on samples collected at Mace blvd (see Figure 7).

Figure 7 Map of the Putah Creek and Cache Creek Watersheds Showing Location of Mace Blvd

Adapted from UCD Putah-Cache Bioregion Project: UCD Davis
http://bioregion.ucdavis.edu/where/featrmap.html



This location is located several miles upstream of where Putah Creek enters the Yolo Bypass. Between Mace blvd and the Yolo Bypass agricultural interests divert Putah Creek water to irrigate crops. Further according to Feliz (2008) during Putah Creek high flows, creek waters flood agricultural lands west of the Bypass. Both of these situations lead to mercury being deposited on agricultural lands. Some of this mercury is transported from the irrigated lands in the tail water discharges to the Yolo Bypass where it becomes part of the mercury load to the Yolo Bypass. The flow into parts of the Yolo Bypass is controlled by the Los Rios Check Dam. The DFG et al. (2008) discusses the influence of this check dam on Putah Creek flow into to the Yolo Bypass. Seasonally, this dam is operated to increase the elevation of Putah Creek to assist in irrigation water diversion of the Creek. During the fall/winter the boards that control the spillway elevation at the dam are removed to facilitate the migration of Chinook Salmon and Steelhead trout from the Bypass to upstream Putah Creek for spawning. When the boards are removed the flow to Putah Creek is via a channel to the Toe Drain. During the time that the boards are in place some of the Putah Creek water and its associated mercury in diverted into Bypass near the west side of the By Pass.

According to C. Foe (personal communication 2008) of the CVRWQCB has suggested that the development of settling basin to settle Putah Creek particulate mercury before it enters the Yolo Bypass. A major issue is the development of a funding and disposal of the mercury containing sediments from the settling basin.

Mercury TMDL Implementation

The implementation of the TMDL for controlling mercury in Putah Creek that is derived from stormwater runoff from the areas along Putah Creek that used to flood during the periods of high Putah Creek flows approach that is followed by the CVRWQCB in regulating stormwater runoff from NPDES regulated urban areas such as Davis, CA and from irrigated agriculture. Urban areas such as Davis are not required to monitor stormwater runoff and therefore are not required to control mercury discharges to Putah Creek in stormwater runoff. At the LEHR site the stormwater from the east (LEHR) side of Old Davis Road is regulated so that it cannot contain more than the CTR criterion for mercury. However the UCD property on the west side of Old Davis Road which has the same elevated mercury in surface soils as present at the LEHR site is not required by its Phase II NPDES stormwater permit does not have to monitor the stormwater runoff for any pollutants including mercury even though samples of this stormwater has been found to contain over 500 ng/L total recoverable mercury.

A similar situation exists for the regulation of mercury in tail water discharges and stormwater runoff from irrigated agriculture where the CVRWQCB does not require monitoring of the streams impacted by runoff/discharges from irrigated lands for mercury. Since many of the waters that are used by irrigated agriculture are polluted with mercury. The diverted water associated mercury makes irrigated agriculture tail water discharges/stormwater runoff a source of mercury. At this time there is no information on whether mercury that becomes associated with irrigated lands significantly impacts

how the mercury discharged from these lands impacts the impact of mercury on excessive bioaccumulation mercury in downstream of the discharge location. The change in the release pattern and transformation of mercury that occur on the agriculture lands need to be investigated to determine if additional mercury bioaccumulation problems occur because of the irrigated lands discharge of mercury.

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Acknowledgements

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