Mercury Contamination in the Yuba and Bear River Watersheds

A Report of the
South Yuba River Citizens League

by
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Humbug Creek – David Fallside
Summary of the Problem

Historic hydraulic mining and the use of mercury to remove gold through amalgamation has left the Bear and Yuba Rivers and watersheds with a legacy of eroding hillsides, mercury, and excess sediment. The USGS estimates that up to 8,000,000 of the 26,000,000 lbs used in the Sierra Nevada may have been “lost” during gold recovery. The mercury is present in the bottom (benthos) of rivers and reservoirs, as well as in pits, sluices, and tunnels remaining in abandoned mine lands (AMLs) from which it may be mobilized. It is transported by erosion and runoff as elemental mercury and in ionic form (e.g., Hg^{2+}), in dissolved form, adsorbed to particles, and as droplets of the metal. The mercury can be converted by microbial action into methylmercury, which can then be absorbed by microbes, plants, and animals. As methylmercury makes its way up the food chain (bioaccumulation) it is concentrated (biomagnification), so that in larger predatory fish (e.g., trout and bass) concentrations can exceed levels of concern for human consumption (>0.3 parts per million, ppm). There are very few areas (primarily within AMLs) where mercury concentrations in surface water are high enough to warrant concern for public health from consuming the water itself.

Studies by scientists at the University of California, Davis in the mid-90s and follow-up studies by US Geological Survey scientists in 1998-2000 have demonstrated that there are both “hotspots” of mercury contamination in AMLs and in downstream aquatic wildlife populations that have levels approaching and exceeding 1 ppm. Although concentrations of methylmercury in fish, amphibians, aquatic insects, and water are known for certain sites, the total amount of mercury (“load”) in the watersheds and rivers is not known and can currently only be guessed. In addition, it is unknown what populations within the Sierra Nevada and the Sacramento Valley could be affected and to what extent, due to consumption of mercury-labeled fish.

Mercury can cause a variety of health problems in humans, primarily neurological, including declining motor skills and sensory ability, tremors, inability to walk, convulsions, and death. The primary pathway for mercury poisoning in humans (and other animals) is through fish consumption and is a more serious problem for children due to their lower weight. Although there have been national surveys of mercury exposure through fish consumption, this information is not adequate for a local or regional analysis of mercury exposure for humans.

Human Health

Health Impacts from Mercury Exposure

Although elemental and inorganic mercury can cause health problems, methylmercury in fish is likely to be the primary cause of exposure in the Sierra Nevada and the Sacramento Valley. Assessing the risk of exposure and potential health effects depends upon knowledge of the exposed population, including age groupings, where fish are caught, what species of fish are caught, the methylmercury load in the fish by species, rate of fish consumption, and the individual’s body weight (EPA, 1996). Most of our knowledge about mercury poisoning from fish came from the epidemic of mercury-related health problems in Minamata Bay and Niigata, Japan in the 1950’s and 60’s. Thousands of people suffered temporary and permanent impairment of speech, hearing, vision, and motor coordination. In addition fetuses and infants were especially susceptible due to their low weight and need for rapid development. Methylmercury readily crosses the gastrointestinal lining, the blood-brain barrier, and the placental barrier. Because methylmercury is only slowly de-methylated in the body, it may accumulate with steady contaminated fish consumption, resulting in increasing exposure levels.
Monitoring Human Health

The primary studies that have been conducted of mercury exposure through fish consumption have been epidemiological studies to establish connections among methylmercury and fish consumption rates, body size and age, and mercury-related disease. The most well-known of these studies have been the Japanese mercury poisoning epidemics of the 1950’s and 60’s, the Iraqi epidemics (related to methylmercury contaminated grain) in the 1950’s and early 1970’s, the more recent and long-term studies of fish-consuming populations in the Seychelles and Faroe Islands, and smaller studies around the Great Lakes of the U.S. Although these studies result in reliable “reference doses” and “dose-response curves” (relationship between amount of mercury consumed and effect), they lack the precision that would come with site-specific studies for water bodies containing containing contaminated fish. Children and pregnant women that may be consuming certain fish species from a limited area known to be a problem are most in need of individual assessments of risk. This can often be accomplished by measuring the mercury concentrations in hair, which has been found to correlate well with actual exposure to mercury. The thresholds for concern ranges from 25 to 50 μg/gram of hair for the general population to 10 to 20 μg/gram of hair for pregnant mothers (World Health Organization). The maximum concentration in the U.S. by 1996 (date of the EPA study) was 15.6 μg/gram of hair for people who consumed wildlife in the Florida Everglades, a well-known mercury hot-spot.

How Much Methylmercury is “Too Much”

The new Environmental Protection Agency standard for mercury concentration in fish is 0.3 ppm. The load considered in 1996 by the EPA to be a “reference dose” (a methylmercury dose beneath which no adverse health effects were identified) is 100 nanograms of methylmercury per kilogram body-weight per day (EPA, 1996). In order to exceed this amount, a 50 kilogram (110 lb) person would have to eat more than 35 grams (>1 oz) of fish tissue per week from fish with a methylmercury concentration of 1 ppm, or more than 100 grams (>3 oz) of fish per week with 0.3 ppm methylmercury. One ppm is equivalent to 1 microgram methylmercury per gram of fish, the concentration found in some fish from several Yuba/Bear River reservoirs. As the reference dose is exceeded, risk of methylmercury-related health effects may increase, however, it depends upon various factors associated with consumption rate and body size. In addition, exceeding the reference dose does not necessarily mean that health impacts will be found. One comparison for the consumers of Yuba/Bear fish is a recommendation from the World Health Organization that populations that eat more than 100 grams per day of any commercial fish should be monitored for methylmercury poisoning. The average methylmercury concentrations for commercial fish and shellfish ranges from 0.02 ppm for clams to 0.2 ppm for tuna (EPA, 1996). The average fish consumption rates in the U.S. are 8 – 15 grams/day for the total population and 20 to 40 grams/day for anglers and Native Americans outside of Alaska.

Mercury and Methylmercury in the Yuba and Bear Rivers

How Much Methylmercury is in the Yuba/Bear Fish and other Aquatic Wildlife

The recent report by Charlie Alpers and co-workers (US Geological Survey) of mercury contamination in fish provided the most detail to date of the extent of the problem in the Yuba and Bear River water bodies (http://ca.water.usgs.gov/rep/ofr00367/ofr00367.pdf). Concentrations ranged from barely detectable to over 1 ppm mercury in fish tissue. Certain reservoirs stood out as having a
greater problem, with lower, warmer reservoirs seeming to predominate. The Environmental Protection Agency and the Office of Environmental Health Hazard Assessment (OEHHHA) standard for concentrations needing greater attention ("screening value") currently stands at 0.3 ppm. Most of the game fish tested and the waterbodies sampled fall above this threshold, suggesting that although there may be very hot spots, most of the Yuba and Bear systems should be considered worthy of attention. The Food and Drug Administration's (FDA) action level for regulating mercury in commercial fish is 1.0 mg/kg (1 ppm) wet weight of fish tissue.

The values found in the most recent and comprehensive survey of fish in the Yuba and Bear watershed meet and exceed the EPA/OEHHHA and the FDA levels in some cases and places:

1) Englebright Reservoir: all smallmouth and spotted bass that were >1 foot and >250 grams (1/2 lb) had levels >0.3 ppm
2) Scotts Flat Reservoir: most largemouth bass >1 foot and 500 grams (1 lb) had levels >0.3 ppm
3) Rollins Reservoir: most channel catfish and most largemouth bass >1 foot and >400 grams had levels >0.3 ppm
4) Lake Combie: all largemouth bass >1 foot and >400 grams had levels >0.7 ppm
5) Camp Far West: all spotted and largemouth bass and channel catfish >1 foot and >300 grams had levels >0.5 ppm, ½ of the spotted bass exceeded FDA action level of 1.0 ppm
6) Bear R. at Dog Bar Rd. and Little Deer Creek at Pioneer Park: ½ of brown trout sampled >10 inches and >200 grams had levels >0.3 ppm

The USGS has also measured the methylmercury concentrations in aquatic and terrestrial invertebrates, amphibians, and cliff swallow eggs. This survey was conducted in order to see how well the measured concentrations correlated with the fish data. It was also intended that this approach may lead to a rapid and broad assessment technique for prioritizing mine sites and streams for cleanup and monitoring action based on non-fish data. The aquatic insects sampled (dragonflies, stoneflies, hellgrammites, diving beetles, and giant waterbugs) had concentrations of methylmercury ranging from 0.01 ppm to 1.6 ppm for dragonfly larvae in Buckeye Flats (South Greenhorn Creek). The areas with the highest concentrations found in the different species were Boston pit and mine tunnel, Buckeye Flats (Greenhorn Creek), and Missouri Canyon. The foothill yellow-legged frogs, Pacific tree frogs, and bullfrogs had concentrations ranging from 0.23 ppm to 0.39 ppm, with the areas rating the highest being Missouri Canyon, Diggins Pond (Malakoff Diggins), and Polar Star mine tunnels.

The best conclusions to draw from this study are that a comprehensive understanding of fish consumption by humans and wildlife around these reservoirs is needed, that there should probably be monitoring of the mercury levels in people who eat a lot of fish from these waterbodies, and that a continuing surveying of mercury in fish and other biota is essential, especially in years where the precipitation and other environmental conditions are different from 1999, the year the samples were taken.

What are the Sources and Distribution of Mercury and Methylmercury in the Yuba/Bear

Mercury may originate from abandoned mine lands in the watersheds, from points where it has temporarily collected on its journey to the ocean, and from the atmosphere. The US Geological Survey and others are conducting measurements of the mercury and methylmercury in the biota, sediments, and water in reservoirs and near/within abandoned mine lands of the Yuba/Bear systems. There do not appear to be direct measurements of the atmospheric deposition of mercury. There also are few measurements taking place in the waters and sediments of the upper Bear and Yuba and their
tributaries. The extent of current knowledge is that the mercury is at minimum leaking gradually from abandoned mine tunnels, sluice boxes, and pits. Dredge tailings are also thought to be a potential hotspot, as is sediment disturbance during secondary mining near abandoned mine features, or in contaminated sediments. Mercury is also assumed to be slowly migrating downstream in the creeks and rivers, temporarily lodging in the benthic sediments and pockets in the channel bedrock.

There are frequent discussions about the way that mercury assessment and surveying should be conducted with limited resources. For example, infrequent sampling at many sites may say where mercury is originating, but not allow a “load determination”. The ideal appears to be that sampling should be at well-distributed sites to capture the “where” of mercury contamination and during and after storm events to capture the when and get a better sense of load. Monthly or other periodic sampling is important if the mercury is continuously moving through the system even without storm events. The Sacramento River Watershed Program has initiated a Mercury Monitoring Program which includes monitoring mercury at the tributary mouths (e.g., the Yuba River), but which does not extend far into the Yuba or Bear Rivers.

Gaps in Our Knowledge of the Problem

There are a huge variety of problem areas for understanding the extent of mercury contamination in the Sierra Nevada, the distribution of hotspots of contamination, the exposure rates of humans and fish-eating wildlife, the potential success for particular sites of available remediation and management techniques, and the various physical, chemical, and biological factors that influence the bioavailability of mercury. The following list is not all inclusive, but identifies some of the major areas where there are big enough gaps in knowledge to inhibit our understanding of the nature of the problem and possible ways to address it.

1) how mercury is transformed among its different forms in the environments of concern (creeks, rivers, and reservoirs), including the environmental factors that influence that transformation;
2) what the actual distribution and “load” of mercury is for any given waterbody;
3) how the mercury is partitioned among “compartments”, such as the benthic sediment, suspended sediments, biota, and in the water;
4) how mercury is moved the different compartments in #3;
5) what the likely impacts are from conducting the various remediation techniques available (e.g., tunnel closure, pit draining and filling, and local hydrology diversions);
6) what the exposure rates are for wildlife and humans consuming contaminated fish.

Fixing the Problem

Planning and Assessment Efforts to Date

Two overlapping planning groups have met periodically over the last several years to discuss mercury contamination in the Bear and Yuba (the Bear/Yuba/Trinity Abandoned Mine Lands group, AML group) and for all tributaries to the Bay and Delta (the Delta Tributaries Mercury Council, DTMC). Both groups are multi-agency (county, state, and federal) and to a limited extent include non-agency people. The Delta Tributaries Mercury Council went through an exercise in November the product of which is worth looking at here. The Council spent an hour in break-out groups strategizing around the basic question of what knowledge is needed (regardless of how much it might cost) and how to get it for understanding mercury contamination and remediation. The notes from that meeting are attached to the end of this report (“DTMC Appendix”). The Sacramento River Watershed Program also tracks mercury pollution in the Sacramento River and tributaries and has developed assessment
and management models. In terms of the Sierra Nevada, studies by Darrell Slutton (UC Davis) and co-workers in the mid-90s and Charlie Alpers (USGS) and co-workers more recently have provided much of the substance for the discussion groups. The CALFED Bay-Delta program, the State Water Resources Control Board, and other programs targeting water quality problems have provided ad hoc leadership and funding for assessing the nature of the mercury contamination problem. Technical reports from these studies provide monitoring data for the particular places, species, and time frames chosen. However, as noted above, there has not been a comprehensive assessment of the extent, sources, and fates of the mercury for any of these basins.

Mitigation and Clean-up Trials

The most recent attempt at abandoned mine land treatment was at Polar Star Mine in the Bear River watershed. The US-EPA spent >$1.5 million to remove mercury contaminated sediment from abandoned sluice box tunnels on the site. The stated reason for the clean up action by the EPA was to responsibly remove the mercury before someone else removed it in a way that threatened human health. Removal of a potential source of methylmercury was considered a secondary environmental benefit (Jones, 2001). The EPA chose removal of mercury-contaminated sediment in the tunnel as preferable to gating the tunnel and routing water through it so that it did not contact the sediment. The removal action itself required access road improvements, decontamination of rocks removed from the tunnel, screening and size separation of removed sediment, leveling of the tunnel floor, and shipping of mercury-contaminated material to Oklahoma and Idaho.

There were mixed reports as to the effectiveness of the strategy chosen and EPA has claimed in meetings to be adapting to lessons learned. The site was successfully cleaned up as planned at the amount budgeted. The EPA considers the following to be lessons from the project: 1) site disturbance during clean up should be minimized so as to not make matters worse; 2) a site reclamation plan should be prepared prior to project initiation; 3) if gold or mercury recovery is expected, then advance sampling should take place to determine optimum sediment processing equipment and the amounts of the metals present; 4) measuring mercury contamination concentrations will also allow calculation of disposal costs; 5) choice of contractor must be based on a realistic analysis of the permits, planning, and other actions required; 6) sumps and other mechanisms for modifying local hydrology must be maintained and designed to withstand 100 year flood events; 7) post-cleanup monitoring should be conducted to assess the changes in mercury movement within and from the site. The site cleanup was complicated by the desire of the landowner for part of the area wanting to log during the project. The EPA was challenged during this complication to show how their action was less disturbing than a timber harvest plan. Ultimately, the project was successful at removing 200 lbs of elemental mercury and 2000 lbs of highly-contaminated sediment, as well as serving as an example for future cleanup projects.

At meetings of the Abandoned Mine Lands group, Buckeye Flats (which is on private and USFS lands), near Greenhorn Creek in the Bear River watershed appears to be next up for this treatment.

Nevada County has also joined with SWRCB and the USFS in requesting that county residents bring mercury they may have to a central location on special collection days. Over two hundred pounds of mercury was recovered in this fashion on two separate days at a cost of over $1,000. Because this approach will eventually reach the end of casually-available mercury (e.g., from peoples’ garages), it has limited impact on the problem. Similar outreach is being attempted to recreational dredge miners in order to encourage them to collect mercury they observe or recover incidental to their operations. This method has slightly greater potential to recover mercury from the rivers and streams where it is, presumably, continuously being re-supplied from surrounding AML lands and tunnels.

Immediate and Medium-Term Research and Management Needs
Staffing

One obvious feature of the policy landscape is that all of the concerned parties are undergoing a rapid education process and are developing management and other strategies in a somewhat ad hoc fashion. There is an immediate need for decision-support for both the research and monitoring funding and for clean-up and management strategies. Dedicated staff for this role are needed who are not also the researchers or regulatory agents. The county could play this role, or some state or federal body that is charged with technical support for pollution control. Another role for such staff would be public education and outreach to assist in public health surveys, mercury reclamation/collection, education about health impacts of mercury, and identification of populations in need of additional attention (e.g., subsistence fishers).

Research needs

Discussions with key scientists in mercury research and management (both casually and at meetings of the Yuba/Bear/Trinity AML group and the DTMC) and reading of available technical reports suggest the following are funding needs for research to support long-term mitigation and restoration decision-making: 1) better understanding of the process of methylation and de-methylation of mercury under various realistic biological, chemical, and physical regimes; 2) measurements of river and reservoirs mercury loads in order to understand the distribution of mercury contamination of sediments and water; 3) measurements of the association of mercury and methylmercury with particular features of river and reservoir water/sediment (e.g., suspended particles); 4) determination of potential contributions of land-use/development and atmospheric deposition to river loads; and 5) monitoring of pilot clean-up and mitigation efforts in order to understand their beneficial and harmful impacts.

1) **Methylation and de-methylation** Although the possible pathways of the chemical conversion of mercury are well-known for certain environments, the actual pathways in situ (e.g., in the reservoir) are unknown for many of the Yuba/Bear system’s waterbodies and sediments. For example, sulfate-reducing bacteria are known to methylate mercury, but they are not the only mediators of this reaction and are dependent on certain environmental conditions in order to thrive and survive. Knowing the actual pathways for mercury (de)methylation and the rates of reaction under ambient environmental conditions is critical in evaluating the transformation of mercury in the river and reservoir system and modeling the likely impacts of restoration and management actions.

2) **Mercury load in the watershed** There have been several assessments of mercury contamination “hotspots” in the Yuba and Bear, primarily in or near abandoned mine lands. There have also been spot measurements (as opposed to long-term monitoring) of mercury in aquatic invertebrates, fish, and amphibians in creeks and reservoirs in the system. There has not been a survey of the mercury “load” in the entire system, composed of measurements of mercury and methylmercury in the water, sediments, and biotic components. We therefore cannot say what the total mercury is in the watershed at any given time. Nor do we know how it is moving and being stored throughout the watershed. Understanding the total amount of mercury in its various states and its bulk movement through the hydraulic system is critical to prioritizing actions and areas to focus limited resources. Methylmercury contamination in insects and fish serve as a surrogate for methylmercury availability within the life span of these organisms, but may not indicate the actual loads in reservoir sediments, for example.

3) **Association of mercury with other elements/features in the water** Mercury in its various chemical forms may associate preferentially with fine particles suspended in the water or in benthic sediments. This association has ramifications for bacterial activity and bulk movement of mercury through a river system. Bacteria often adhere to particles and anything associate with fine particles will move according to the flow regime over the benthic sediments. It is important to know what
proportion of mercury and methylmercury is associated with various sediment size classes, as well as how much these sediments are disturbed by actual and potential flow regimes in the Yuba/Bear systems. This information will aid in determining the fine-scale distribution and potential movement of mercury.

4) Contributing factors to mercury contamination  Atmospheric deposition of mercury can be a significant source of mercury in certain regions. There have been measurements of mercury deposition downwind of the Bay Area showing deposition rates higher than other areas in Northern California. Urban centers are a potentially significant source of mercury due to incinerators, automobiles, and poor emission controls. This mercury could be considered the background level, however, its actual contribution to current mercury contamination is unknown and may be worth measuring. Land-use near abandoned mine lands and within the affected watersheds (Yuba/Bear) can impact the distribution of mercury, its chemical transformation, and growth of mercury-methylating bacteria. Most human land-use results in impacts on hydrology, nutrient cycles, or sediment contributions to streams and rivers. Because these processes all influence mercury distribution and transformation, assessing their potential or actual impacts is an important part of managing and cleaning up mercury-contaminated landscapes and river systems. This could be accomplished through a GIS that included potential and actual land-use/development maps, topography and hydrology, and other natural resource information.

5) Monitoring clean-up/restoration actions  Abandoned mine lands are currently being targeted for pilot restoration projects aimed at removing mercury and mercury-contaminated sediments and modifying local hydrology to reduce flow of mercury into local creeks. The value of the actions is unknown without careful assessment of the condition before action, monitoring during water and ground disturbance, and long-term follow-up monitoring of soils, biota, and water. Without this monitoring the action loses its values as a local clean-up effort as well serving as an experiment to increase understanding of how to conduct these actions.

County programs

Additional funding should be sought to meet county needs for mitigation and management of mercury contamination, as well as decision-support for land-use/development in areas that are known to be contaminated. The California Department of Conservation has entered into an agreement with Nevada County to provide such support through a DOC staff person tasked with supporting the county’s approach to mercury contamination in land, water, and biota. Nevada County has partnered with state and federal agencies in collecting mercury from residents on Hazardous Waste pick up days and at relatively central drop-off points. Programs that support receiving newly-collected or recycled mercury by affected counties should be encouraged and specifically funded. Recreational and small-scale gold-miners have been identified by the AML group as a community that could both assist in collecting mercury from stream and river bed gravels and be a target of regulatory action if they are disturbing or returning mercury to the river through their operations. Continuing education of river miners through mailings attached to California Department of Fish and Game permits and other devices could aid in collecting mercury directly from the river and stream bed gravels.

Monitoring human health

One common theme in the mercury literature and in discussions within the Delta Tributaries Mercury Council and the AML group is the need for testing of methylmercury and mercury levels in human populations that are likely to be exposed to these toxicants, primarily through fish consumption. This could be approached through a combined public education and hair testing programs. Rigorous design of the sampling regime and parallel analysis of fish consumption rates could make this a region-specific epidemiological study. Alternatively, mercury testing in hair could be carried out as a voluntary program where a public health agency is funded to take hair samples and submit them for analysis during routine health exams. This would allow follow-up with individuals
found to be at risk of exposure and mercury-related disease. An important component of this would an interview/questionnaire process that addressed fish consumption.

**Monitoring Wildlife and Fish Health**

One idea that tends to get left out of discussions about mercury contamination in fish is the potential impact on fish-eating animals, primarily hawks and eagles. Exposure of wildlife to mercury in fish can be a much more serious event because certain animals may rely primarily on fish as a source of food, as opposed to humans who consume a much lower proportion of their total diet as fish. Wildlife will suffer neurological damage from mercury exposure, with the relevant dose likely being size and species-dependent. Discussions at the Delta Tributaries Mercury Council and the EPA report (1996) lead to the recommendation that there needs to be a comprehensive study of mercury exposure for hawks and eagles, and mammals such as otters. This could require fairly specialized sampling techniques (trapping the animals), unless there are surrogate measures (e.g., use of feathers or hairs) that would allow sampling. The fish consumption rates could be estimated from published literature, but the concentrations in particular areas for particular fish sizes would have to be known. Thus, by running such a study in parallel with ongoing or proposed measurements of mercury in fish for human consumption concerns, the same fish data could be used to estimate both human and wildlife exposure rates.

**Bibliography and Online Resources**


Mercury sources in the Sacramento River watershed (technical report to the Sacramento River Watershed Program, 1/2000).

The historic use of mercury for gold mining in the Yuba River watershed (H. Meals, unpublished report).


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

http://www.ice.ucdavis.edu/Hg/default.htm (Delta Tributaries Mercury Council)

http://www.epa.gov/ncea/methmerc.htm (EPA reference dose for Methylmercury, 10/00)
http://www.epa.gov/watertscience/criteria/methylmercury/ (EPA Water quality criteria for methylmercury, 12/00)
http://www.epa.gov/ost/fishadvice/ (EPA Fact sheet on mercury in fish consumption advisory for women and children, 1/01)
http://www.epa.gov/mercury/fish.htm (EPA Fish Advisories, 12/00)
Some terms and explanations

“Load” refers to the total amount of something in the river or reservoir. For example, the sediment load would include the bed sediment and suspended sediment (unless the term “bed load” was used in reference only to bed sediment). Determining load is a critical feature in understanding the benefits of potential clean-up and mitigation actions, as well as understanding the impacts of actions where the load may be disturbed.

“Concentration” refers to the load per unit volume, for example, 1 microgram of mercury per liter of water. Thus if you know the concentration of something and the continuously or periodically measured river volume per unit time (cubic feet per second) you could calculate the load per unit time of the something in the river. Concentration is also expressed per unit mass in organisms, as in “parts per million” (ppm). One ppm of mercury in fish tissue would be equivalent to one microgram of mercury per gram of fish tissue.

Mercury can occur in a variety of forms in river systems. Uncharged or elemental mercury can be dissolved, adsorbed to particles, or in the characteristic silvery droplets of “quicksilver”. Charged mercury, Hg\(^{2+}\), can occur in compounds such as mercury chloride or hydroxide, which are relatively reactive. “Inert” mercury, such as cinnabar, refers to mercury involved in compounds that are relatively un-reactive. Methylmercury chloride and mercury chloride are the most available for uptake by microbial life, such as phytoplankton. Chloride concentration, pH, sulfate/sulfide concentration, redox conditions, suspended solid concentration, and the presence of sulfate-reducing bacteria are all important in determining what form(s) of mercury will be present as well as the opportunities for methylation of mercury. Suspended particles are a particularly good site for bacterial conversion of mercury to methylmercury.
“Atmospheric deposition” of mercury occurs constantly throughout the world, with varying amounts deposited depending on weather, proximity to sources of airborne mercury, and other factors. The technical report “Mercury Sources in the Sacramento River Watershed” cited above includes the estimate of 720 kg/yr of mercury deposited in that watershed. It is unknown how much actually is deposited and what the fate of the mercury is (i.e., whether it ends up in the river or not). This may be an issue for watersheds downwind of the Bay Area, which has the highest airborne mercury concentrations in Northern/Central California.

It is not a trivial task to determine the rates of and conditions for mercury methylation and the interaction of mercury and methylmercury with naturally-occurring features of rivers and reservoirs (water, biota, and sediment). Without this knowledge, it will be difficult to determine prioritization of clean-up or potential impacts of management actions. There is probably sufficient knowledge to proceed with tunnel and sluicebox cleanup activities, but benthic sediments in reservoirs and sediment-borne and dissolved mercury in rivers will need more study before clean-up action should be considered.

**DTMC Appendix**

**DTMC STRATEGIC PLANNING**

In response to the strategic planning discussion at the last DTMC meeting the group planned to dedicate a major portion of the meeting to strategic planning. The primary goal was to establish a plan for mercury management that would guide the group and help to establish priorities. The plan and resulting priorities would not be tied directly to any one project or budget, but would be integrated with all that were relevant. For example, the results of the planning would help to shape feedback to the SRWP on their next phase of planning and budgeting. After a detailed discussion of the direction, the group agreed to use its existing objectives as the framework for its planning. They agreed to break into two subgroups to flush out the details of four of the objectives:

- Group one
  1. Develop Goals and Targets
  2. Develop Models

- Group Two
  3. Identify Sources, Fate and Impact
  4. Identify Control Measures

The results from the breakout groups are outlined as tasks for each objective as follows:

**Goals and Targets**

1) Problem definition (DTMC responsibility)
   - Historical knowledge of solutions/successes
   - Identify data gaps
   - Identify exposure population
   - Monitor humans, fish
2) Educating public/private parties (DTMC responsibility)
more public health personnel/education
3) Develop programs and identify sources/players and answers (DTMC responsibility)
   i.e. agriculture, BLM, Forest Service, environmental groups, gravel operators,
   suction dredgers, OEHHA, planners
4) Fund
5) Risk appraisal

Modeling

1) Link tools to reach goals (GIS) land, stream bed use, alteration
2) Test strategic controls plan, alternatives, success of goals.
3) Identify critical paths and how to interfere successfully. (DTMC responsibility)
4) Everyday exposure (included in model), air, industry, ambient occurrence. (DTMC
   responsibility)
5) Data collection and input
   validate data
   synthesis
   data gap identification
6) bring model/chart/graphic/poster to every meeting to record where we have gone and
   where we are going. (DTMC responsibility)
7) build model

“Identify Sources Fate and Transport” was divided as follows:

Impact Issues

Human Health:
   1. What are the Hg levels in fish tissue?
   2. Who eats what?
      a. Are there routes of human exposure?
   3. What are Hg levels in people?
   4. Is the reference (USEPA) appropriate?

Wildlife:
   1. What are the appropriate wildlife indices of impact?
   2. How do you measure these impacts?

Pathways + Transformations
   1. Rates of methylation/demethylation.
   2. Where are these occurring?
   3. What factors control methylation/demethylation rates?
   4. Biotic/Abiotic factors influence all three above.
   5. What are the region specific pathways of uptake?

Distribution + Sources
   1. How are the forms of Hg distributed in air, water, sediment and terrestrial?
   2. Identify natural and anthropogenic sources.
3. What is the relative significance of the different forms of Hg and how do they transform from one to another?
4. What are the chemical/physical processes that release Hg to the environment?
5. What sources are most important in causing effects?
6. What processes are most important?
7. Which sources and processes are most susceptible to modification?

Steps
- Identify relevant/necessary pieces
- Categorize
- Identify what is already going on
- Timing, sequencing scheduling
- Identify Gaps
- Identify budget needs
- Evaluating/reviewing effectiveness
- Use logic, strategy to integrate
- Framework
Mercury Contamination in the Yuba and Bear River Watersheds

South Yuba River Citizen’s League

Nature and Extent of the Problem

Historic hydraulic mining and the use of mercury to remove gold through amalgamation has left the Bear and Yuba Rivers and watersheds with a legacy of eroding hillsides, mercury, and excess sediment. The USGS estimates that up to 8,000,000 of the 26,000,000 lbs used in the Sierra Nevada may have been “lost” during gold recovery. The mercury is present in the bottom (benthos) of rivers and reservoirs, as well as in pits, sluices, and tunnels remaining in abandoned mine lands (AMLs). It is transported by erosion and runoff as elemental mercury and in ionic form (e.g., Hg\(^2\)) in dissolved form, adsorbed to particles, and as droplets of the metal. The mercury can be converted by microbial action into methyl-mercury, which can then be absorbed by microbes, plants, and animals. As methyl-mercury makes its way up the food chain (bioaccumulation) it is concentrated (biomagnification), so that in larger predatory fish (e.g., trout and bass) concentrations can reach levels of concern for human consumption (>1 parts per million, ppm). There are very few areas (primarily within AMLs) where mercury concentrations in surface water are high enough to warrant concern for public health.

Studies by scientists at the University of California, Davis in the mid-90s and follow-up studies by US Geological Survey scientists in 1998-2000 have demonstrated that there are both “hotspots” of mercury contamination in AMLs and in downstream aquatic wildlife populations that have levels approaching and exceeding 1 ppm. Although concentrations in fish, amphibians, aquatic insects, and water are known for certain sites, the total amount of mercury (“load”) in the watersheds and rivers is not known and can currently only be guessed.

Planning and Assessment Efforts to Date

Two overlapping planning groups have met periodically over the last several years to discuss mercury contamination in the Bear and Yuba (the Bear/Yuba/Trinity Abandoned Mine Lands group) and for all tributaries to the Bay and Delta (the Delta Tributaries Mercury Council). Both groups are multi-agency (county, state, and federal) and to a limited extent include non-agency people. The Sacramento River Watershed Program also tracks mercury pollution in the Sacramento River and tributaries and has developed assessment and management models. In terms of the Sierra Nevada, studies by Darrell Slotton (UC Davis) and co-workers in the mid-90s and Charlie Alpers (USGS) and co-workers more recently have provided much of the substance for the discussion groups. The CALFED Bay-Delta program, the State Water Resources Control Board, and other programs targeting water quality problems have provided ad hoc leadership and funding for assessing the nature of the mercury contamination problem. Technical reports from these studies provide monitoring data for the particular places, species, and time frames chosen. However, as noted above, there has not been a comprehensive assessment of the extent, sources, and fates of the mercury for any of these basins.

Mitigation and Clean-up Trials

The most recent attempt at AML treatment was at Polar Star Mine in the Bear River watershed. The US-EPA spent >$1 million to remove mercury contaminated sediment from tunnels and sluice boxes on the site. There were mixed reports as to the effectiveness of the strategy chosen and EPA has claimed in meetings to be adapting to lessons learned. Buckeye Flats (which is on private and USFS lands), near Greenhorn Creek in the Bear River watershed appears to be next up for this treatment.
Nevada County has also joined with SWRCB and the USFS in requesting that county residents bring mercury they may have to a central location on special collection days. Over two hundred pounds of mercury was recovered in this fashion on two separate days at a cost of over $1,000. Because this approach will eventually reach the end of casually-available mercury (e.g., from peoples’ garages), it has limited impact on the problem. Similar outreach is being attempted to recreational dredge miners in order to encourage them to collect mercury they observe or recover incidental to their operations. This method has slightly greater potential to recover mercury from the rivers and streams where it is, presumably, continuously being re-supplied from surrounding AML lands and tunnels.

**Immediate and Medium-Term Needs**

One obvious feature of the policy landscape is that all of the concerned parties are undergoing a rapid education process and are developing management and other strategies in a somewhat *ad hoc* fashion. There is an immediate need for decision-support for both the research and monitoring funding and for clean-up and management strategies. Dedicated staff for this role are needed who are not also the researchers or regulatory agents. The county could play this role, or some state or federal body that is charged with technical support for pollution control.

Discussions with key scientists in mercury research and management (both casually and at meetings of the Yuba/Bear/Trinity AML group and the DTMC) and reading of available technical reports suggest the following are funding needs for research to support long-term mitigation and restoration decision-making: 1) better understanding of the process of methylation and de-methylation of mercury under various realistic biological, chemical, and physical regimes; 2) measurements of river and reservoirs mercury loads in order to understand the distribution of mercury contamination of sediments and water; 3) measurements of the association of mercury and methyl-mercury with particular features of river and reservoir water/sediment (e.g., suspended particles); 4) determination of potential contributions of land-use/development and atmospheric deposition to river loads; and 5) monitoring of pilot clean-up and mitigation efforts in order to understand their beneficial and harmful impacts.

Additional funding should be sought to meet county needs for mitigation and management of mercury contamination, as well as decision-support for land-use/development in areas that are known to be contaminated. Continuing education of river miners and receiving newly-collected or recycled mercury by the affected counties should be encouraged and specifically funded.

**Bibliography and Online Resources**

- The historic use of mercury for gold mining in the Yuba River watershed (H. Meads, unpublished report).

http://minerals.usgs.gov/mercury/index.html (links to USGS and other mercury studies and research)
http://www.epa.gov/oar/mercury.html (EPA, Mercury Study Report to Congress, 12/97)
Some terms and explanations

“Load” refers to the total amount of something in the river or reservoir. For example, the sediment load would include the bed sediment and suspended sediment (unless the term “bed load” was used in reference only to bed sediment). Determining load is a critical feature in understanding the benefits of potential clean-up and mitigation actions, as well as understanding the impacts of actions where the load may be disturbed.

“Concentration” refers to the load per unit volume, for example, 1 microgram of mercury per liter of water. Thus if you know the concentration of something and the continuously or periodically measured river volume per unit time (cubic feet per second) you could calculate the load per unit time of the something in the river. Concentration is also expressed per unit mass in organisms, as in “parts per million” (ppm). One ppm of mercury in fish tissue would be equivalent to one microgram of mercury per gram of fish tissue.

Mercury can occur in a variety of forms in river systems. Uncharged or elemental mercury can be dissolved, adsorbed to particles, or in the characteristic silvery droplets of “quicksilver”. Charged mercury, Hg^{2+}, can occur in compounds such as mercury chloride or hydroxide, which are relatively reactive. “Inert” mercury, such as cinnabar, refers to mercury involved in compounds that are relatively un-reactive. Methyl-mercury chloride and mercury chloride are the most available for uptake by microbial life, such as phytoplankton. Chloride concentration, pH, sulfate/sulfide concentration, redox conditions, suspended solid concentration, and the presence of sulfate-reducing bacteria are all important in determining what form(s) of mercury will be present as well as the opportunities for methylation of mercury. Suspended particles are a particularly good site for bacterial conversion of mercury to methyl-mercury.

“Atmospheric deposition” of mercury occurs constantly throughout the world, with varying amounts deposited depending on weather, proximity to sources of airborne mercury, and other factors. The technical report “Mercury Sources in the Sacramento River Watershed” cited above includes the estimate of 720 kg/yr of mercury deposited in that watershed. It is unknown how much actually is deposited and what the fate of the mercury is (i.e., whether it ends up in the river or not). This may be an issue for watersheds downwind of the Bay Area, which has the highest airborne mercury concentrations in Northern/Central California.

It is not a trivial task to determine the rates of and conditions for mercury methylation and the interaction of mercury and methylmercury with naturally-occurring features of rivers and reservoirs (water, biota, and sediment). Without this knowledge, it will be difficult to determine prioritization of clean-up or potential impacts of management actions. There is probably sufficient knowledge to proceed with tunnel and sluicebox cleanup activities, but benthic sediments in reservoirs and sediment-borne and dissolved mercury in rivers will need more study before clean-up action should be considered.
Proposed Mercury Strategy for SYRCL
Fraser Shilling, April 2, 2001

The following summarizes short and long term actions that can be taken to understand and remediate mercury contamination in the Bear and Yuba basins. For more detailed information refer to the report of 2/15/01 to SYRCL.

Research
Short-term There is immediate need for critical information on mercury distribution (sediment, water column, reservoirs, rivers, land, fish) and transformation (methylation and de-methylation). This information will inform decisions about specific areas and techniques for mercury cleanup.
SYRCL’s role: Advocate for increased and consistent mercury research funds from state and federal sources
Actions: Develop “white paper” showing support for specific actions that justifies and describes particular research needs. Use 2/15/01 report as basis.

Long-term Two important areas are 1) the long time-frame mass balance and movements of mercury through the whole river system and 2) the effectiveness of any attempt at cleanup of mercury in the system.
SYRCL’s role: Advocate for long-term programs and play an integral role in the actual monitoring side of the research
Actions: As part of the overall design of the “Yuba River Monitoring Program”, design a module that deals explicitly with mercury in sediment/water/biota. Apply for grants to support this from Calfed/Prop 13 over next year or so.

Planning
Short-term Local agencies needing to assess mercury contamination or plan remediation efforts require access to sufficient information to make good decisions. Local expertise in relevant technical skills is minimal and should be enhanced.
SYRCL’s role: Advocate for state resources to support local capacity building as well as supplying some of that expertise
Actions: Apply for grants that accomplish this goal, specifically from Calfed’s money earmarked for abandoned mine lands reclamation/cleanup. Consider approaching state legislature with suggestion that agencies make their local staff available for this too.

Long-term There is currently no programmatic approach to mercury contamination of fish, lands, rivers, or reservoirs in the Bear/Yuba. Such a program could serve as the organizing principle for research, remediation, monitoring, and public education.
SYRCL’s role: work with the county and other local agencies and organizations to establish such a program
Actions: Proactively develop an MOU or equivalent among agencies and SYRCL dealing explicitly with coordinated mercury/AML cleanup planning and funding.
Remediation & Monitoring

Short-term Planning and implementation of the pilot cleanup efforts in the watersheds (e.g., Polar Star Mine tunnel) has recently begun. USFS is focusing currently on Sailor Flat in the Yuba basin and is in the planning phase for a cleanup project.

SYRCL's role/actions: Immediately become involved in the planning of these projects, beginning with Sailor Flat. Advocate for a systematic approach to the cleanup, meaning focus on the ones with greatest impact first. Refine YR monitoring program so that a push to do the post-project monitoring is supported by an obvious ability to do the work.

Actions: Meet/talk with Steve Eubanks or Rick Weaver (TNF) to discuss SYRCL's involvement.

Long-term Major cleanup projects may be best left in the hands of large agencies, however, there needs to be clear evidence for conducting the projects, expending the funds, etc. Effectiveness monitoring should be part of or added on to every cleanup project, which is not always the case (e.g., Polar Star Mine). This monitoring should be done over years to decades, depending on the nature of the problem.

SYRCL's role: compose clear justification for particular cleanup and remediation strategies. Create within SYRCL a clear programmatic approach toward effectiveness monitoring.

Public Health

Short-term It is not clear currently who is potentially or actually affected by high mercury levels in fish caught and consumed in the Bear/Yuba reservoirs. Research is needed to determine the affected populations, measure their mercury levels (e.g., from hair clippings) and ensure that they are sufficiently informed. It should be recognized that the Bay-Delta is a potential recipient of the mercury originating from the Bear/Yuba.

SYRCL's role: advocate for a detailed analysis of the risk of exposure of people who fish within the Bear/Yuba and other affected waterbodies.

Actions: Join the County in introducing legislation or writing grants to conduct a “risk of exposure” study for the County and relevant surrounding area.

Long-term At some point a determination will have to be made as to the extent and nature of risk of mercury exposure to people in the watersheds. This will inform the strategy that should be taken to limit this risk.

SYRCL's role: ensure that the risk studies that are conducted are detailed enough to support long-term decisions about consumption rates of fish, flows, and presence of dams.

Policy

Short-term Current “policy” development is ad hoc and largely based on limited knowledge of mercury distribution, movement, fate, and risk to human health. Local policy is to understand the problem to support decisions about cleanup and fish advisories. Regional policy is similar, with the difference being that the valleys aren’t so much the source of the mercury as the repository and the place where methylation occurs more readily.
SYRCL's role: advocate for state and county policies and management guidelines that maximize information gathering and minimize potential sources of risk (e.g., maintain fish advisories and limit contaminated land disturbance). Assist in fund authorization and regulatory policy language.
Actions: Develop a policy “white paper” laying out SYRCL’s position and desired or anticipated role in mercury research and clean-up Use as foundation for leg language development.

Long-term Once the long-term risk to human and wildlife health is determined and the extent of the contamination better understood, policy will be needed that appropriately supports any remediation and other actions needed.
SYRCL's role: same as short-term

Public Education
Short-term There is evidence for mercury contamination of fish in Bear/Yuba waterbodies that exceeds federal and state standards. Without knowledge of the actual fish consumption from these waterbodies, the best approach is to caution against too much consumption. Public forums and workshops, brochures, and radio spots should be used to convey summaries of the information about mercury contamination.
SYRCL's role: design or co-design the informational literature etc. that conveys the essential information (including the unknowns) about the extent of fish contamination.
Actions: Develop brochure and workshop for this summer or fall highlighting issues, using Prop 204 funding. Coordinate with RCD who has funding to do same, needs organizing help, and has been approached by Rick Humphrey of SWRCB already.

Long-term The public in the Bear/Yuba and Nevada County have limited resources to rely on to learn about potential and actual mercury impacts to their health. A “center of information” (virtual or physical) is always a valuable and appreciated service to the public, especially if it is designed in a way to make it physically and intellectually accessible. The importance of such a center varies in direct proportion to the level of the “crisis”, so decisions about developing these resources should be based on knowledge of the extent and nature of mercury contamination in the watersheds.
SYRCL's role: consider developing a long-term mercury resource presence through a physical center, resource materials, web site, column in the newsletters, etc. This could be stand-alone or in collaboration with the county, USFS, and/or RCD.
Actions: Ask potential interested users of such information to describe what kind of information they would want to have and in what form.
>X-From_: Jeff.Shellito@sen.ca.gov  Mon May 14 12:19:36 2001
>Date: Mon, 14 May 2001 12:18:10 -0700
>From: "Shellito, Jeff" <Jeff.Shellito@sen.ca.gov>
>Subject: mercury story in Ventura newspaper
>To: "izzy@oro.net" <izzy@oro.net>
>MIME-version: 1.0
>
>Ventura County Star
>
>To print this page, select File then Print from your browser
>URL: http://www.insidevc.com/vcs/news/article/0,1375,VCS_121_465450,00.html
>
>
>Gold Rush leaves state toxic legacy
>
>IN SIERRA NEVADA: Mercury made miners’ work easier, now it poisons water, fish.
>
>By John Krist, Senior reporter
>
>NEVADA CITY -- Nevada County Supervisor Elizabeth Martin vividly recalls the day she learned her rural district was at the epicenter of California’s most widespread industrial pollution problem.
>
>She was attending a meeting of the Regional Council of Rural Counties, or RCRC, at which scientists from the U.S. Geological Survey had asked to speak. The researchers had information they thought might be of interest to some of the RCRC’s members, who represent mostly small, politically conservative communities scattered across the Sierra Nevada and its foothills, the high desert and the Klamath-Trinity region.
>
The scientists had been looking for mercury-contaminated fish. They knew the toxic element could be found nearly everywhere gold mining had been conducted in the 19th century. They knew that in streams and lakes it could be transformed into methylmercury, a form that accumulates in living tissue, can be passed up the food chain and is a neurotoxin capable of causing brain damage. They also knew that mercury was traveling downstream to pollute water near distant urban areas, such as San Francisco Bay.
>What they wanted to know was how bad the upstream contamination really was and how difficult it might be to clean it up.
>
>To find out, the researchers traveled to the heart of Gold Rush country, to the place where miners chewed up more countryside and spilled more mercury than anywhere else in California.
The news was not good, they told the RCRC members. Many of the fish the researchers tested in 1999 were contaminated enough to be potentially unsafe for children and pregnant women to eat. They illustrated their presentation with a map of the potential danger area, the watersheds of the South Yuba River, Deer Creek and the Bear River.

Essentially, it was a map of Nevada County Supervisorial District 4.

Martin's district.

"They showed their PowerPoint presentation, and the first thing that went up was (a slide of) the Yuba-Bear area," Martin said. They said, 'What we did was, we picked the area we thought would be the worst. And if it wasn't a problem there, it wouldn't be a problem anywhere.'"

It turned out that mercury was a problem in the Bear-Yuba watersheds. The USGS team found elevated levels in fish just about everywhere they looked in Martin's district.

Knowing that a problem exists, however, is not the same as being able to solve it. The dimensions of California's mercury contamination are daunting, constituting a vast, toxic bequest from the 19th century to the 21st. That unwelcome legacy ties the state's high-tech present to its rambunctious past and in coming years will unite rural mountain counties and coastal metropolitan areas in a search for solutions.

The Mother Lode

Generations of California schoolchildren have been introduced to the traditional image of the 49er, icon of the gold rush. He's a bearded guy in flannel and denim carrying a pick and a pan, wandering the stream-cut canyons with his trusty burro in solitary pursuit of riches.

It was a bit like that in the first few years after James Marshall found gold in the tailrace of Sutter's Mill beside the American River. But the rich, easy-to-work deposits were exhausted within a decade after Marshall's 1848 discovery. Gold mining in California then became a large-scale industrial activity, one requiring great infusions of investment capital to erect the elaborate infrastructure -- mills, rail lines, dams, flumes, smelters -- required to separate tiny quantities of gold from the vast deposits of buried gravel and bedrock in which it was mixed.

There were two basic ways to do this, depending on whether the gold was trapped in solid rock ore or mixed with sand and gravel. Mercury became a crucial ingredient in both processes. It is heavy, and easily combines with other metals to form an amalgam. Miners learned to use it as a trap, a metallic tar baby to keep the gold from getting away.

In stamp mills, where gold-bearing ore was pounded into dust by heavy iron shoes driven by steam
engines, the pulverized debris was allowed to wash across long copper plates coated with mercury. Fine
bits of gold would sink and stick, while the more buoyant rock debris flowed away on the stream of water. Periodically, mill workers would shut down the stamps and scrape the mercury-gold amalgam into bails. These would be cooked in furnaces, vaporizing the mercury and leaving behind the gold.

Much of the evaporating mercury was captured in a condensation chamber for re-use. Some escaped into the air. Some was pulverized by the iron shoes of the stamp mill and floated away in the water, making its way into nearby streams.

The biggest source of mercury contamination in the California environment, however, was the practice known as hydraulic placer mining.

Fifty million years ago, the landscape that now constitutes the Sierra Nevada foothills was a low coastal plain. Across it wound huge and powerful rivers, which deposited vast quantities of sand and gravel in their beds. Those deposits, eventually buried and then lifted by the titanic forces that created the Sierra Nevada itself, were laced with gold. They became famous worldwide as "the auriferous gravels" ("auriferous" being Latin for "gold-bearing") and they eventually yielded a quarter of all the gold mined in California.

In 1853, a miner named Edward Matteson figured out a safe and efficient way to excavate those placer deposits, some of which were hundreds of feet thick. ("Placer" is Spanish, and refers to a sand bank or shoal; it also means "pleasure" and might connote the ease with which such deposits could be worked).

He and his partners fashioned a brass nozzle, attached it to a rawhide hose and used a blast of water to wash away the gold-bearing gravel.

The technique caught on and spread. Eventually, mining companies diverted entire creek systems into reservoirs, feeding that water at high pressure through aqueducts and steel pipes to huge nozzles known as "monitors" or "giants." Ressembling military cannons, some of them 16 feet long, they could deliver up to 30,000 gallons a minute in a nine-inch stream at a pressure of 125 pounds per square inch.

Directed at the gold-bearing gravel, this liquid artillery barrage could level entire hillsides — rock, soil, forest — with startling efficiency.

It is difficult to appreciate the scale of landscape rearrangement made possible by this rather crude technology. The biggest such mining operation was in Nevada County, upstream from Martin's supervisory district. Now preserved within Malakoff Diggins State Historic Park, the hydraulic mining operation there managed to wash away 41 million cubic yards of gravel, sending it all downstream into the Yuba River and its tributaries. The resulting pit was 7,000 feet long,
>3,000 feet wide and more than
>600 feet deep. Although partially filled by erosion, it remains a startling
>sight today: a huge man-made
>analog to Utah's Bryce Canyon, with multicolored walls eroded into fantastic
>shapes.
>
The debris brought down by the monitors was directed into sluices containing
>mercury. Sometimes the
>sluices were wooden troughs with perpendicular cleats in the bottom; mercury
>was dumped behind the
>cleats to trap the gold. At other mines, ground sluices were used. Miners
>would simply pour liquid mercury
>into long trenches or tunnels dug into the ground below the mining pit and
>wash the gold-bearing gravel
>through them.
>
>As it washed through the sluices, leaving behind its gold, the gravel and
>sand (henceforth referred to as
>"tailings") became contaminated with mercury that either leaked from the
>sluices or was washed away by
>the flowing water. This is the essence of California's Gold Rush pollution
>problem.
>
>Nearly unimaginable quantities of debris washing downstream from the Sierra
>Nevada hydraulic mines
>choked rivers and buried farmland all the way to San Francisco Bay. The
>Sacramento River rose seven
>feet in elevation as its bed was inundated with sand and silt. Great fans of
>milky white gravel, sand and
>cobbles -- the water-polished legacy of those 50 million-year-old rivers --
>filled canyons throughout the
>mining belt and spilled 10 miles out across the Central Valley. More than a
>billion cubic yards of tailings
>washed into San Francisco Bay, impeding navigation and turning the ocean
>brown at the Golden Gate.
>
>Before the practice was largely halted by an 1884 court ruling, hydraulic
>miners sent 1.6 billion cubic
>yards of sediment into the state's waterways, according to Charlie Alpers, a
>USGS research chemist.
>Hard-rock miners produced 30 million cubic yards of tailings. Dredges, which
>used mercury to process
>sand and gravel scooped from river channels and flood plains, left about 4
>billion cubic yards of debris
>heaped alongside streams. Altogether, gold miners picked up and moved about
>5.6 billion cubic yards of
>California.
>
>Spread a foot deep, that much debris would cover 5,424 square miles.
>Connecticut has an area of 5,544
>square miles.
>
>According to Ronald Churchill, who surveyed historical data to arrive at an
>estimate for his employer, the
>state Division of Mines and Geology, early hydraulic miners "lost" as much
>as one pound of mercury for
>every three or four ounces of gold they recovered.
>
>A standard household fever thermometer contains a half a gram of mercury,
>enough to contaminate a
>25-acre lake to the degree that its fish become unsafe to eat. A pound of
>mercury is enough to fill about
>900 thermometers.

>Operations eventually became more efficient (and dredging was never quite as
>sloppy as hydraulic
>mining). Still, Churchill estimates that gold miners in California lost
>about 12.8 million pounds of mercury in
>the 19th and early 20th centuries, 80 to 90 percent of it in the Sierra
>Nevada. Enough mercury, in other
>words, to fill more than 11.5 billion household thermometers.
>
>Most of it is still out there. Somewhere.
>
>The Coast Ranges
>
The Sierra Nevada gold fields are not the only source of mercury released
>into the California environment.
>In a geological coincidence that gratified the mining industry but has
>brought no joy to modern-day public
>health experts, the state is one of the few places in the world to possess
>both rich gold deposits and
>abundant natural sources of the mercury so helpful in gold extraction.
>
>Mercury ore, primarily a form known as cinnabar -- a reddish rock, in which
>mercury forms a compound
>with sulfur -- occurs in the Coast Ranges between Clear Lake and Santa
>Barbara County. The deposits
>are some of the richest in the world. Between 1846 and 1981 they produced
>227 million pounds of
>mercury, Churchill estimates. Half the total came from the two largest of
>the mines -- New Idria
>(northwest of Coalinga) and New Almaden (12 miles southwest of San Jose, now
>a Santa Clara County
>park with a stunning view of Silicon Valley).
>
>In 1861, a state geological survey team visited New Idria, named after the
>Idria mining region in
>Yugoslavia (New Almaden was named after the Almaden region in Spain, the
>richest mercury deposit in
>the world.) Member William Brewer's journal of that survey, "Up and Down
>California in 1860-1864."
>offers a glimpse into the business of 19th mercury production, and it is not
>a romantic one.
>
>"Sulphurous acids, arsenic, vapors of mercury, etc., make a horrible
>atmosphere, which tells fearfully on
>the health of the workmen," Brewer wrote, "but the wages always command men
>and there is no want
>of hands. The ore is roasted in furnaces and the vapors are condensed in
>great brick chambers, or
>'condensers.' These have to be cleaned every year by workmen going into
>them, and they may have their
>health ruined forever by the three of four days' labor, and all are injured;
>but the wages, twenty dollars a
>day, always bring victims. There are but few Americans, only the
>superintendent and one or two other
>officials; the rest are Mexicans, Chileans, Irish (a few) and Cornish
>miners."
>
>>From 1850 to the 1890s, California was the only source of mercury in the
>United States. Production
>greatly exceeded domestic demand, and 70 percent of California's mercury was
>exported, mainly to other
Pacific Rim countries.

Much of what remained was hauled across the state to the gold fields or to mining regions elsewhere in the West. (A major destination was the rich Comstock Lode in Nevada, about 20 miles east of Lake Tahoe, where an estimated 14 million pounds of mercury ended up in the Carson River). Mercury escaped into the environment wherever it was mined and processed — spilled during handling, escaping up the chimney during refining, absorbed into the bricks of the refinery furnaces themselves. Churchill estimates that 75.9 million pounds of mercury may have been lost to the environment in California during cinnabar mining and refining.

More significantly, the mining operations left behind vast quantities of mercury-contaminated tailings and ore. As a result, the old mines today continue to send mercury into creeks, rivers and lakes. Eleven of the 12 water bodies where the state has issued fish consumption warnings because of methylmercury are contaminated exclusively by old mercury mines; the 12th, the San Francisco Bay-Delta region, has been contaminated by mercury and gold mining operations.

According to records kept by the California Department of Conservation and the U.S. Bureau of Mines, at least 239 mines in the state produced at least one flask of mercury. (A flask is the standard industry measurement, referring to a steel bottle shaped like a squat scuba tank that contains about 76 pounds of mercury.) Another 54 sites may have had unrecorded production.

Government records list about 13,500 historic gold mines and prospects in California, most in the Sierra Nevada but a significant percentage in the Klamath-Trinity mountains in the northwestern part of the state.

Nearly any of these thousands of mercury and gold mines could be a source of contamination, rendering fish downstream unsafe for children and pregnant women to eat.

The past is alive.

In most cases, the standard approach to discovery of a dangerous environmental contaminant is to clean it up: scrape off the asbestos, scoop up the crude oil, haul away the pesticide-laced soil. To understand what it might mean to clean up California's mercury-contaminated mining areas, perhaps the best place to look is Greenhorn Creek, a small tributary of the Bear River in Elizabeth Martin's supervisorial district.

This is not just because Greenhorn Creek is a scenic, peaceful place for a picnic — although it certainly is that — but because of the story it tells.

To reach the creek, you must drive for several miles out of Nevada City (the county seat, location of the government center where Martin has her office), following a succession of progressively narrower,
>rougher roads. Eventually the route becomes dirt and descends into a canyon
>carved through forested
>slopes.
>
The road ends at the lip of the stream bed. Greenhorn Creek is nearly lost
>as it wanders In sparkling
>braids across a vast expanse of white gravel, sand and cobbles. The debris
>is almost Saharan in its
>apparent lifelessness. Protruding from the blinding expanse of rock are what
>look like charred tree
>stumps.
>
>To a geology buff, the polished, quartz-rich rock and sand filling the creek
>bed are instantly identifiable.
>They are the fabled "auriferous gravels," the gold-bearing deposits laid
>down by long-lost rivers as big as
>the Yukon. The gravel is here because 150 years ago there was a hydraulic
>mining operation upstream.
>
The tree "stumps" are actually the tops of mature Douglas firs, perhaps 150
>feet tall, buried from root to
>crown by a 200-foot blanket of hydraulic mining tailings swept into the
>canyon more than a century ago.
>Partially exposed now by erosion, the trees are rooted along the original
>bank of Greenhorn Creek, which
>lies 100 feet beneath the gravel.
>
>All that gravel is mixed with minute quantities of mercury, which is adding
>to the toxic load in rivers and
>lakes downstream. How much would it cost to remove it, even if such a thing
>were technically feasible?
>And what about the scores of other creeks and canyons just like it
>throughout the heart of California gold
>country?
>
>"The idea of removing all the mercury from the watershed is pretty
>unrealistic," said Alpers, whose
>agency has proposed additional studies in the region to help explain how
>mercury behaves once it enters
>the aquatic environment.
>
>"Everywhere they did gold mining, they did a couple of things," Martin said.
>"One thing they did was
>redirect all the water in the area through sluices. They used sluices to do
>this mercury treatment. So,
>they basically replumbed the Sierra Nevada to run (its rivers) through
>sluices where mercury was applied.
>Today, the watershed still runs into the same old tunnels, the same old
>watercourses, which are very
>different than what we had 200 years ago. No one is thinking we're going to
>be able to go back to the
>landscape of more than 150 years ago, but we need to identify where those
>hot spots are."
>
>Even identifying particularly "hot" sources of mercury contamination can
>lead to a difficult and costly
_cleanup. The EPA recently spent about $1.4 million to remove mercury from a
>single 500-foot long tunnel
>at the Polar Star mine in Placer County. It spent $2 million partially
>cleaning up two modest mercury
>mines in San Luis Obispo County. It has spent more than $1.5 million on
<preliminary work at the Sulphur
Bank mercury mine on the shore of Clear Lake and still has years of work
left to do.

Contaminated streams and lakes are not the only issues facing Martin and
other public officials in gold
country. Land use is also affected by mining's toxic legacy. Builders and
subdividers naturally are drawn
to the rare flat spots in the rugged foothills topography, but in most cases
those flat spots are the result
of mining excavation.

Opportunities for developers to run afoul of mercury contamination in the
soil are increasing. Foothills
communities are among the fastest-growing areas of California, according to
the 2000 Census,
particularly in gold country. Placer County's population swelled 43.8
percent between 1990 and 2000, the
second-highest growth rate among California's 58 counties. El Dorado County
grew 24.1 percent, ranking
ninth. Nevada County didn't grow quite as fast, but it still made it into
the top half: Its population
increase of 17.2 percent ranked 25th.

That's one of the reasons Martin was so disturbed to learn of the 1999 USGS
study finding elevated
levels of methylmercury in fish from streams and lakes in her district.

"We immediately became alarmed that we were going to suddenly be ordering
landowners to do mercury
evaluations, which were going to cost gazillions of dollars, and then
tyler's going to discover that their
land is contaminated and they can't build on it," she said.

Mercury also has potentially costly implications for local government as
federal regulators begin imposing
limits on the amount of that contaminant in the discharge from sewage
treatment plants -- mercury that,
for the most part, enters the municipal system in the water supply.

"Every little gold country sanitation system is going to have to be looked
at," Martin said.

Already, state and federal taxpayers are spending millions of dollars to
study the effect mercury
contamination might have on plans to restore salmon and steelhead runs in
the northern part of the
state. Among the key strategies being examined under CALFED, a state-federal
partnership launched in
1994 to rectify a host of problems besetting the Sacramento-San Joaquin
river delta, is restoration of
tidal marsh around San Francisco Bay and removal of key upstream dams --
among them the 260-foot
concrete arch at Englebright Lake, one of the reservoirs identified by the
USGS as harboring
contaminated fish.

Wetlands are critical nurseries for young fish, but they also are known to
be places where toxic elemental
mercury is transformed into methylmercury, the neurotoxic form that makes
its way into fish. And
removing Englebright Dam would open up many miles of potential spawning
habitat but also would send
millions of cubic yards of contaminated sediment downstream. 

The presence of a dangerous contaminant in the scenic lakes and mountain streams also is annoyingly ironic to Martin and other community leaders. Like other rural areas in the American West, Nevada County and its neighbors are trying to make the bumpy transition from an economy based on natural-resource extraction -- mainly mining and logging -- to one based on tourism, recreation and service industries attracted by the quality of life the cool, pine-studded mountains offer their employees.

Fishable lakes and streams are a big part of the area's lure. So are the charm and historical interest conferred by its mining past. It seems a cruel jest now to learn that the mining legacy drawing visitors to the museums, parks, shops and inns of gold country might also poison them if they eat too many of its fish.

Everyone lives downstream

Whether they realize it or not, urban communities in the Central Valley and along the California coast have a stake in the future of the foothills, and Martin hopes to capitalize on that to clean up the mess in her own back yard.

Sacramento County, for example, has been ordered by the Central Valley Regional Water Quality Control Board to limit the amount of mercury in its sewage discharge to the Sacramento River. Unless it can find a way to keep mercury from entering the municipal system in the first place, it will have to install costly treatment equipment. Martin would like to see that money invested instead in cleaning up a primary source of mercury in the river: old mining debris in the mountains.

The problem is even more acute in the San Francisco Bay area. The bay is downstream from 40 percent of the state and receives 80 percent of its runoff. This vast estuary, largest on the West Coast, also lies at the heart of a metropolitan region that's home to 6.7 million people, and it receives discharges from 36 municipal sewer plants and 18 industrial treatment plants.

Water containing mercury flows into the bay from every side, although the biggest single source appears to be the abandoned New Idria and New Almaden mines to the south, according to Khalil Abu-Saba, an environmental specialist with the San Francisco Bay Regional Water Quality Control Board.

The bay also received huge quantities of hydraulic mining debris in the 18th and early 20th century before dams were built in the foothills and reservoirs became receptacles for the flood of tailings. At the north end of the bay, where it pokes into Napa and Marin counties, the bottom is buried beneath six feet of mercury-contaminated gold mining debris, Abu-Saba said.
As a consequence of mining, the bay's fish are contaminated with methylmercury. The state has issued warnings to limit consumption of all sport fish caught there, with particular cautions against striped bass and shark. The striped bass warning for pregnant women and children has been in effect since 1971.

Unlike vacationers who pull a few trout or bass once a year from a lake or stream in Sierra Nevada gold country, people who fish on San Francisco Bay are more likely for economic or cultural reasons to eat a lot of what they catch. They are therefore more likely to be at risk of suffering ill effects from methylmercury exposure. In recognition of this, the Save the San Francisco Bay Association received an EPA grant five years ago for a program offering at-home workshops directed primarily at Hispanic and Asian households on how to avoid eating contaminated fish.

Abu-Saba is working to develop a total maximum daily load, or TMDL, for mercury in San Francisco Bay. A TMDL sets a limit for the amount of a particular contaminant entering a body of water, intended to ensure that it meets federal Clean Water Act standards. The Regional Water Quality Control Board allocates a percentage of that total load to each source of the pollutant in the watershed. Those sources -- industrial facilities, municipal sewer plants, water agencies -- must then reduce their emission of that pollutant to meet their share of the TMDL.

The mercury TMDL (a draft version of which was released last summer) will be intended to cut the amount of mercury in the bay by half, Abu-Saba said. That would still be higher than the background level -- a consequence of natural processes such as erosion of ore deposits and emissions from volcanoes and geothermal springs -- which researchers have determined by analyzing core samples of bay sediments.

From before and after the mining era. Nevertheless, he said, it should be enough to keep the levels in fish tissue low enough to be safe.

Filtering mercury from waste discharges can be an expensive proposition. It is possible that the TMDL standards might send Bay area industries and public agencies searching upstream for the source of the contaminant. If so, Martin and other community leaders in gold country will welcome them, as long as they bring money.

"They have the health cost," Martin said. "We're going to have the economic impacts."

Cooperation makes sense to the rural upstream towns, because big cities and big industry -- which face the costliest consequences of mercury in California's environment -- have the money to do something about it. The small rural counties, where the problem originates, do not.

Cooperation makes sense from another standpoint. Mercury pollution, after all, respects no political
>boundaries. Although a significant share of the mercury coming into San
>Francisco Bay arrives in municipal
>and industrial wastewater discharges from the necklace of cities encircling
>it, the biggest source is old
>mines and mining debris elsewhere in the state. A small but measurable
>contribution also comes from the
>atmosphere and is a consequence of fossil-fuel combustion -- the leading
>artificial source of mercury
>released into the environment -- thousands of miles away.
>
>"This is a global problem," Abu-Saba said. "I don't have regulatory
>authority over airborne emissions from
>China."
>
>-- John Krist's e-mail address is krist@insidevc.com

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