A. Project Title and Investigators

Upper Yuba River Studies Program – Water Quality Studies

Project chief:
Charles N. Alpers, U.S. Geological Survey, California Water Science Center, Sacramento CA

Collaborators:
Ronald C. Antweiler, and Howard E. Taylor, USGS, Boulder, CO
Jennifer A. Curtis, Lorraine A. Flint, and Michael P. Hunerlach, USGS, Sacramento, CA
John F. DeWild and David P. Krabbenhoft, USGS, Madison, WI
Mark C. Marvin-DiPasquale, USGS, Menlo Park, CA
Darell G. Slotton and Shaun M. Ayers, Univ. of California, Davis, CA
Noah P. Snyder, Boston College, Boston, MA

B. Introduction to the Project

Brief background:

The Upper Yuba River Studies Program (UYRSP, http://www.upperyuba.com/), sponsored by CALFED, is evaluating the feasibility of introducing anadromous fish species to the Yuba River system upstream from Englebright Dam (Fig. 1). The scope of the UYRSP has six elements: (1) sediment (quality and quantity), (2) water quality, (3) habitat, (4) flood risk, (5) water supply and hydropower, and (6) socio-economics; the U.S. Geological Survey (USGS) is responsible for the technical aspects of the sediment and water-quality elements of the program. To achieve the UYRSP objective of determining the feasibility of improving fish passage at Englebright Dam, future management scenarios under consideration include lowering or removing the dam. Any reduction in size of the dam would result in some change in the sediment regime of the lower Yuba River and could cause the release of material stored in Englebright Lake. This increased sediment load could exacerbate existing physical and chemical hazards in the lower Yuba River area. Sediment deposition could raise riverbed elevations and therefore increase flood risk in the valley around Marysville (Fig. 1). Because much of the stored material is likely derived from historical gold mining areas in the Yuba River watershed (James, 2005), it may contain high concentrations of mercury (Hg) and other heavy metals that were lost during gold mining and recovery operations (Alpers and Hunerlach, 2000; Ashley, 2002; Hunerlach et al., 2004; Alpers and others, 2005a and 2005b).

Scientific goals and objectives of the project:

1. Characterize bed sediments in Englebright Lake with regard to total mercury (THg), methylmercury (MeHg), other trace elements, organic content, and grain-size distribution.
2. Determine loads of THg and MeHg in major inflows and outflow from Englebright Lake and evaluate mass balance and trapping efficiency of the reservoir in relation to suspended sediment.
3. Quantify bioaccumulation of MeHg in sport fish species within Englebright Lake as a function of fish size and age.

4. Evaluate spatial variability of MeHg bioaccumulation in fish and invertebrates in the upper Yuba River watershed (Middle and South Yuba Rivers) and the lower Yuba River (downstream of Englebright Dam).

Current working hypotheses:

1. Englebright Lake traps suspended sediment and also serves as a sink for THg and MeHg associated with suspended particles.
2. Transport of THg correlates closely with that of suspended sediment, with most transport (and highest aqueous concentrations of THg and suspended sediment) occurring during high flows associated with late-fall and winter storm events.
3. Transport of MeHg is influenced by winter storm events but there is also a trend toward higher MeHg concentrations in the summer, associated with warmer conditions and higher rates of microbial (Hg-methylation) activity.
4. The spatial distribution of MeHg bioaccumulation indicates that historical gold mining is a more important source of reactive Hg relative to.atmospheric sources in the upper Yuba River watershed.
5. The persistence of moderately high MeHg concentrations and MeHg/THg ratios in deep sediments from Englebright Lake (up to 33 m below reservoir floor) is likely caused by the rapid sedimentation rate, co-burial of organics and sulfur, and ongoing production of MeHg in excess of demethylation.

Management goals and objectives addressed by the project:

1. Determine the extent to which mercury contamination in Englebright Lake and the Upper Yuba River may present risks to downstream environments with regard to improvements to fish passage at Englebright Dam.

C. Project Timetable and Progress

Starting and target completion dates:
Jan. 2001 – Project started
June 2004 – Original target completion date (prior to amendments)
Jan. 2006 – Revised target completion date for draft reports
June 2006 – Revised target completion date for final reports

Project status:

The project is on schedule with regard to the revised target completion dates in the amended joint funding agreement.

Project milestones achieved:
Jan. 2001 – Gaging stations upgraded, monitoring begun at 4 Yuba River stations
Oct. 2001 – First meeting of Technical Review Panel
May-June 2002 – Deep drilling and sampling of Englebright Lake sediments
June 2002 – End of initial 18-month monitoring period at 4 gaging stations
Sept. 2002 – Sampling completed of fish and zooplankton in Englebright Lake
Oct. 2002 – Shallow sampling of Englebright Lake sediments

Nov. 2002 – Synpotic sampling of water, sediment, and biota at 13 stream sites
Jan. 2003 – Autosamplers installed on S. Yuba and M. Yuba gaging stations
Oct. 2003 – Second meeting of Technical Review Panel
May 2004 – Completion of monthly and storm-event monitoring at gaging stations

D. Project Highlights and Results

[NOTE: According to USGS policy, interpretive reports must receive USGS Director's approval prior to public distribution. Because of time and budget constraints, it was not possible to write a new summary of USGS project results for this review. Instead, this section contains two abstracts from the 2004 CALFED Science Conference.]

Alpers, C. N.* (1), M. P. Hunerlach (1), M. Marvin-DiPasquale (2), N. P. Snyder (3, 4), D. P. Krabbenhoft (5). (1) U.S. Geological Survey (USGS), Placer Hall, 6000 J Street, Sacramento, CA 95819. (2) USGS, MS 480, 345 Middlefield Road, Menlo Park, CA 94025. (3) Department of Geology and Geophysics, Boston College, 140 Commonwealth Ave., Chestnut Hill, MA 02467. (4) USGS, 400 Natural Bridges Drive, Santa Cruz, CA 95060. (6) USGS, 8505 Research Way, Middleton, WI 53562. cnalpers@usgs.gov

MERCURY AND METHYLMERCURY IN THE UPPER YUBA RIVER WATERSHED: FLUVIAL TRANSPORT AND RESERVOIR SEDIMENTATION

The potential introduction of anadromous fish to the upper Yuba River watershed (upstream of Englebright Dam) has raised questions concerning possible risks associated with exposure to mercury contamination from historical gold mining. These concerns were investigated by monitoring mercury (Hg) and methylmercury (MeHg) concentrations in water, suspended sediment, and reservoir-bed sediment during 2001–2003.

Concentrations of Hg and MeHg were determined in both unfiltered and 0.45-micrometer-filtered water, along with suspended-sediment concentration (SSC) at gaging stations on the South Yuba River (SY), the Middle Yuba River (MY), and the Yuba River below Englebright Dam. At SY and MY, there were positive correlations between discharge, SSC, and Hg in unfiltered water. Average Hg in suspended silt and clay at SY was about 350 nanograms per gram (ng/g) dry sediment. The highest concentrations of Hg and SSC relative to discharge at SY and MY occurred during rising limbs of early-wet-season storms. About 25% of unfiltered MeHg analyses were > 0.10 nanograms per liter, mostly during storms.

Deep sediment coring during 2002 penetrated the entire post-dam sediment pile at six locations in Englebright Lake. Sediment thickness ranged from 6 m near Englebright Dam to 33 m in the mid-reservoir area. Sediment Hg concentrations ranged from 2 to 1,150 ng/g (median 139 ng/g, n=166); MeHg concentrations ranged from 0.007 to 6.8 ng/g (median 0.36 ng/g; n=166). The persistence of moderately elevated MeHg concentrations throughout the sediment pile suggests several causative factors, including rapid burial and preservation of the deposited MeHg, moderately low rates of MeHg demethylation, and (or) persistent Hg methylation in relatively organic-rich sediments.

Exposure levels of MeHg in water and sediment in upper Yuba River watershed may represent significant ecological risk to aquatic species. Potential MeHg exposure and associated risk should be considered in the development of anadromous-fish-introduction scenarios above Englebright Dam.

Slotton*[1], D.G., S.M. Ayers[1], C.N. Alpers[2], and C.R. Goldman[1]
[1]University of California at Davis (UC Davis), Dept. of Environmental Science and Policy, 1 Shields Ave, Davis, CA 95616
[2]U.S. Geological Survey (USGS), Water Resources Discipline, 6000 J Street, Sacramento, CA 95819
dgslotton@ucdavis.edu

BIOACCUMULATION OF GOLD-RUSH MERCURY IN REACHES OF THE YUBA RIVER WATERSHED PROPOSED FOR ANADROMOUS FISH REINTRODUCTION

The Middle Yuba and South Yuba rivers are being considered as sites of renewed spawning access for anadromous salmonids, including steelhead and spring-run Chinook salmon. This would require fish passage at Englebright Dam (79 m high), which is being considered for decommissioning or modification. The potential for juvenile anadromous salmonids to be exposed to elevated methylmercury (MeHg) in the upper watershed is of concern.

Biotic mercury was sampled at 13 sites, 10 upstream and 3 downstream of Englebright Lake. Sites spanned the zone of historical gold-mining activity (200-900 m elevation), with additional sites upstream and downstream (30-1,700 m elevation). Adult and juvenile trout, hydropsychid caddisflies, and perlid stoneflies were utilized as biosentinels of relative MeHg exposure. Non-anadromous rainbow trout were sampled from upstream sites as surrogates for potentially reintroduced anadromous salmonids.

All biotic samples showed consistent, statistically significant increases in MeHg and total mercury (THg) within the historical gold mining zone: 4- to 6-fold increases of MeHg in invertebrates, 2- to 4-fold increases of THg in juvenile trout, and 2- to 3-fold increases of THg in adult trout. Mercury bioaccumulation was significantly lower immediately downstream from Englebright Lake, although some higher values were noted further downstream in the lower Yuba River, the site of large-scale historical and ongoing dredging activity. MeHg concentrations in aquatic insects and juvenile trout correlated strongly with each other and with THg concentrations in adult trout, all exhibiting system-wide R^2 correlation coefficients greater than 0.90.

Significant mercury bioaccumulation was found within the historical gold-mining region in the upper Yuba River watershed. If mercury-contaminated stream reaches are re-opened for migration and rearing of anadromous salmonids, juveniles are likely to be exposed to elevated MeHg, with possible adverse effects. This study confirms the utility of young-of-year fish and aquatic insects as biosentinels for MeHg exposure and bioaccumulation.

E. Potential Management Implications of Findings to Date

[NOTE: The following bullets relating to the Upper Yuba River Studies Program are from a draft Session Summary for the Watershed Perspectives session at the 2004 CALFED Science Workshop. The draft document was prepared by Michael Kiparsky with assistance from the presenters and sessions chairs (Ted Frink and Stefan Lorenzato).]

(Water Quality)

- Exposure levels of MeHg in the upper Yuba River watershed do not appear to be acutely toxic, but may pose a chronic risk to aquatic species. Potential MeHg exposure and associated risk should be considered in anadromous-fish-introduction scenarios above Englebright Dam. (Slotton/Alpers)
- If a high concentration of Hg or MeHg were released downstream, as from dredging sediment with Englebright Lake or removal of Englebright Dam, it could be a concern. Any future dredging of sand and gold must be weighed against risk of MeHg release downstream (Alpers).
- In the South Yuba River, there is excellent correlation of total Hg with suspended silt and clay. This indicates the potential for using turbidity as a proxy for total Hg (Alpers).

(Sediment)

- Suspended sediment concentration in the Yuba River and tributaries in 2001-3 was not a limiting factor for potential long-term fish introduction (Curtis).
- Modeling technology has advanced to the point where it can help in assessing possible consequences of restoration actions, including complex ones in heterogeneous watersheds, even in the absence of copious field-gauged data. However, different geomorphological conditions demand different model treatments (Kavvas, Flint).

(General)

- The Yuba River technical framework and process for engaging stakeholders in the identification of scientific questions has direct application to other large, collaborative ecosystem projects. The framework helped integration of various studies, framing the question and primary purpose, identifying the key study questions needed to address purpose questions, and identified the studies needed to address each question (Christophel).
- The factors influencing success in the Yuba River include stakeholders' commitment, a clear decision process, and the technical framework that integrates science into this process. Ultimately, a facilitated collaborative process is critically important to project success as well as having credible scientific results and expert review of findings to inform stakeholder discussions and support decision processes (Christophel).

F. (Appendix) Products to date (list reports, publications, and presentations)

[NOTE: Because of the integrated nature of the Upper Yuba River Studies Program, results of the sediment studies are considered essential to the water quality studies. Reports and presentations are provided in three categories: (1) Water Quality, (2) Sediment, and (3) General. Reports and publications are listed by in alphabetical order by author; presentations are listed in chronological order. Presentations listed below are those that were made at organized conferences and workshops. In addition, several less formal presentations, seminars, or briefings including results from the UYRSP were made during 2002–2005 at venues such as the University of California, Davis, and for various stakeholder or governmental groups such as the UYRSP Workgroup and Technical Committees, the Delta Tributaries Mercury Council, the Yuba Watershed Council, and the Nevada County Board of Supervisors.]

Reports and Publications (Water Quality):

Alpers, C.N., Hunerlach, M.P., Marvin-DiPasquale, M.C., Antweiler, R.C., and Snyder, N.P., in review, Geochemical data for mercury, methylmercury, and other constituents in sediments from Englebright Lake, California, 2002, U.S. Geological Survey Data Series Report.(Status: Colleague reviews received and revised manuscript submitted for USGS approval.)

Alpers, C.N., Curtis, J.A., Snyder, N.P., and Meyer, R.W., in preparation, Mercury transport in the upper Yuba River, journal article to be submitted to Water Resources Research. (Status: Analyses complete, data compiled; load calculations and mercury mass balance for Englebright Lake in progress.)

Slotton, D.G., Ayers, S.M., Alpers, C.N., and Goldman, C.R., in preparation, Bioaccumulation legacy of Gold Rush mercury in watersheds of the Sierra Nevada of California, journal article to be submitted to one of the following journals: Canadian Journal of Fisheries and Aquatic Sciences, Science of the Total Environment, or Environmental Research (Status: Analyses complete, data compiled, report in preparation).

Slotton, D.G., Ayers, S.M., and Alpers, C.N., in preparation, Mercury bioaccumulation in fish from Englebright Lake, California, 2002. U.S. Geological Survey Data Series Report. (Status: Analyses complete, data compiled, report in preparation).

Reports and Publications (Sediment):

Childs, J.R., Snyder, N.P., Hampton, M.A., 2003, Bathymetric and geophysical surveys of Englebright Lake, Yuba-Nevada Counties, California, U.S. Geological Survey Open-File Report 03-383, http://geopubs.wr.usgs.gov/open-file/of03-383/, 20 p.

Curtis, J.A., Flint, L.E., Alpers, C.N., Wright, S.A., and Snyder N.P., in press, Sediment Transport in the Upper Yuba River Watershed, California, 2001–03, U.S. Geological Survey Scientific Investigations Report.

Curtis, J.A., Flint, L.E., Alpers, C.N., and Yarnell, S., 2005, Conceptual model of sediment processes in the upper Yuba River watershed, Sierra Nevada, CA: Geomorphology, v. 68, p. 149-166. *doi:10.1016/j.geomorph.2004.11.019*

Snyder, N.P., and Hampton, M.A., 2003, Preliminary cross section of Englebright Lake sediments, U.S. Geological Survey Open-File Report 03-397, http://geopubs.wr.usgs.gov/open-file/of03-397/, 1 plate.

Snyder, N.P., Allen, J.R., Dare, C., Hampton, M.A., Schneider, G., Wooley, R.J., Alpers, C.N., and Marvin-DiPasquale, M.C., 2004b, Sediment grain-size and loss-on-ignition analyses from 2002 Englebright Lake coring and sampling campaigns: U.S. Geological Survey Open-File Report 2004-1080 http://pubs.usgs.gov/of/2004/1080/.

Snyder, N.P., Alpers, C.N., Flint, L.E., Curtis, J.A., Hampton, M.A., Haskell, B.J., and Nielson, D.L., 2004a, Report on the May-June 2002 Englebright Lake deep coring campaign: U.S. Geological Survey Open-File Report 2004-1061 http://pubs.usgs.gov/of/2004/1061/

Snyder, N.P., Rubin, D.M., Alpers, C.N., Childs, J.R., Curtis, J.A., Flint, L.E., and Wright, S.A., 2004c, Estimating rates and properties of sediment accumulation behind a dam: Englebright Lake, Yuba River, northern California, Water Resources Research, v. 40, W11301, doi:10.1029/2004WR003279
http://www2.bc.edu/~snyderno/snyder_etal_2004.pdf

Reports and Publications (General):

Alpers, C.N., Hunerlach, M.P., May, J.T., and Hothem, R.L., 2005, Mercury contamination from historical gold mining in California, U.S. Geological Survey Fact Sheet 2005-3014, 6 p. http://water.usgs.gov/pubs/fs/2005/3014/

Presentations and Abstracts (Water Quality):

Alpers, C.N., Hunerlach, M.P., Taylor, H.E., Marvin-DiPasquale, M.P., Kuwabara, J.S., and Krabbenhoft, D.P., 2003, Preliminary results of mercury and methylmercury transport studies in the Bear River and Yuba River watersheds, 1999–2002. CALFED Science Conference 2003, Sacramento, Calif. (talk)

Alpers, C.N., Hunerlach, M.P., Marvin-DiPasquale, M.C., May, J.T., Hothem, R.L., Saiki, M.K., Stewart, A.R., Kuwabara, J.S., Taylor, H.E., and Krabbenhoft, D.P., 2004, Mercury cycling and bioaccumulation in fish in northern Sierra Nevada watersheds contaminated by historical gold mining, American Fisheries Society California-Nevada and Humboldt Chapters Symposium and 38th Annual Meeting, Redding, Calif., April 22–24, 2004, Program, unnumbered pages. (invited talk)

Alpers, C.N., Hunerlach, M.P., Marvin-DiPasquale, M., Snyder, N.P., and Krabbenhoft, D.P., 2004, Mercury and methylmercury in the upper Yuba River watershed: Fluvial transport and reservoir sedimentation. Third Biennial CALFED Bay-Delta Program Science Conference Abstracts, October 4-6, 2004, Sacramento, Calif., p. 4. (talk)

Slotton, D.G., Ayers, S.M., Alpers, C.N., and Goldman, C.R., 2004, Bioaccumulation legacy of Gold Rush mercury in watersheds of the Sierra Nevada of California. Third Biennial CALFED Bay-Delta Program Science Conference Abstracts, October 4-6, 2004, Sacramento, Calif., p. 388. (poster)

Alpers, C.N., Hunerlach, M.P., Marvin-DiPasquale, M., May, J.T., Hothem, R.L., Saiki, M.K., Stewart, A.R., Kuwabara, J.S., Taylor, H.E., and Krabbenhoft, D.P., 2005, Mercury contamination, methylation, and bioaccumulation associated with historical gold mining, Sierra Nevada, California Geological Association of Canada / Mineralogical Association of Canada (GAC/MAC), Halifax, Nova Scotia, Canada, May 2005. (invited talk; keynote address, presented by J .Rytuba)

Hunerlach, M.P., Alpers, C.N., and Marvin-DiPasquale, M., 2005, Mercury and methylmercury distribution in sediments affected by historical gold mining, Sierra Nevada, California, 15th Annual Goldschmidt Meeting (The Geochemical Society), Moscow, Idaho, May 20-25, 2005. (invited talk, not given because of travel problems) abstract published in Geochimica et Cosmochimica Acta, v. 69, No. 10, Supplement 1, p. A707.

Presentations and Abstracts (Sediment):

Snyder, N.P., Rubin, D.M., Alpers, C.N., Flint, L.E., Curtis, J.A., Childs, J.R., and Haskell, B.J., 2002, A record of rapid fluvial sedimentation in the Sierra Nevada hydraulic-mining region: Preliminary results from the 2002 Englebright Lake coring project. Geological Society of America, Abstracts with Programs, Paper 78-2. (talk)

Curtis, J.A., Flint, L.E., and Yarnell, S., 2003, Conceptual model of sediment processes in the upper Yuba River watershed, Sierra Nevada, CA. CALFED Science Conference 2003, Sacramento, Calif. (poster)

Snyder, N.P., Rubin, D.M., Alpers, C.N., Flint, L.E., Curtis, J.A., Childs, J.R., and Haskell, B.J., 2003, A record of rapid fluvial sedimentation in the Sierra Nevada hydraulic-mining region: Preliminary results from the 2002 Englebright Lake coring project. CALFED Science Conference 2003, Sacramento, Calif. (talk)

Curtis, J.A., Flint, L.E., and Alpers, C.N., 2004, Sediment transport in the upper Yuba River watershed, 2001–03. Third Biennial CALFED Bay-Delta Program Science Conference Abstracts, October 4-6, 2004, Sacramento, Calif., p. 48. (talk)

Flint, L.A., Guay, J.R., Flint, A.L., Curtis, J.A., and Alpers, C.N., 2004, Spatially distributed model of flow and sediment transport in the upper Yuba River watershed. Third Biennial

CALFED Bay-Delta Program Science Conference Abstracts, October 4-6, 2004, Sacramento, Calif., p. 78. (talk)

Snyder, N.P., Alpers, C.N., Childs, J.R., Curtis, J.A., Flint, L.E., Holmes, C.W., Rubin, D.M., and Wright, S.A., 2004, Rates and history of sediment accumulation behind Englebright Dam. Third Biennial CALFED Bay-Delta Program Science Conference Abstracts, October 4-6, 2004, Sacramento, Calif., p. 202. (talk)

Snyder, N.P., Alpers, C.N., Childs, J.R., Curtis, J.A., Flint, L.E., Holmes, C.W., Rubin, D.M., and Wright, S.A., 2004, Reconstructing watershed history from reservoir stratigraphy: Englebright Lake, Yuba River, northern California. EOS, Transactions American Geophysical Union, v. 85, no. 47, Fall Meeting Supplement (invited talk).

Flint, L.E., Guay, J.R., Flint, A.L., Curtis, J.A., and C.N. Alpers, 2005, Influence of climate on flow and sediment transport in the upper Yuba River basin, American River Science Conference, Sacramento, Calif., April 21-22, 2005. (talk)

G. References Cited

Alpers, C.N., and Hunerlach, M.P., 2000, Mercury contamination from historic gold mining in California. U.S. Geological Survey Fact Sheet FS-061-00, 6 p. *http://ca.water.usgs.gov/mercury/fs06100.html*

Alpers, C.N., Hunerlach, M.P., May, J.T., and Hothem, R.L., 2005a, Mercury contamination from historical gold mining in California, U.S. Geological Survey Fact Sheet 2005-3014, 6 p. *http://water.usgs.gov/pubs/fs/2005/3014/*

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

Ashley, R.P. 2002, Geoenvironmental model for low-sulfide gold-quartz vein deposits, in Seal, R.R. II and Foley, N.K. (eds.) Progress on Geoenvironmental Models for Selected Mineral Deposit Types. U.S. Geological Survey Open-File Report 02-195, p. 176–195. *http://pubs.usgs.gov/of/2002/of02-195/*

Hunerlach, M.P., Alpers, C.N., Marvin-DiPasquale, M., Taylor, H.E., and De Wild, J.F., 2004, Geochemistry of fluvial sediment impounded behind Daguerre Point Dam, Yuba River, California, U.S. Geological Survey Scientific Investigations Report 2004-516, 66 p. *http://water.usgs.gov/pubs/sir/2004/5165/*

James, L.A., 2005, Sediment from hydraulic mining detained by Englebright and small dams in the Yuba Basin. Geomorphology. *doi:10.1016/j.geomorph.2004.02.016*

H. Figure

Figure 1. Map showing location of Englebright Lake in the Yuba River watershed, California. Modified from Snyder and others (2004b). UYRSP, Upper Yuba River Studies Program.