Data Gaps Analysis for FERC Relicensing on the Yuba and Bear Rivers

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On behalf of the

Foothills Water Network Yuba-Bear Working Group
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Introduction

This Data Gaps Analysis has been prepared on behalf of the Foothills Water Network Yuba-Bear Working Group. Its' purpose is to identify, collect, organize, and analyze available literature and data relevant to the FERC Relicensings on the Yuba and Bear Rivers. The outcome is this status report which identifies the data gaps that should be considered when writing studies for the Yuba and Bear relicensings. This is considered a living document and will be augmented as needed and time and funding permit.

1. Reference Database for Yuba and Bear Relicensing

The database contains different types of references, which include: references on specific places, methods, and topics. The primary regions of interest are the Yuba and Bear watersheds. This database is intended to be a work in progress that can be updated over time and continue to serve as a decision-making tool.

The Yuba River has three forks the North, Middle and South which have multiple power generating facilities under two projects licensed by Federal Energy Regulatory Commission (FERC), namely the Yuba-Bear and Drum-Spaulding projects. FERC licenses for both projects expire in 2013. The Bear River relies heavily on Yuba river imports and as such needs to be considered jointly when making recommendations for the future operations of the Yuba-Bear and Drum-Spaulding hydropower projects.

The references included in this library are primarily scientific documents of the research that has occurred in the Yuba and Bear River watersheds. However the library also contains documents included from outside the region on methods or topics that may be of use. A number of management documents that are relevant to a larger region than just the Yuba and Bear watersheds, such as the American and Feather River Watersheds are included. To date the Reference Database consists of 398 references.

The Database of References was used to conduct a preliminary data gaps analysis. The database was used as a tool for searching, selecting, and reviewing references that contain data on the environmental topics relevant to the Yuba-Bear relicensing efforts. These topics include:

- Geological and soil resources
- Water/aquatic resources
- Fisheries resources
- Terrestrial resources
- Shoreline management
- Recreation
- Economics
- Cultural Resources

These topics reflect the categorization of studies typical in the context of FERC Relicensings. These topics were identified by the Foothills Water Network Yuba-Bear working group as a framework of relevant topics for the Yuba-Bear region.

1.1 ProCite - Information Organizing Software

This database was created in ProCite. ProCite is a bibliography program designed to assist in reference management. The intent of building this database in ProCite was to provide a program that can be uploaded to the Internet to allow this database to be accessed remotely in a web user-friendly format. (The program that interfaces ProCite with the web is called Reference Web Poster.) ProCite functions not only for information storage but also as a powerful tool for searching and organizing the information. Many of the references stored in this ProCite database have abstracts, links to the pdf files, and/or website addresses where the pdf can be downloaded.

One very useful tool in ProCite allows one to make groups of references. For example, one can search the topic "sediment", and then make a group of the documents related to sediment as an additional way of organizing the information, personalizing it, and using it to ascertain the number of references on a particular topic. For detailed instructions on the use of this program please see the downloaded user manual stored with the pdf files.

1.2 Sources for the References

A number of different bibliographies were used to build this database, including those from the Upper American FERC Application (203 references). We added other references pertaining to the UARP Amphibians and Reptiles (6 references), the Middle and South Yuba Rainbow Trout Dive Counts Aug 2004 (18 references) and the UC Davis dissertations and masters theses relevant to the Yuba Bear watersheds.

1.3 Data Gaps Analysis

ProCite was used to prioritize references into groups associated by topic and location in order to determine the extent and character of general data gaps (See Figure 1). This feature was used to determine which documents should be the highest priority documents to review. The documents were prioritized based on the location of the study, the date, the type of reference and the likelihood that the references would contain scientific data relating to the environmental topics relevant to the Yuba-Bear relicensing efforts. For example a peer reviewed journal article or dissertation written within the last 5 years that directly addressed the Yuba or the Bear watersheds and directly contributed to one of the topics listed in the Framework would rank the highest priority. The next most highly ranked document would be a recent report written by a technical advisory group that summarized a number of different resources and developed recommendations from the review. After this, references were ranked according to their direct relevance to the topic areas and the date that they were published and included agency documents.

The top ranking references were reviewed in detail and the data they contained are listed in an at-a-glance table (Table 1). Following the table is a summary of the data gaps for each topic area written with the intent of informing the process of making recommendations for additional studies that would fill cumulative data gaps for the Yuba and Bear watersheds.

The Literature Review section is an in-depth summary of the top ranking references, which included specifics about what was done in the study, what the major findings were, what the underlying assumptions were and what the data gaps were. These references were organized by topic to provide structure and coherency to the analysis.

Figure 1: Top 50 References grouped by topic and region

a) This chart shows the number of references that have one of the following words in the title and/or abstract: Sediment, Fish, Mercury, Temperature or Discharge.
b) This chart shows the number of references in the Database that have one of the following words in the title and/or abstract: South Yuba, Middle Yuba, North Yuba or Bear.
c) This chart shows the number of South Yuba references that have the above (a) topic words in the title and/or abstract.
d) This chart shows the number of Bear River references that the above (a) topic words in the title and/or abstract.

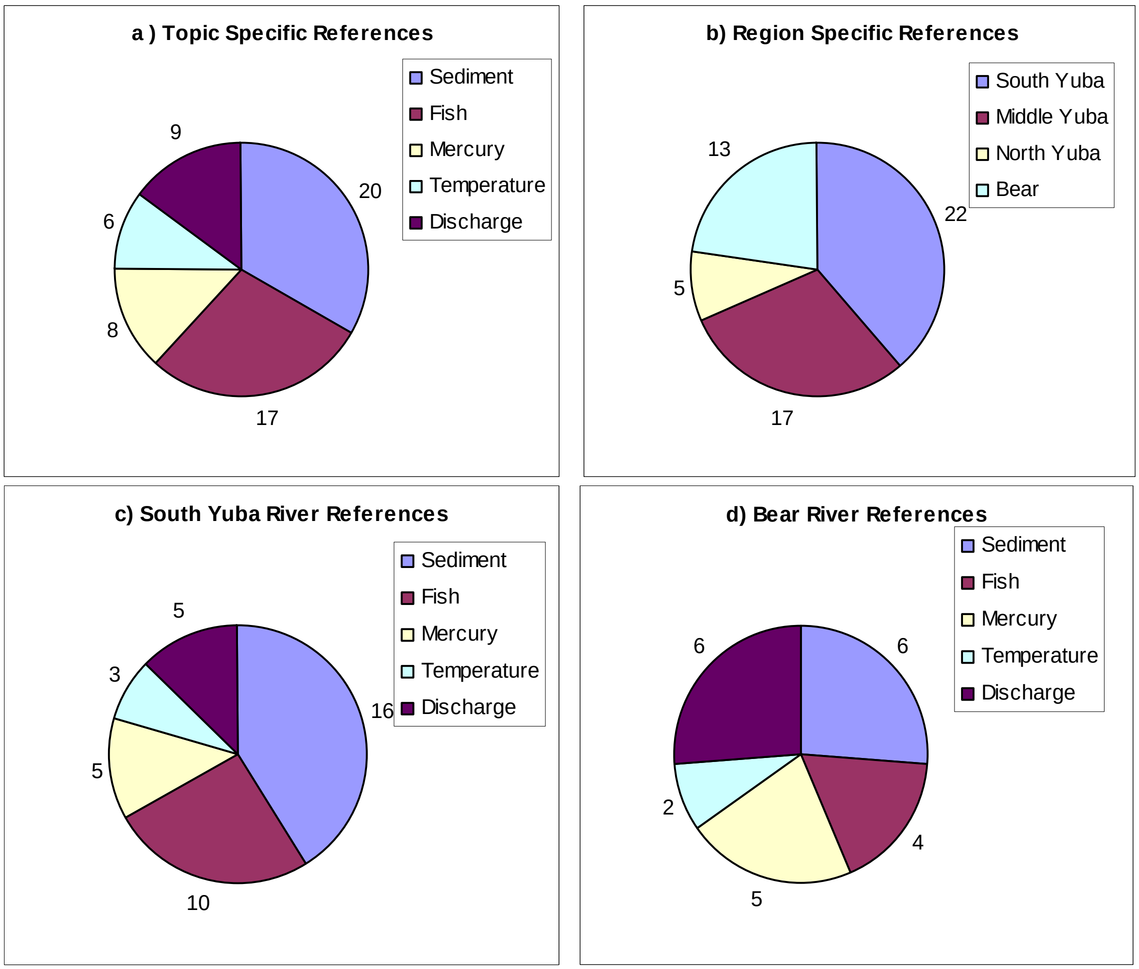

Table 1: At-a-Glance Data for the Yuba Bear Watersheds

Topic	Author	Date	Location	Description
Fish	Gast et al.	2004	South and Middle Yuba	Snorkel Counts between Aug. 21 2004 and Sep. 4 2004 at 18 runs randomly selected on South Yuba, 14 runs on Middle Yuba, 24 pools on South Yuba and 9 pools on North Yuba
Fish	Kozlowski	2004	Lower Yuba River	Electroshocking and sorkel surveys during summer 2000, hourly water temperature data loggers deployed at 5 locations in summer 1999 and 2000, Physical habitat parameters at sampling sites included: water depth (cm), water velocity (cm/sec), substrate composition (i.e., pebble counts), and cover.
Fish and Temperature	CDFG	1988	Bear River	Evaluated streamflow and temperature with respect to Fish habitat needs, uses temperature studies developed by SSWD's consultants and temperatures collected once monthly associated with DWR's water quality assessment program at the USGS gage station site just downstream of Highway 65 near Wheatland.
Temperature	CH2MHill	Referenced in Gast et al. 2004	South and Middle Yuba	Temperature Data collected at 8 locations on Middle Yuba and 7 locations on the South Yuba in July 2004
Habitat	Yoshiyama et al.	2001	Yuba and Bear Watersheds	Determined historical distribution limits
Habitat	Shilling and Evans	2003	Bear River Watershed	Spatial data that represent: Plant Community Distribution, Invasive Plant Species, Monitoring Stations, Topography, Fire history, Land Ownership, County Plans, Population, Roads, Canals Ditches, and Water Storage Facilities, Mine Lands and Mercury
Mercury	Kuwabara et al.	2003	Bear River, Camp far West	During two sampling events, two replicate sediment cores from each of three reservoir locations were used in incubation experiments to provide flux estimates and benthic biological characterizations, measured benthic flux of mercury, comprehensive examination of transport processes affecting mercury dynamics in Camp Far West Reservoir
Mercury	May et al.	2000	Yuba and Bear Watersheds	161 fish samples analyses for mercury, from Englebright, Scotts Flat, Rollins, Lake Combie, Camp Far West, 14 stream sites; Bear River at Dog Bar Road, Little Deer Creek at Pioneer Park, Dear Creek at Willow Valley Rd.
Geomorphology, Macroinverts, Electroshocking	Randall	1994	South Yuba	Took 33 grab samples of substrate, 12 upstream of Humbug Creek, 21 downstream of Humbug Creek July and Aug 1991, sampled pools with fine sediment, conducted sediment grain size analysis, Took 36 macroinvertabrate samples July and Aug 1991, 8 from 3 riffles upstream of Humbug, 24 samples from 9 riffles from DS of Humbug, fish snorkeling on South Yuba at 150 pools and runs, at Missouri Bar, at sites 300 m above and below Humbug, and at 7 sites below Humbug In 1991 and 1992 also did electro fishing, and aged squaw fish as well as other fish caught.
Topic	**Author**	**Date**	**Location**	**Description**
Frogs	Yarnell	1997	South and Middle Yuba Tributaries	Sampled biota in summer of 1995 and 1996 at 40 sites on Kentucky Ravine, French Corral Creek, Owl Creek, Shady Creek, Rush Creek, Augustine Creek, Rock Creek, Spring Creek and Humbug Creek, sampled for foothill yellow frogs, bull frogs, California Newt and environmental variables

Frogs	Curtis et al	2000	Shady Creek	12 sampling sites on Shady Creek surveyed 4 times between fall 1997 and spring 1999 for foothill yellow frog, pacific tree frog, western toad, bull frogs, western pond turtle, common garter snake, and egg masses of FYF also measured hydraulic geometry and calculated bedload transport rates at sites
Sediment	Curtis et al	2006	Middle and South Yuba	Streamflow measurements and suspended-sediment samples were collected at four upper Yuba River gaging stations: Middle Yuba River near North San Juan (USGS station ID 11410000), South Yuba River at Jones Bar near Grass Valley (USGS station ID 11417500), Yuba River below New Colgate Powerplant near French Corral (USGS station ID 11413700), and Yuba River below Englebright Dam near Smartville (USGS station ID 11418000). Continuously recording optical backscatter sensors (OBS) were installed at the Middle Yuba River (11410000) gage and South Yuba River (11417500) gage to provide 15-minute time-series records of suspended sediment concentration
Sediment	James	2005	Middle and South Yuba	Developed a conceptual model of sediment dynamics in the Upper Yuba River, The conceptual model illustrates key processes controlling sediment dynamics in the upper Yuba River watershed and was tested and revised using field measurements, aerial photography, and low elevation videography. Field reconnaissance included mass wasting and channel storage inventories, assessment of annual channel change in upland tributaries, and evaluation of the relative importance of sediment sources and transport processes
Sediment	Allen	2005	South Yuba	Field surveys in 1989 sampled grid-sample counts of pebbles, bulk sample sieving of channel materials at 8 sites on South Yuba, calculated mean grain size and recorded percent frequency of quartz
Sediment		1989	Bear River	Valley cross-sections were surveyed at 22 sites to measure width, depth, and cross-section area of eroded mining sediment, Channel-bed grain intermediate-axis dimensions were sampled in 1985 throughout the basin
Sediment	Snyder	2004	Englebright	Sampled top 1 meter of Englebright sediments to date sedimentation rates using cores, calculated medial grain size of Yuba

Pending Corrected Data: Upper Yuba River Studies Project

The Upper Yuba River Studies Project (UYRSP) has not yet published its data nor final reports by agreement of the participants. The UYRSP habitat assessment and water quality and temperature monitoring could fill a gap in the data for the Yuba and Bear Rivers.

Temperature	UYRSP	2006	South and Middle Yuba	Modeled water temperatures in the South and Middle Yubas
Habitat	UYRSP	2006	South and Middle Yuba	Redd density

Habitat	UYRSP	2003	South and Middle Yuba	Fish barriers, holding habitat/pools, substrate size, large woody debris, cover, habitat type, confinement

2. Summary of Data Needs

This section outlines, existing data, data gaps, and the appropriate recommended study elements to fill them. For now, this analysis focuses primarily on Aquatic and Terrestrial Resources study elements in the context of FERC Relicensing. Recreation, Cultural Resources, Land Use, and Economics could be considered in a subsequent analysis.

2.1 Aquatic Resources

Macroinvertebrates

Macroinvertabrates are key indicators of stream health and provide the basis for a healthy food chain. To date there is no macroinvertebrate data available on the North Yuba, and limited macroinvertebrate data for the Middle Yuba. (Gard took 36 macroinvertebrate samples between July and Aug 1991 from riffles upstream and downstream of Humbug Creek on the Middle Yuba. There are also preliminary data available from the citizen-monitoring group SYRCL, for the Middle and South Yuba Rivers.) It would be helpful to the FERC relicensing effort to quantify the relationship between different flow regimes and macroinvertebrate habitat.

Fish

Fish data for the Yuba River include snorkel surveys in the South and Middle fork conducted in late summer 2004 by Gast et al 2004. The runs that were sampled were randomly selected. Pools were also surveyed. Kozlowski completed a summers worth of electroshocking and snorkel surveys in 2000 on the lower Yuba. The Department of Fish and Game evaluated the fish habitat needs in the Bear River and discussed these needs with respect to the current environmental conditions. The snorkel counts by Gast et al. were done to assess the extent of potential salmon habitat, using trout as a surrogate. However, their findings were not compared to water temperature. Understanding the relationship between fish habitat use and water temperature will be a key factor in determining flow release schedules. No data were collected for the North Yuba, and the tributaries were only preliminarily assessed. As a result the habitat needs for native fish assemblages, including Spring-run Chinook, speckled dace, riffle sculpins, and California roach, are incomplete.

To date there are no data on fish population dynamics in the North Yuba, and little to no data on non-trout fish species in the South Yuba, Middle Yuba or Bear rivers. Additional information needs are to determine native fish population abundance and distribution (including growth, age class distribution, and health) in the Bear River, in the Yubas and in the major tributaries. This could be done in part with a population dynamics model for Spring-run Chinook, speckled dace, riffle sculpins, and California roach. These modeling efforts would require complementary field work to support and validate findings. In addition to understanding the population dynamics of native fish populations it is also essential to evaluate predation and bias of the system for other non-native sportfish (bass, blue gill, green sunfish in relations special-status species) i.e. predation of native and non-native fish on special on special- status species due to altered system conditions. This includes evaluation of predation effects due to reservoirs.

Habitat

It is essential to characterize existing aquatic habitat in the mainstems of the Yubas and Bear Rivers as well as to evaluate tributaries as potential refugia. There are numerous aquatic and terrestrial components that together make up habitat for a multitude of species and it will be essential to develop a limiting factors analysis to target specific habitat components for additional monitoring and evaluation.

Despite the work that has been done to describe habitat characteristics by the UYRSP, there are still many unknowns. For example, additional research is needed on water quality and its impact to sensitive species, such as the temperature regime and its relationship to suitable habitat for native fish and amphibians. Additional data on macroinvertabrates, key indicators of aquatic habitat suitability, water quality and environmental conditions, would be an excellent metric for measuring and monitoring habitat conditions throughout the length of the rivers.

Riparian

Of the studies that were reviewed there were not any that included vegetation surveys or transects of the riparian area. However, the Upper Yuba River Studies program took low altitude videography which may contain useful information on the current status of the riparian area. In addition, the channel cross sections conducted by Yarnell 2000 may be useful for predicting the extent of inundation in the riparian area for different flow releases. Additional cross sections and vegetation transects will be necessary to generate an accurate picture of riparian floodplain habitat and its relationship to proposed flow regimes. Data on the distribution and condition of existing riparian resources should be collected (regeneration, encroachment into channel, health, and vigor). In addition, the study should characterize the relationship between reservoir water surface elevations and aquatic resources and reservoir marginal vegetation by comparing former riparian habitat now replaced by reservoir and shoreline habitat.

Sensitive Species

Surveys of Foothill Yellow Legged frogs, bull frogs and the California Newts were conducted on the tributaries of the Middle and South Yubas (Yarnell 2000, Randell 1997) but the other reaches of interests are lacking such data. Tributary junctions on the Middle Yuba at the confluences of Oregon Creek, Wolf Creek, Owl Creek, Spring Creek, Mckilligan Creek and Poorman Creek have been found to be hotspots for biodiversity especially during high summer temperatures (See Randall 1997). As a preliminary step on this issue it is necessary to document the spatial-status of amphibians and reptiles and their habitat that are found in the project area. Specifically the habitat of Foothill Yellow Frogs and their use of tributaries should be studied in greater stream reaches on Spring, Rush, and Humbug Creeks. In addition, the bullfrog populations and the threat they create to the Foothill Yellow Legged Frog populations should be studied.

Hydrology

There are a number of USGS operated gages on the South, Middle and North Yuba Rivers and one on the Bear River.

The USGS gages are:

Station number 11414250 South Yuba River at Langs Crossing
Station number 11417500 South Yuba River at Jones Bar
Station number 11408880 Middle Yuba River below Our House Dam

Station number 11408550 Middle Yuba River below Milton dam
Station number 11413000 North Yuba below Goodyears Bar (10/1/1930-present)
Station number 11421000 Lower Yuba River near Marysville (10/1/1943-present)
Station number 11424000 Bear River near Wheatland (10/23/1928-present)

The USGS gage data includes, real time data, daily data, peak flow data and annual data. A hydrograph component analysis is necessary to compare unimpaired (pre-project or modeled data) and impaired flows (current and proposed operations); identify and evaluate project betterments that could enhance the availability of cold water to the streams; and evaluate the potential habitat effects of increased flow releases below Milton or Spaulding. The hydrograph component analysis should evaluate, summer base flows, winter floods, winter base flows, spring snowmelt runoff peak flows and recession limbs for unimpaired flows and current flow regimes. These data should be evaluated with respect to aquatic habitat and riparian habitat. Licensees are required to submit flow data to FERC that demonstrates compliance with minimum flow requirements of FERC licenses.

Temperature
The most immanent data gap in the Yuba-Bear watershed is the lack of temperature data. Gast et al. 2004, reference data collected by CH2M Hill. CH2MHill deployed temperature loggers on the Middle Yuba in eight locations and at seven locations on the South Yuba in the summer of 2004. In addition to these data, the Upper Yuba River Studies Program modeled temperatures in South and Middle Yuba. On the Bear River the California Department of Water Resources collect temperature data at the USGS gage station just downstream of Highway 65 near Wheatland once monthly. However, at this time there is no record of continuous temperature data collected on the Yubas nor on the Bear. In addition, no data exist on the flow and temperatures of tributaries to the Yuba and Bear Rivers, which would be helpful for determining project effects on temperature and flow regimes.

There are at least three atmospheric continuous monitoring stations nearby – Browns Valley, Blue Canyon, and Grass Valley. Continuous temperature loggers should be deployed at key locations throughout the South, Middle, North and Bear River basins to be able to characterize temperature variations for reaches of the Yubas and the Bear. The deployment of continuous temperature loggers along the length of the Yuba and Bear Rivers should be coupled with air temperature loggers. In addition, adequate data on reservoir temperatures do not exist, which will provide a description of the volume of the "cold water pools" available throughout the hydro projects..

Sediment
Data showing the connection between hydrology, sediment transport rates and habitat are currently lacking. Curtis et al. (2005) developed a conceptual model of sediment dynamics in the Upper Yuba River. The conceptual model illustrates key processes controlling sediment dynamics in the upper Yuba River watershed and was tested and revised using field measurements, aerial photography, and low elevation videography. This conceptual model and the work done by Curtis et al. (2006) where streamflow and suspended-sediment samples were collected at four upper Yuba River gauging stations, are the best up-to-date resources in the unique challenges that the Middle and South Yuba rivers face with respect to returning sediment dynamics to pre project conditions. This work did not however, evaluate gravel recruitment needs for fish spawning below dams and changes in sediment distribution resulting from the project in relation to heterogeneity in substrate sediments.

Table 2: Summary of Key Data Gaps

SUBJECT	North Yuba	Middle Yuba	South Yuba	Bear
Aquatic				
Fish	No data avail	Need limiting factors analysis, non-trout fish Spring and Steel population dynamics	Need limiting factors analysis, non-trout fish Spring and Steel population dynamics	No data available, just historical accounts
Macros	No data avail	Need macro surveys	Need macro surveys	Need macro surveys
Habitat	No data avail	Need info on passage flows Thermal refugia, Habitat for non-native trout	Need info on passage flows thermal refugia, Habitat for non-native trout	Need info on passage flows thermal refugia, Habitat for non-native trout
Riparian	No data avail, Need info on dams and riparian vegetation and riparian focal species health	Need to relate to Flood Flows, need info on dams and riparian vegetation and riparian focal species health	Need to relate to Flood Flows, need info on dams and riparian vegetation and riparian focal species health	Spatial Data need to be ground truthed, need info on dams and riparian vegetation and riparian focal species health
Sensitive Species	Need info on Spring YLF surveys, California newt	Need info on Spring YLF surveys California newt, Bull Frogs	Need info on Spring YLF surveys California newt, Bull Frogs	Need into on Spring YLF surveys and California newt, Bull Frogs
Hydrology	Need info on hydrologic alteration	Need info on hydrologic alteration	Need info on hydrologic alteration	Need info on hydrologic alteration
Sediment	No data avail,	Need to relate to Habitat Need info on dams and sediment transport/gravel recruitment	Need to relate to Habitat Need info on dams and sediment transport/gravel recruitment	Need to relate to Habitat Need info on dams and sediment transport/gravel recruitment

3. Literature Reviews

This next section provides a summary review of priority references. They have been grouped into the following topics: Fish in the Yuba and Bear, Frogs in the Yuba, Sediment in the Yuba and Bear, and Bear River.

3.1 Fish in the Yuba and Bear

Gast M., M. Allen S. Riley. Middle and South Yuba Rainbow Trout Distribution and Abundance Dive Counts August 2004 Final Draft. Tomas Payne and Associates Arcata CA; 2005.

Collected data from July and August 2004 on the Middle and South Forks of the Yuba River to determine the relationship between water temperature and distribution of salmon habitat, this was done by assessing the endemic rainbow trout population, abundance and distribution as a surrogate for salmon.

What they did:

- Conducted snorkel counts between Aug. 21, 2004 and Sep. 4, 2004 at runs randomly selected in the South and Middle Yuba Rivers
- Surveyed 18 runs on the South Yuba and 14 runs on the Middle Yuba, 24 pools were surveyed on the South Yuba and 9 pools were surveyed on the North Yuba
- The South Yuba was running at 15-40cfs and ranged from 63.1-78.5 F degrees.
- The Middle Yuba was running 8-40cfs and ranged from 52.7-74.9 F degrees.
- Calculated fish per river mile
- Compared fish density/mile by size class, plotted against river mile, compared distribution to mean July temperatures and compared fish index to other California Streams
- The Thermal refugia temperature was measured wherever fish were clustered, in stratified pools and or above and below tributaries
- Did a qualitative assessment of all tributaries; visually estimated streamflow, measured water temp, visually assessed rearing potential of lower reaches 1,000-2,000ft upstream of confluence or until a barrier was encountered

What they found:

- Trout were more frequently found in pools than in riffle or runs

- Density of trout increased up to river mile 18.1 on South Yuba and up to 17.1 on Middle Yuba Average fish density was 1,506 trout/mile on Middle Yuba and 1,402 trout/mile on South Yuba

- Above river mile 18 there was no more trend and average was 204 trout/mile for Middle Yuba and 273 trout/mile on South Yuba

- Found that Fry were more frequent in riffles than in pools

- And that the index of fry increased as you moved upstream up to river mile 27.5 on Middle and South Yuba Rivers

- Deep pools were the only cool water refugia found, only 2 pools were stratified in South Yuba and only 1 pool was stratified in Middle Yuba (it was hypothesized that deep stratified pools could be a thermal refuge for fish)

- Used CH2MHill Temperature Data collected at 8 locations on the Middle Yuba and 7 locations on the South Yuba in July 2004, made linear regressions to extrapolate average temps at snorkeling sites

Assumptions they made:

1) Endemic trout populations is a good surrogate for salmon habitat
2) Snorkeling methodology did not use nets
3) Randomly selected runs adequately represent the variability in the system
4) Time period snorkeled in August can be compared to stream temps in July
5) Assumed that sampling runs would be the best indicator of habitat use when in reality stressed fish are more likely found in pools

Data Gaps:

- Continuous air and water temperature is needed and would give a better idea of thermal refugia as a result of buffering (difference between air and water temperatures) by hyporeic, tributary inputs or pool stratification
- Many areas were not covered in this survey, how much of the total habitat was actually snorkeled
- Analysis of barriers to fish passage need to be completed as this study was done at low water period only, and therefore barriers would have seemed more prominent that at higher flows, in addition barriers may have been missed due to the random sampling design (See UYRS 2003)
- What is considered impassible by fish needs to be defined and may be quite different from trout versus salmon and dependant on a number of habitat variables that relate to stress (See UYRS 2003)
- There was no fish data collected on the North Yuba which was significantly cooler
- Tributaries that seemed like good habitat and refuge from thermal stress were not sampled adequately, data is needed on tributaries specifically Oregon Creek and Wolf Creek on the Middle Yuba and on Owl Creek, Spring Creek, Mckilligan Creek and Poorman Creek on the South Yuba. (See Randal 1997, UCD masters)

Yoshiyama, RM. E. R Gerstung F. W. Fisher and P B. Moyle. Historical and Present Distribution of Chinook Salmon in the Central Valley Drainage of California . Contributions to the Biology of Central Valley Salmon ids. RL. Brown, ed. CDFG Fish Bulletin 179; 2001.

What they did:

- Used historical narratives and ethnographic accounts, fishery records and locations of in-stream natural barriers to determine the historical distributional limits and describe the abundances of Chinook salmon.

- Compare the historical distributional limits with present day distributions

- Give individual synopses for each of the larger streams

What they found:

- 1,057 miles (48%) of stream lengths historically available to salmon have been lost from the original estimate of 2,183 miles in Central Valley Drainages

- That corresponds to 72% of the spawning or holding habitat that has been lost

- Upper limits of the salmon migration:

    - North Fork of the Yuba: Mouth of Salmon Creek near Sierra City

    - Middle Yuba: Falls about one mile above juncture with North Fork or 1.5 miles upstream of the mouth at a 10ft falls

    - South Yuba: A falls 0.5 miles below Humbug Creek

    - Bear River: Waterfall near location of Camp Far West

    - Bear river was only a Fall run, but was totally decimated by the hydraulic mining by 1876, it apparently has no suitable holding habitat for a Spring-run

    - When Englebright was constructed in 1930 it all but eliminated the Spring-run Chinook, a small population was said to have hung on until as late as 1995, but because of overlapping spawning areas they genetically mixed with the Fall-run Chinook

Assumptions they made:

- That primary source documents were an accurate way of determining the extent of salmon and steelhead migration, for example some accounts reference "salmon-trout" and by this it is assumed to be a reference to steelhead

May, J. T. RL. Hothem CN. Alpers and M. A. Law. Mercury Bioaccumulation in Fish in a Region Affected by Historic Gold Mining: The South Yuba River, Deer Creek, and Bear River Watersheds, California, 1999. U.S. Geological Survey Open-File Report 00-367; 2000.

What they did:

- Took fish samples from South Yuba River, Deer Creek and the Bear River
- Analyzed those tissue samples for mercury concentrations
- Compared results to two different thresholds, 0.3 ppm which is the OEHHA screen and 1 ppm which is the FDA action level

What they found:

- 21 fish from Englebright, 14 from SYR arm near Point Defiance Campground, others from Hogs back ravine, 14 small mouth bass and 3 spotted bass were >0.3ppm the mean was 0.63 ppm; small mouth bass showed a trend in an increase in mercury with length
- 12 fish from Scotts Flat Reservoir, 6 were >0.3ppm none were greater than 0.5 ppm, mean was 0.36ppm, largemouth had the highest concentration of mercury
- 28 fish from Rollins Reservoir, 18 from Bear River Arm, 10 from Greenhorn Creek, 15 fish were > 0.3 ppm, catfish had the highest concentrations mean 0.35ppm, largemouth bass showed a trend in an increase in mercury with length range was from 0.2-0.45 ppm
- 13 fish were sampled from Lake Combie; 9 largemouth bass with a range of 0.74-1.2 ppm**!**, mean was 0.9 ppm
- 21 fish from Camp Far West, 14 from Bear River arm, 19 of 21 samples had greater than 0.3ppm, spotted bass range was from 0.58-1.5 ppm; previous study from Sutton 1997, showed samples with a range of 0.4-0.65 This may indicate problem is getting worse, from dredging and accumulating sediment in the reservoir
- Stream habitats sampled, 14 trout sampled all with levels below 0.3ppm
    - Bear River at Dog Bar Road; 3 fish range was 0.38-0.48ppm
    - Little Dear Creek at Pioneer Park; 6 brown trout mean was 0.32 range was 0.23-0.39 Dear Creek at Willow Valley Rd; four brown trout 0.11-0.32ppm Data Gaps:

- Special need to investigate Reservoirs, because of possible mercury accumulation from sediment and in foodchain of reservoir species such as the largemouth bass and catfish, this could have real relevance to reservoir operations

Kozlowski, Jeffrey F. Summer distribution, abundance, and movements of rainbow trout (Oncorhynchus mykiss) and other fishes in the lower Yuba River, California ; 2004Summer distribution, abundance, and movements of rainbow trout (Oncorhynchus mykiss) and other fishes in the lower Yuba River, California.

What they did:

- Backpack electrofishing and snorkeling techniques were used to identify factors related to summer distribution, abundance, and movements of rainbow trout and other species in the lower Yuba River were in 1999-2000 on the portion of the river between Marysville, at rkm 5.2, and The Narrows, at rkm 35. Within the study area, the lower Yuba River can be divided into 4 reaches based on hydraulic conditions, channel slope and morphology, and fish species distribution. These reaches from downstream to upstream are: Reach 1: First Riffle Upstream of Simpson Lane Bridge (rkm 5.2) to Western Boundary of Yuba Goldfields (rkm 13.4). Reach 2: Western Boundary of Yuba Goldfields (rkm 13.4) to Daguerre Point Dam (rkm 18.4). Reach 3: Daguerre Point Dam (rkm 18.4) to Upstream Side of Long Bar (rkm 26.0). Reach 4: Highway 20 (rkm 26.0) to The Narrows (rkm 35.7).
- Fishes were sampled from shallow water river margins and side channels in the LYR with a battery-operated Smith Root (Type 12B) electrofisher in two separate periods during 2000: 3–14 July and 25 August – 11 September. Nineteen sampling sites were chosen for study in the study area, each sampling site was 30–meters long and approximately 3–meters wide. (Runs dominated sampling sites, although riffles were also sampled)
- Snorkel surveys of mid-channel habitats of the LYR were conducted during two separate periods in 2000: 28 July – August 8 and 13 – 25 September. Snorkel surveys sampled midchannel habitats that were not electrofished. The LYR study area was divided into 54 channel segments based on the dominant habitat type (i.e., pool, riffle, run).
- Snorkel surveys of river margin habitats were conducted 21–24 August 2000, at each one of the 19 sampling sites. These snorkel counts were initiated immediately prior to the second electrofishing period to provide a comparison of the species and number of fish occupying these sites.
- The Department of Fish and Game provided records of fish captured daily at the Hallwood-Cordua fish screen as part of salvage operations from April to August in 1999 and 2000. In addition, DFG provided records of fish captured at the Hallwood RST operated near Hallwood Boulevard from November 1999 to June 2000 and from October 2000 to April 2001. These records included counts, lengths, and weights of rainbow trout captured in each 24-hour period.
- Physical habitat parameters measured at each of the 19 sampling sites included: water temperature, water depth (cm), water velocity (cm/sec), substrate composition (i.e., pebble counts), and cover. Water temperatures were taken with a hand held thermometer. Water velocities were measured with a Marsh-McBirney electronic flowmeter. Water depths were measured to the nearest 3.0 cm with a metal graduated wading rod at 0.5 m increments from shore.
- Yuba County Water Agency provided records of daily flows measured below Englebright Dam at the Smartville stream gaging station (USGS 11418000) and below Daguerre Point

Dam at the Marysville stream gaging station (USGS

- Hourly water temperature data were obtained from automated water temperature loggers deployed at up to 5 locations in 1999 and 2000.
- Fish numbers determined by electrofishing were converted to catch-per-unit-effort (CPUE, number of fish per hectare).
- Snorkel counts of rainbow trout in mid-channel habitats were converted to density (i.e., number of fish per hectare).
- Channel segment lengths were determined from aerial photographs by measuring the thalweg distance of each channel segment with a planimeter.

What they found:

- A total of 6,224 fish, representing 8 taxa in 6 families, were collected in the study area during the two electrofishing periods. All fish collected, with the exception of one green sunfish, were native species. Rainbow trout (3,053) dominated the catch, followed by prickly and riffle sculpins (2,079), speckled dace (730), Sacramento sucker (309), Sacramento pikeminnow (46), Chinook salmon (5), tule perch (1) and green sunfish (1). The majority of fish collected were juveniles, although adult sculpins and speckled dace also were collected.
- Rainbow trout were the dominant species collected at most of the sites upstream of DPD; speckled dace were the dominant species collected immediately upstream of the dam (Sites 10 and 11).
- Sculpins were the dominant species collected at all sites downstream of DPD (Sites 1-9). Although rainbow trout and sculpins were collected from sites downstream and upstream of DPD, respectively, species abundance at these locations was low.
- Overall, sculpins were the second most abundant species captured by electrofishing, and were the most abundant species collected downstream of DPD (i.e., Sites 1-9; Figure 8). Catches exceeded 4,000 fish/hectare at all sites below the dam and the highest catch was recorded at Site 8 during electrofishing Period 1 (13,013 fish/hectare; Table 6). Upstream of DPD, sculpins were collected only at the 4 sites nearest the dam (i.e., Sites 10-13). Abundance at each of these sites was less than 140 fish/hectare.
- Some evidence also suggests that Daguerre Point Dam could be limiting upstream movement of native sculpins
- Upstream distribution of striped bass and American shad was limited by Daguerre Point Dam, which therefore limits their predatory impact on salmonids above the dam.
- Juvenile and adult abundance progressively increased in an upstream direction and appeared to be positively related to river gradient. Age-0, juvenile, and adult rainbow trout predominated in upper river habitats while native and alien non-salmonids predominated downstream. Age-0 rainbow trout distribution patterns appeared to be related to the distribution of adult spawners
- Age-0 and adult rainbow trout were observed throughout the entire study area, but summer densities were highest in upstream habitats and generally declined with increasing distance from The Narrows. The decline in abundance of age-0 rainbow trout over the summer probably reflects changes in habitat use, mortality, and emigration
- Age-0 rainbow trout density was negatively correlated with water temperature and average mean water column velocity. Age-0 rainbow trout density was positively correlated with river kilometer, elevation, median substrate size, and substrate cover.
- The distribution of age-0 rainbow trout appears to be related to the distribution of spawning adults and redds, the majority of which occurred between Long Bar and The Narrows in winter and spring 2000. This highlights the importance of the upper reaches of the river as spawning and rearing habitat for LYR rainbow trout
- The positive correlation between age-0 density and both median substrate size and the number of unembedded cobbles is supported by observations of age-0 rainbow trout hiding in substrate interstices and suggests that substrate cover is an important component of age-0 rainbow trout habitat in the LYR.
- Downstream movement in age-0 rainbow trout occurred throughout the summer and daily counts were highest immediately preceding and following the new moon. Water temperature

and flow did not appear to cause age-0 rainbow trout to initiate these downstream movements

- Greater numbers of juvenile and adult rainbow trout were observed in pool rather than in run habitats and pools were present more frequently in the steeper upstream areas.
- Similarities and differences between results of electrofishing and snorkeling emphasize the necessity of using two or more sampling techniques to accurately assess fish distribution and abundance in the lower Yuba River. Snorkeling appeared to underestimate age-0 rainbow trout numbers at sites where electrofishing yielded relatively high catches. This was attributed to age-0 rainbow trout occupying the interstices of the substrate. Conversely, snorkeling appeared to be a better estimator of fish density at sites where electrofishing yielded low numbers and was attributed to rainbow trout fleeing sampling sites rather than hiding in the substrate as the electrofishing crew sampled the river margin. The tendency for diver counts to underestimate the abundance of cryptic species also was likely a factor in the lower counts of nonsalmonid species, compared to electrofishing.

Data Gaps:

- Do the rainbow trout in the LYR represent migratory (steelhead) or non-migratory life history forms. Understanding whether sympatric steelhead and non-migratory rainbow trout are a single population or 2 reproductively isolated populations also has significant implications concerning the conservation of the species.
- Additional information from other seasons would be helpful to determine what other habitats are important.
- More detailed studies of spawning habitat use and availability is warranted. These studies should identify the factors (e.g., flow, temperature, water depth and velocity, gravel composition and permeability, and other factors) that are most important for successful spawning. This information would help to identify whether spawning habitat is limiting in the river, especially in downstream reaches. This information would then be useful in guiding habitat restoration in the lower Yuba River.
- Some studies have shown that the biomass of trout increased after the number, depth, and total volume of pool habitats increased after structures were added to the stream (Bjornn and Reiser 1991). Furthermore, reestablishing a pool-riffle sequence in these reaches may improve hydraulic and sediment transport and deposition processes necessary for establishing suitable spawning habitat.
- Efforts to increase shaded river aquatic (SRA) cover through riparian habitat restoration, channel restructuring, and biotechnical approaches would increase the quantity and quality of cover for fish. Fish abundance in streams has been positively correlated with the abundance and quality of cover (Bjornn and Reiser 1991). Increasing shade along river margins would also reduce solar heating in nearshore areas, thereby reducing water temperatures in these areas.
- Additional information is needed on the effects of DPD on fish community structure and fish movements. Specifically, research is needed to determine the fate of age-0 rainbow trout that pass over DPD while dispersing downstream. Fish trapped in the Hallwood-Cordua canal bypass could be used as a control in mark-recapture experiments to determine whether DPD is hindering downstream dispersal of fish through increased injury rates or through increased mortality resulting from predation immediately downstream of the dam.

Gard, Mark Freeman. Biotic and abiotic factors affecting native stream fishes in the South Yuba River, Nevada County, California : UC Davis; 1994Shields LibraryMicrocopy CollectionLD781.D5j 1994 G375.

What he did:

- Generated stream profile using USGS maps and underlying rock types for Jennings 1977, to compute a plausible equilibrium profile and look for any knick points
- Took 33 grab samples of substrate, 12 upstream of Humbug Creek, 21 downstream of Humbug Creek between July and Aug 1991, sampled pools with fine sediment, conducted sediment grain size analysis, specifically compared percent by weight for substrate between 0.3-3.35 to look for significant difference upstream and downstream of Humbug Creek Took 36 macroinvertabrate samples between July and Aug 1991, used kick net screen, 8 from 3 riffles upstream of Humbug, 24 samples from 9 riffles from DS of Humbug Measured average water depth, velocity and median grain size
- Conducted fish snorkeling on South Yuba at Missouri Bar, at sites 300 m above and below Humbug, and at 7 sites below Humbug (Illions crossing, Edwards crossing, Purdon Crossing, Hoyt Crossing, Jones Bar, and at Bridgport)
- In 1991 and 1992 also did electrofishing, and aged squaw fish as well as other caught

What he found:

- The South Yuba river stream profile is not in equilibrium, there is a knick point 1 km downstream of Edwards Crossing
- Substrate did not vary significantly upstream compared to downstream of Humbug Creek Malakoff Diggens sediment load did not effect the biota due to sediment starved state of river
- There was no significant difference between macroinvertebrate functional groups above and below Humbug Creek, due to limited duration and frequency of suspended sediment loading or that populations recovered from Fall rain events by the time summer sampling was done Speckled dace, riffle sculpin, California roach, and rainbow trout all could have been extirpated from South Yuba River by tremendous sediment loads from hydraulic mining, where as squawfish, hardhead, sacramento sucker and rainbow trout could have moved far enough upstream to avoid impacts of sediment loads

Data Gaps:

- Restoring the native fish assemblage requires more information on the environmental habitat needs of the entire native fish assemblage such as speckled dace, riffle sculpin, California roach

- Reintroduction of these species, monitoring and management of tributaries is needed to restore the native fish assemblage as well as reduced summertime temperatures

- Reducing hydraulic mining sediment loads is not necessary at this time, due to the sediment starved state of the Yuba already (this does not take into account the fact that much of the hydraulic mining sediment, though the right size for spawning, may carry heavy medals that are toxic to aquatic biota and their eggs)

3.2 Frogs in the Yuba

Randall, Paul J. Distribution and ecology of fish and frogs in tributaries to the South Fork Yuba River. 1997; 1997mastersShields Library Microcopy Collection

What he did:

- Sampled aquatic biota in the summers of 1995-1996 in 9 tributaries at 40 sites and analyzed species abundance with respect to environmental variables using step-wise regression
    - o Kentucky Ravine, French Corral Creek, Owl Creek, Shady Creek, Rush Creek, Augustine Creek, Rock Creek, Spring Creek, and Humbug Creek
- Sampled 7 farm ponds to determine aquatic species composition and determine if they were a source of non-native species in nearby in-stream habitat
- Surveyed streams to determine presence of foothill yellow-legged frog, bull frogs and California Newt, surveyed Rush Creek, Spring Creek, and Humbug Creek
- Investigated the effects of suspended sediment on fish in Humbug creek, above and below Malakoff Diggings

What he found:

- Table 1: Fish and amphibians found in the South Fork of the Yuba River compared to Tributaries (page14)
    - o The tributaries provide refuge for several native species unable to persist in the main stem, such as trout, roach, and the sucker
- Table 2: Means of environmental variables for fish and amphibians species in tributaries to the South Fork of the Yuba (pg 16)
    - o Trout are positively correlated with low temperatures, steep gradients, in-stream shade and water depth
- Table 3: Total number and density of Foothill yellow-legged frog for three tributaries (page 21)
    - o Total number and density of Foothill yellow-legged frog for three tributaries shows that in Spring Creek 4 frogs were found in 1995 and 7 were found in 1996; 15 frogs were found in Rush Creek and 4 were found in 1996; 1 frog found in Humbug Creek in 1995 and 4 found in 1996

- Suspended sediment from active mine on Spring Creek is a potential threat to the largest Yellow-legged frog population in the study area, bull frog invasion, sediment loads, and altered flows are threatening native frog populations

- Natural barriers limit the available habitat for native fishes

- Upstream fish assemblages are largely the result of non-native introductions

- Suspended sediment negatively effects trout in Humbug Creek

Assumptions he made:

- Frog surveys were conducted in the worst possible time of year, at the time of tadpole metamorphosis, which is the most difficult time to capture and locate foothill yellow-legged frogs

Data Gaps:

- Greater lengths of tributaries should be sampled for yellow-legged frogs in the Spring, and their micro habitat locations should be marked and protected, surveys should especially be done in Spring, Rush and Humbug Creeks. This should be done in conjunction with wide spread bull frog eradiation efforts focused on the ponds (See Yarnell, UCD masters 2000) The Best method of bull frog eradication need to be developed

Yarnell, Sarah Munro. The influence of sediment supply and transport capacity on foothill yellow-legged frog habitat, South Yuba River, California ; 2000mastersShields LibraryMicrocopy CollectionLD781.D5j 2000 Y374.

What she did:

- Used process-based geomorphic techniques to better understand channel dynamics and discern aquatic habitat preferences of the Foothill yellow-legged frog (species of special concern in the state of California, that relies solely on stream habitat)

- Evaluate hydraulic geometry, bedload transport rates, and relationship between transport capacity and sediment supply with respect to physical stream process and R.boylii habitat preference

    o Processes that control channel shape (hydraulic geometry) and surface texture (dimensionless bedload transport q*(the ability of the flow to move the channel surface sediments and the channel ability to move the bedload supplied to the stream) acts like an index that reflects the geomorphic response of channel habitat to various basin conditions)

    o 12 sampling sites (figure 4, pg 54, table2, pg 76), channel cross-sections at each site and long profile, discharge measurements (float timed method over 5m), calculated cross-sectional area, estimated bankfull water-surface elevations, pebble counts o 4 Frog surveys, between fall of 1997 and spring of 1999, walked 2-3 km reach with three observers, visual ID and count, measured without handeling them, and did egg mass surveys, also identified, pacific tree frog, western toad, bull frogs, western pond turtle, common garter snake

o Summer of 1997, spotted 38 adults, 150+ tadpoles, July 1998, spotted 10 adults, 20 juveniles, 200+ tadpoles, October 1998 spotted 82 adults and 330 juveniles

- Conducted field analyses on Shady Creek, tributary to South Fork of the Yuba, between the town of Bridgeport and Lake Spalding, and has lots of hydraulic mining debris, still has wide braded reaches from mining debris

    o There is one artificial pond, Ponderosa Pond, and it has bullfrogs, at weir site just under Shady Road bridge near station 9970m, perennial pools in adjacent creek have small established bullfrog population

- Compared population density of R.boylii age class to geomorphic characteristics at the cross-section and reach scale

    o At-a-station hydraulic geometry, give quantified description of channel morphology, bedload transport rate

- Do wide shallow channels with stable, low-mobility bed surface textures will support more R. boylii

What she found:

- Single channel morphologies are defined by bankfull flows
- Channel shape at different flow regimes are determined by hydraulic geometry and channel bed mobility and profoundly affects aquatic habitat
- Different life stages of R.boylii prefer different channel morphologies and substrate characteristics

    o Young frogs prefer swift, narrow channels in fall (perhaps for protection or temperature control) and retreat to wide shallow banks with protected overflow areas in winter and spring

    o Adults prefer deep, narrow pool-type habitats year round, data suggests that adults prefer habitats with an intermediate relationship between sediment supply and transport capacity, indicating that channel bedforms and large grain sizes play a key role in habitat suitability

    o Juveniles prefer swift flowing habitats in fall and a variety of habitats in spring

- Shady creek is a relatively lower mobility channel bed and preferred by R. boylii

Data Gaps:

- Need to understand flows that flush fines through a stream system but do not adversely modify the size distribution of the material to manage aquatic habitat restoration. We need a sediment budget for the South Yuba and relate to water management activities and sediment transport to define these special flows. Specifically how the temporal and special variability in the bottom shear stress effect the diversity of bentic communities, dynamic flow regime is essentiual to provide heterogeneity in substrait sediments for health successful communities.

- Stream restoration for one species such as salmonid spawning habitat sometimes has deleterious effects on other less studies species. We need to know how restoration/changes in water management would impact R.boylii and T.atratus (Western Aquatic Garter Snake), data on this is very limited.

3.3 Sediment in the Yuba and Bear

Curtis, J.A., Flint, L.E., Alpers, C.N., Wright, S.A., and Snyder N.P., 2006, Sediment transport in the Upper Yuba River Watershed, California, 2001–03, U.S. Geological Survey Scientific Investigations Report 2005-5246, 84 pp.

What they did:

- Sediment transport in the upper Yuba River watershed,California, was evaluated from October 2001 through September2003.
- Streamflow and suspended-sediment concentration (SSC) samples were collected at four gaging stations; however, this report focuses on sediment transport at the Middle Yuba River (11410000) and the South Yuba River (11417500) gaging stations.
- Streamflow measurements and suspended-sediment samples were collected at four upper Yuba River gaging stations (fig. 1; table 1): Middle Yuba River near North San Juan (USGS station ID 11410000), South Yuba River at Jones Bar near Grass Valley (USGS station ID 11417500), Yuba River below New Colgate Powerplant near French Corral (USGS station ID 11413700), and Yuba River below Englebright Dam near Smartville (USGS station ID 11418000). The Middle Yuba River (11410000) gage operated from 1911 to 1941 and from 2001 to present. The South Yuba River (11417500) gage operated from 1940 to 1948 and from 1959 to present. The Yuba River below New Colgate Powerplant (11413700) gage was established in 2001 but was abandoned in 2003 owing to a poor gaging record. The Yuba River below Englebright Dam (11418000) gage operated continually from 1941 to present. Daily records of streamflow and suspended-sediment loads for water years 2001, 2002, and 2003 (Raw data are in Appendix A)
- Suspendedsediment samples were collected 1 to 7 days per week at all gaging stations, depending on hydrologic conditions, and samples were collected at the Middle Yuba River (11410000) gage and South Yuba River (11417500) gage during four storms in water year 2003.
- Seasonal suspended-sediment rating curves were developed using a group-average method and non-linear least-squares regression.
- Annual suspended-sediment loads estimated using seasonal SSC rating curves were compared with previously published annual loads estimated using the Graphical Constituent Loading Analysis System (GCLAS).
- Continuously recording optical backscatter sensors (OBS) were installed at the Middle Yuba River (11410000) gage and South Yuba River (11417500) gage to provide 15-minute time-series records of suspended sediment concentration.
- The sediment rating curves and OBS time-series data were used to calibrate a watershed-scale sediment transport model (Flint and others, 2004) and to assess the magnitude and duration of sediment loads that may impact the viability of long-term fish-introduction strategies

What they found:

- The estimated average annual sediment yield at the Middle Yuba River (11410000) gage (5 tons/mi2) was significantly lower than that estimated at the South Yuba River (11417500) gage (14 tons/mi2). In both rivers, bed load represented 1 percent or less of the total annual load throughout the project period. Suspended sediment at the Middle Yuba River (11410000) and South Yuba River (11417500) gages was typically greater than 85 percent silt and clay during water year 2003, and sand concentrations at the South Yuba River (11417500) gage were typically higher than those at the Middle Yuba River (11410000) gage for a given streamflow throughout the three year project period.

- Factors contributing to differences in sediment loads and grain-size distributions at the Middle Yuba River (11410000) and South Yuba River (11417500) gages include contributing drainage area, flow diversions, and deposition of bed-materialsized sediment in reservoirs upstream of the Middle Yuba River (11410000) gage.
- Owing to its larger drainage area, higher flows, and absence of man-made structures that restrict sediment movement in the lower basin, the South Yuba River transports a greater and coarser sediment load.
- Another observation made during storm sampling was of anomalously high suspended-sediment concentrations at the Middle Yuba River (11410000) gage on December 16, 2002 (see inset figure 9B). Significant volumes of sediment are stored behind Log Cabin Dam and Our House Dam (fig. 1), which require periodic dredging (Yuba County Water Agency, 1989). During large runoff events, these facilities discharge water over their spillways, and previously impounded sediment may be scoured and conveyed downstream resulting in elevated suspended-sediment concentrations at the Middle Yuba River (11410000) gage.
- Group-average suspended-sediment rating curves for the Middle Yuba River (11410000) and South Yuba River (11417500) gages describe average, summer/fall, first flush, winter, and spring snowmelt conditions (
    - Variations in the slopes of the rating curves indicate changes in sediment supply throughout the water year. Under average and below-average precipitation conditions, such as occurred during the study period, sediment supply is greatest during the first flush of the water year; therefore, the first flush curves for the Middle Yuba and South Yuba Rivers have the greatest slopes. Sediment supplies decreased following the first flush; thus, the slopes of the winter rating curves are lower than those of the first flush curves. The spring and summer/fall rating curves had the lowest slopes, indicating lower sediment supplies during spring snowmelt conditions and throughout the dry summer and fall months.

Data Gaps:

- Rainfall-runoff conditions were below average during the first two years of this study and average during the last year. Because sediment transport is heavily influenced by extreme rainfall-runoff events, the results of this study are somewhat limited. Additional data collected during wetter years and at higher streamflows would greatly improve the value of the rating curves as tools to estimate long term transport.

Curtis, J. A. L. Flint and S. Yarnell. Conceptual Model of Sediment Processes in the Upper Yuba River Basin. Geomorphology. 2005; Vol. 68, (no. 3-4 (June 2005):p. 149-166.

What they did:

- Developed a conceptual model of sediment dynamics in the Upper Yuba River and groundtruthed it with field testing
- The conceptual model illustrates key processes controlling sediment dynamics in the upper Yuba River watershed and was tested and revised using field measurements, aerial

photography, and low elevation videography. Field reconnaissance included mass wasting and channel storage inventories, assessment of annual channel change in upland tributaries, and evaluation of the relative importance of sediment sources and transport processes

- We used GIS to spatially distribute the components of the conceptual model and created hillslope erosion potential and channel storage models.
- The conceptual model is partitioned into three components: hillslopes, upland tributaries, and mainstem channels (Fig. 3). The three components are further compartmentalized into hillslope sediment sources, channel sediment sources, and transport processes. Arrows with variable line thicknesses denote linkages between compartments and transport directions and indicate the hypothesized relative magnitude of basin-wide sediment transport (e.g., thicker lines represent greater transport).

What they found:

- Hillslope erosion rates throughout the study area are relatively low when compared to more rapidly eroding landscapes such as the Pacific Northwest and notable hillslope sediment sources include highly erodible andesitic mudflows, serpentinized ultramafics, and unvegetated hydraulic mine pits.
- ~5% of upper Yuba River hillslopes are highly erodible, 10% are moderately erodible, 28% are slightly erodible, and 57% are susceptible to negligible erosion;
- important hillslope sediment sources include andesitic mudflows, serpentinized ultramafics, and hydraulic mine pits;
- Mass wasting dominates surface erosion on the hillslopes; however, erosion of stored channel sediment is the primary contributor to annual sediment yield.
- The GIS models exemplify the conceptual model in that landscapes with low potential evapotranspiration, sparse vegetation, steep slopes, erodible geology and soils, and high road densities display the greatest hillslope erosion potential and channel storage increases with increasing stream order. In-channel storage in upland tributaries impacted by hydraulic mining is an exception. Reworking of stored hydraulic mining sediment in low-order tributaries continues to elevate upper Yuba River sediment yields.
- erosion of in-channel sediment from upland tributaries impacted by hydraulic mining will contribute to long-term upper Yuba River sediment yields;
- the central portion of the study area displays the greatest hillslope erosion potential, stores large quantities of active alluvium including an extensive glacial outwash terrace, and is considered an important sediment source area; and
- in-channel sediment stored in active to semiactive channel locations represents the principal sediment source in the upper Yuba River watershed
- Finally, we propose that spatially distributing the components of a conceptual model in a GIS framework provides a guide for developing more detailed sediment budgets or numerical models making it an inexpensive way to develop a roadmap for understanding sediment dynamics at a watershed scale.

James Allan J. Sediment from hydraulic mining detained by Englebright and small dams in the Yuba Basin . Geomorphology. 2005; doi:10.1016/j.geomorph.2004.02.016.

What he did:

- Documents historic hydraulic mining activity and sediment loads as well as discusses the Caminetti Act of 1893 where hydraulic mining was allowed to start back up again if the sediment could be retained. Table 1 pg 209 lists the drainage area, volume of sediment produced, from 1853-1884 and from 1893-1950

- Described detention structures brush and earth dams (often just mine tailing fans, some were debris controlled dams with no engineering, such as brush dams and log-crib dams), and pit storage, CDC records of "20^{th} Century mines and detention structures in report

- Describes modern river conditions, future sediment loads, reworked mine tailings, conducted field surveys in summer 1989, sampled deposits, grid-sample counts of pebbles, and bulk sample sieving of channel materials at 8 sites on South Yuba River and three tributaries (Table 4 page 218)

- Calculated mean grain sizes, intermediate-axis dimensions

- Quantified dilution and mixing of sediment from mining using relationship between quartz and proportion of tailings from hydraulic mines that worked the auriferous Tertiary channels, the percentage of quartz can be used to ascertain the relative importance of mine tailing is the stored material in and along the channels, recorded percent frequency of quartz in pebbles no larger than 50mm

What he found:

- Mine tailings are much finer-grains than channel lag and colluvial materials, mine tailing are mobile and suitable for spawning gravel

- In general found the norm that sediment grain size is more fine as you move downstream; but two exceptions, upper basin had very fine sediment –reflects the lack of coarse colluvium in wide valleys of the glaciated upper basin and very coarse sample found in lower Yuba –from narrow steep stretch of canyon at Highway 49 where colluvila boulders dominate the channel

- Tributaries are holding a lot of the mining sediment, have not got the stream power to flush them down-normally tribs have coarser material main channel, Shady Creek has a lot of mining debris in channel, Humbug Creek has passed a lot of material but is relatively clear because a tunnel was dug to pass the sediment to the main channel in 1870's

- Quartz concentrations in tributaries indicate that they are still receiving contributions of sediment from mining, but with substantial dilution from sediment from other sources

- Main channel is still passing mining sediments successfully; quartz analysis indicates that Main channel is still reworking mine tailings and it constitutes a proportion of sediment load: this contradicts Wave theory!

Data Gaps:

- Numerous detention structures in the Yuba basin built to store mine tailings and their associated sediment deposits should be located, tested for mercury, considered for treatment and or removal, need to assess the sedimentology and geochemistry of detention reservoir sediments for a feasibility assessment for their removal

- Need to sample sediment bed load (See Snyder 2004)

- Map and inventory the location of the 20th century detention structures, their volumes and chemistry, dam remediation or stream restoration plans should consider to remove, repair, or maintain small, poorly maintained orphan dams filled with tailings (such as breach at Scotchman Creek), these plans should consider the disposal or stabilization of sediment,but also the maintenance of gradual sediment releases to sustain spawning habitat, need for geochemical and biological studies that integrate findings of sediment toxicity and decisions about developing salmonid fisheries that may depend on sediment releases from these sites

- Assess dams that plugged tunnels to allow for storage of tailings in abandoned mines where wetlands may now be site of mercury methylation, such as Manzanita Mine pit that now holds a large pond-wetland complex

- Need for ridge to ridge assessment of mining hotspots and outline strategies for clean up

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. Reconstructing watershed history from reservoir stratigraphy: Englebright Lake, Yuba River, northern California. EOS, Transactions American Geophysical Union; 2004Fall Meeting Supplement (invited talk).

What they did:

- Investigated the long-term sedimentary response of a river system to changes in mining-derived sediment load and watershed management

- Sampled the top 1 meter of reservoir deposits with grab samplers, deep cores, box cores, and gravity cores to analyze changes in sedimentation pattern, use to reconstruct the history of flood and drawdowns

- Used 137 Cs, radioactive isotope from nuclear weapon testing in 1952-1954 to date cores

- Performed sediment transport calculations

What they found:

- Median grain size of Yuba River mainstem is 90.5mm (99% gravel, 1% sand) , on the South Yuba is 22.6mm (72%gravel, 28% sand)

- Reservoir sedimentation rates, declined 26% between the first and second 30 year periods looked

Data Gaps:

- Despite the presence of a sediment budget in this report, the connection between hydrology and sediment transport rates is not made, there needs to be an investigation of the streams ability to transport sediment, what the pre historic mining sediment budget looked like vs the sediment budget after hydrologic mining, and how the fluvial geomorphic processes have changes as a result of the altered sediment regime and the hydrologic regime

3.3 Bear River

History and Development

The Bear basin is 292 sq mile watershed, is 65 miles from headwaters to confluence with the Feather River and is 20 miles across at its greatest width. The Bear River originates at an elevation of 5,500 ft in the region of Tahoe National Forest, northeast of Emigrant Gap. The Bear River heads at a relatively low elevation of 1770m, so snow-melt is not a dominant source of runoff in the basin. The Bear River Basin can be delineated into three sections: the upper basin above Rollins Reservoir, the middle basin between Rollins and Camp Far West reservoirs, and the lower basin below Camp Far West Reservoir.

The river starts out as a clear, cold, fast-flowing stream at it source but it is impounded at the existing reservoirs, Rollins, Combie, and Camp Far West. The storage capacities at these reservoirs are 66,000 AF at Rollins, 9,000 AF at Combie, and 104,400 AF at Camp Far West. The main tributaries to the Bear are Steephollow and Greenhorn creeks above Rollins Reservoir, Wolf and Little Wolf creeks between Lake Combie and Camp Far West Reservoir, Rock Creek drains directly into Camp Far West Reservoir, and Dry Creek in the western portion of the valley.

In 1851, the first permanent diversion (Bear River Canal) from the Bear River occurred near Colfax. This and other mining canals (i.e., Gold Hill and South Yuba) and reservoirs were constructed to supply water for hydraulic mining and milling operations (PG&E 1969). Following the hydraulic mining period, these canals and reservoirs would be appropriated for irrigation and power. By the late 1880’s, small hydroelectric power generation facilities were being used at mines in the area and by the early 1900's hydroelectric power development had expanded to domestic use (PG&E 1969). The demand for hydroelectric power brought many new diversion facilities to the area in the early 1900's. This was the beginning of the extensive interbasin transfer system that would permanently link the Yuba, American, and Bear Riversystems (Pagenhart 1969).

The start of construction of the Bear River Canal (1851) was followed by the Upper Boardrnan Canal (previously called Dutch Flat Ditch) in 1852 (PG&E 1969). The beginnings of the Drum Canal system occurred in 1912. In 1927 came the development of the original Camp Far West Reservoir which was then quickly followed by Lake Combie in 1928 (DWR 1965). In 1963, SSWD began storing water in the enlarged Camp Far West Reservoir and in1965, NID began storage of water in Rollins Reservoir. The SSWD Main Canal began in 1964. Diversion into the CFWID Canal began prior to completion of Camp Far West Reservoir in 1927 accomplished by damning the Bear River annually with a small earth dike (Bob Melton, SSWD, 7/31/91, personal comm.).

PG&E placed in operation the Halsey and Wise power facilities on the Bear River Canal in 1916 and 1917, respectively (PG&E 1969). The Dutch Flat power system began diverting the Bear River in 1943. NID's Chicago Park power facilities went on line in 1965 followed by the Rollins Power Plant in 1977 at the existing Rollins Dam. SSWD was granted a license by the Federal Energy Regulatory Commission (FERC) to develop power at Camp Far West Dam in 1981. Bear River development continued to be profitable for energy companies and farmers when in 1985, SSWD submitted to FERC a license application to develop power at its proposed. Garden Bar Dam and Reservoir Water Power Project. Following the initial application to FERC, SSWD failed in its attempt to amend the application from a run-of-the-river project to a pump/storage project and has requested a new application (Bob Melton, SSWD, 7/31/97 personal comm.).

About 200,000 AF of water annually is imported from the South Fork of the Yuba River and Lake Spaulding through the Drum Canal system and American River from the North Fork of North Fork American River through the Lake Valley Canal Water in the upper Bear River watershed is directed into the South Yuba Canal, the Upper Boardman Canal, and the Drum Canal in addition to the Bear River (SSWD 1988). The water is used to generate hydroelectric power at PG&E powerhouses in Spaulding Units 1 and 2, Drum Units 1 and 2, Alta, and Dutch Flat Units 1 and 2. NID also has the Chicago Park Powerhouse on the Bear River above Rollins Reservoir. Below Rollins Reservoir, about 290,000 AF of water is exported annually for use by the PCWA and PG&E's Halsey and Wise Powerhouses in the North Fork American River watershed (SSWD 1988). Below Combie Reservoir, about 43,400 AF annually is diverted through NID's old Magnolia Ditch and the Gold Hill Canal primarily for irrigation (SSWD 1985). These canals have been replaced by the Combie Phase 1 Canal. Measured immediately below Camp Far West Diversion Dam, minimum flows to protect and enhance the fishery resources in the Bear River are required and contained in Article 29 of the Federal E;nergy Regulatory Commission (FERC) license 2997 amended 1/26/89 a.s follows: 25 cfs April 1 - June 30 and 10 cfs July 1 - March 31, or inflow to the project reservoir, whichever is less. Through its water permits, SSWD is not required to release water it has developed by storage

Shilling, Fraser and Evan Girvetz, 2003. Bear River Watershed Disturbance Inventory and Spatial Data Encyclopedia. Department of Environmental Science and Policy University of California at Davis. Bear River CRMP and Nevada County RCD.

What they did:

- Spatial and other data were collected for the Bear River watershed to represent the condition and extent of the natural resources and potential human impacts. Statewide, regional, and county level data were collected and "clipped" to the watershed boundary.

What they found:

- Plant Community Distribution: The lower watershed (below Camp Far West Reservoir) is dominated by grasslands and agricultural production (row crops and orchards). The mid-watershed (below Rollins Reservoir/Chicago Park) is dominated by Blue Oak Woodlands, Blue Oak-Foothill Pine, and Mixed Hardwood/Conifer forests. The upper watershed (above Rollins Reservoir) is dominated by Montane Hardwood, Mixed Hardwood/Conifer, Sierran Mixed Conifer, and Pine forests. The data comes from the Gap Analysis Project (Davis and Stoms, 1996), which analyzed the vegetation cover on the ground.
- Terrestrial vertebrate species: They show the terrestrial/amphibious vertebrate wildlife species that may occur in the watershed according to the California Wildlife Habitat Relations model (CWHR). This model was developed by the California Department of Fish and Game and others and uses the plant community types in the area, habitat characteristics of the individual communities, and habitat needs of the individual species to determine the potential occupation of an area by particular species.
- Native Fish: The following native fish species (Table 3) are known to occur in the watershed (Moyle personal communication and Moyle et al., 1996), with the highest richness of species being in the lower watershed (Moyle personal communication and Moyle et al., 1996).
- Rare Species: The following plant and animal species listed in the CNDDB are found in the watershed: (animals) Giant garter snake, Chinook salmon, Northwestern pond turtle, California horned lizard (plants) Stebbin's morning glory, Pine Hill flannelbush, Follett's monardella, Red-anthered rush, Wooly violet, and Monadenia Mormonum buttoni (Figure 2).
- Invasive Plant Species: The following weeds occur in Nevada, Placer, Sutter, and Yuba Counties: Dalmation toadflax (Linaria genistifolia ssp. dalmatica), Italian thistle (Carduus pycnocephalus), Klamathweed (Hypericum perforatum), Musk thistle (Carduus nutans), Puncturevine (Tribulus terrestris), Scotch thistle (Onopardium acanthium), Spotted knapweed (Centaurea maculosa), Diffuse knapweed (Centaurea diffusa), Yellow starthistle (Centaurea solstitialis), Himalayan blackberry (Rubus discolor), Scotch broom (Cytisus scoparius), gorse (Ulex europaeus), Skeletonweed (Chondrella juncea), Coontail (Ceratophyllum demersum), and Hydrilla (Hydrilla verticillata). (http://endeavor.des.ucdavis.edu/weeds/countylist.asp)
- Watersheds: There are over 990 miles of streams, creeks, and rivers within the Bear River watershed (Figure 4, National Hydrography Dataset 1999). These range from small creeks running most of the year to the mainstem of the Bear River itself. The ephemeral, or seasonal streams are not included in the mileage figure because they have not been well mapped. If included they would increase the total mileage by several-fold. Each creek or stream has its own watershed (drainage area), which are called "sub-watersheds" here to indicate that they are within the larger Bear River watershed.
- Topography: The majority of the basin consists of steep-sided creek and river canyons, like its larger neighboring watershed the Yuba River (Figure 5). A large portion of the watershed is in the lower foothills and the Valley, characterized by gentler slopes (<30 degrees). Slope steepness is a critical piece of information when assessing risk of erosion, slope failure, or risk to and from infrastructure (e.g., roads). Similarly, slope steepness should be an important factor in determining the management or development practices carried out on the landscape. This is primarily due to the potential for these activities to contribute to soil erosion and slope failure. Currently, data about steepness comes from a "digital elevation model" (DEM) based on 30 m X 30 m "pixels".

- Location of Stations: Various agencies and Pacific Gas & Electric maintain measuring devices at particular locations in the watershed for in-stream flow, climatic conditions, precipitation, and storage (Figure 6). In general, there are very few such stations. There are three long-term stations for measuring precipitation and flow measurements are primarily on the mainstem of the Bear River. Large areas of the watershed have no effective measurements of the hydrologic cycle. This situation would be best remedied by installing stations on tributaries such as Wolf Creek and making the data publicly available, as is the case for most hydrologic data in the watershed.
- Also includes, Fire history, land ownership, County Plans, Population, Roads, Canals Ditches, and Water Storage Facilities, Mine Lands and Mercury

Data Gaps:

- Almost all digital, spatial data available for the watershed is of lower resolution than would be optimal for site and parcel-specific protection, management and restoration decision-making. The solution is to communicate with private, state, academic, and federal enterprises that develop and collect digital, spatial data according to federal standards.

- The most important data for understanding disturbance to support good management and restoration decisions are for human features like roads, mines, and resource extraction activities and natural features and processes, like soils, hydrologic flows, terrestrial and aquatic wildlife, changes in plant communities (these are not all-inclusive lists). The solution is to prioritize data types for particular types of decisions – restoration, regulatory, management – and procure these data either commercially or from a free data provider (e.g., a public agency).

- The potential and actual impacts of human activities are rarely measured in the watershed, as is true for most places. Knowledge of beneficial or negative impacts of human activities is critical information for informing future restoration, management, and extraction activities. This knowledge allows adaptive management and decision-making for reducing disturbances from human activities and learning how to protect and restore watershed function

Yardas D. and A. Eberhart. 2005. Awakening the Bear: Assessing Flow Improvement Needs and Opportunities in Northern California's Bear River Problemshed. Environmental Defense. Oakland, CA.

What they did:

- Review data related to the Bear River and make recommendations for improvements

What they recommend:

- Restoration of salmon bearing streams: Auburn Ravine-Coon Creek, Secret-Ravine-Dry Creek, and Dry Creek –Spenceville, and the middle reach of the Bear River

- Lower temperature flows are needed for native fish in middle section of the Bear
- Combie Dam needs operational and structural improvements
- Lower section of the Bear below Combie reservoir need physical remediation because it is narrow and incised
- Below Dam environments require gravel recruitment for suitable habitat
- Strategic responses and an action agenda are proposed to achieve the above goals

HDR, Kennith Myers, Technical Memorandum Alternatives Analysis. Reclamation District No. 784 Design of Bear River and WP Interceptor Canal Levees Improvements Project. 2004.

What they did:

- Hydraulic analysis, geotechnical assessment, and description of levee improvement options
- Hydraulic models were provided by USACE from their lower Feather River Floodplain Study, determined the 100 and 200 year water surface elevations and velocities

What they found:

- Levees improvements are needed to address seepage, freeboard and erosion issues on the Bear River north levee and the WPIC west levee

Data Gaps:

- Environmental Effects of levee improvements include impact to land vegetation and wildlife habitat, filling of wetlands to accommodate footprint of berm, loss of habitat for VELB, giant garter snake, and other aquatic and terrestrial species, loss of shaded riverine habitat, alterations of hydraulic flow patterns. We need more information on these impacts articulated

James Allan J. Sustained Storage and Transport of Hydraulic Gold Mining Sediment in the Bear River, California. Annals of the Association of American Geographers. 1989; Volume 79(Issue 4): Page 570.

> Spatial and temporal patterns of sedimentation are relevant to such diverse practical concerns as flood-frequency evaluation, reservoir sedimentation rates, channel stability, water pollution, aquatic habitat management, interpretation of the geologic record, and erosion of bridge abutments, levees, and other engineering works.

What they did:

- This study examines mining sediment storage and mobilization in the Bear River, more than 100 years after the cessation of large-scale mining
- Mining sediment volumes in the lower basin were calculated as products of surface area and mean depths of deposits and were used to calculate mining sediment volumes.
- Valley cross-sections were surveyed at 22 sites to measure width, depth, and cross-section area of eroded mining sediment.
- Cross-sections derived from the three transects reveal the subsurface topography and processes of sedimentation in the lower basin
- Channel-bed grain intermediate-axis dimensions were sampled in 1985 throughout the basin (James 1988a), using a stratified random grid method
- Sediment textures and mineralogic compositions were described from cores (James 1988a), and surface topography along each transect was surveyed with a rod and level.
    - Subsurface coring of the mining sediment was possible in the lower basin, because mining sediment is fine textured. In the summers of 1983,1984, and 1985, more than 125 sediment cores were extracted with a 2-cm diameter siltprobe along three transects extending 2 to 3 km across the valley
- Depths of floods competent to move the mining sediment were calculated using an expression of channel cross-section maximum depth (D, in meters) as a function of bedload particle size and slope
- Discharges (Q) associated with competent flow depths were calculated using the Manning equation. Cross-section areas and hydraulic radii were measured from channel cross-section plots at stages of maximum depths calculated with Equation 2. Topographic maps were used to measure valley-bottom slopes to approximate the energy grade line. This method of slope determination may overestimate the energy grade line for unsteady, non-uniform flows (Magilligan 1988)) so estimates of discharges required to move bed material may be somewhat high.
- Flood frequencies were calculated using a three-parameter lognormal probability mass function, values for 2, 5 and 10 year floods were calculated

What they found:

- The results of this study show that the volume of historical sediment stored in the lower Bear Basin is more than twice as large as the largest previous estimates
    - most of the sediment is still stored in narrow valleys from the mining districts downstream to Combie Reservoir and in wide, flat valleys of the lower basin from Camp Far West Dam to the mouth of the Feather River
    - During the peak period of aggradation, the lower basin storage volume was about 116 x 10^6 m3. Depth-area products indicate that the present volumes of historical sediment stored in the lower Bear are about 116 x 10^6 m3, so less than 10 percent of the lower basin deposit has been eroded.
    - Coring and mapping reveal that the mining sediment deposit in the lower Bear River has mean depths between 2.0 and 2.8 m and covers about 5010 hectares (50 kin*). Most of the deposit was emplaced between 1862 and 1900, so rates of aggradation during that period ranged from 4.7 to 7.4 cm yr-1 when averaged across valley transects 2 to 3 km in length. About 106 x 10^6 m3 of the mining sediment remains

stored in the lower Bear Basin below Camp Far West Reservoir. ,
  - the total volume of sediment produced in the Bear Basin, when scaled to basin area, is considerably greater than in the Yuba or American basins
    - The Bear River heads only 15 km upstream from the mining districts, so discharges in main channels near the mines are much smaller than in the Yuba or American rivers, which head at high elevations (Manson 1882, 90).
- Prior to mining, mountain channels had only thin patches of alluvium and were dominated by bedrock and coarse, bouldery material.
  - The pre-mining surface beneath the transects is buried by as much as 5.1 m of mining sediment.
  - Mean rates of aggradation ranged from 4.7 to 7.4 cm yr-l, averaged across the valley transects over this 38-year period (1862-1900). At the maximum observed depth of fill (5.1 m) on the Transect C, aggradation rates averaged about 13.4 cm yr-l
  - Measured depths of incision into the mining sediment above Combie Resevoir average about 10 m and range to more than 27m. Little or no erosion has occurred in steep, narrow gorges where deposits were negligible, or near Rollins Reservoir where post-mining aggradation has dominated
- The mining sediment is moving
  - The field evidence outlined above records a large volume of mining sediment remaining in the Bear River that continues to be reworked and is slowly progressing down-valley through repetitive erosion and resedimentation.
  - Competent discharges at the seven sections range from 2 to 36 m3 s-1, suggesting that mining sediment is transported by relatively small flows.
  - Stabilized colluvium represents a dormant sediment source that can be reactivated by channel incision, thus prolonging high sediment loads.
- Present sediment transport rates are greater than pre-mining rates.
  - In some narrow valleys within the mining area, the present channel is more than 20 m below terrace tops. Vertical terrace scarps are so unstable at some sites that micro-scale mass wasting events were observed during calm summer afternoons
  - The double concave-upward longitudinal profile of the Bear River has had great bearing, therefore, on spatial patterns of sediment deposition (Fig. 3).
  - The greatest erosion has occurred near tailings fans, which formed at confluences where tributaries draining mines joined main channels
  - Delta sedimentation behind Combie and Rollins reservoirs documents high rates of mining sediment transport in the upper Bear. About 1.2.106 m3 of sediment was deposited in Combie Reservoir from 1928 to 1935 (Brown and Thorp 1947). Spring floods annually refill excavations made by a commercial aggregate mining company in the Combie delta (Dupras and Chevreaux 1984; Chevreaux 1985) and in the Rollins deltas. Quartz concentrations of sediment in the Rollins Delta on Greenhorn Creek (Fig. 138) indicate that the delta is composed of from 70 to 85 percent mining sediment (James 1988a)

Assumptions they made:

- The symmetrical wave model is inappropriate for the Bear River
- A stochastic model developed by Kelsey et al. (1986) indicates that sediment can enter stable deposits and remain there for thousands of years. Sediment residence times in Redwood Creek range from 9- 26 years for active storage sites in and near the channel to 700-7200

years for stable sites largely in isolated terraces covered by old-growth forest (Madej 1984).

Data Gaps:

- In the upper basin, a large but unknown volume of sediment remains in and near the active channel, beneath the bed, and in massive terraces. Further research is needed to determine upper basin volumes, total basin storage, and sediment delivery ratios, but foothill deposits are clearly vast. These vast reservoirs of stored sediment provide potential sediment sources for future channel erosion.
- There is no reference to how the mining sediment is effecting water quality or habitat
- What are the best management techniques/strategies for dealing with the sediment waves loads to the Bear
- More research is needed to identify the factors determining the shape of sediment waves in various basins under various conditions.

Bear River CDFG, 1988. unpublished

What they did:

- DFG focused upon environmental problems downstream of Camp Far West Reservoir to develop measures to restore habitat conditions and to identify flow regimes which would restore Bear River chinook salmon and steelhead trout resources and habitat
- This report evaluates streamflow and temperature needs for spawning and rearing Chinook salmon and steelhead trout of the Lower Bear River downstream of Camp Far West Reservoir to the Confluence with the Feather River. The report uses temperature studies developed by SSWD's consultants, DFG, independent review of historical and current records of the aquatic resources of the Bear River
- Seining studies in the Bear River during 1984 confirmed the presence of small recently hatched chinook salmon (38-40 mm FL) present in the catch through April (DFG 1984). This study showed that the May catch drastically reduced as flows reduced from 693 cfs in April to 161 cfs in May and water temperatures increased to 65°F
- Spring seining and electrofishing surveys indicated the presence of juvenile trout during 1984 and 1985. Adult steelhead were observed in 1981 and 1982 (DFG 1981, 1982) .
- Water temperature records collected by California Department of Water Resources (DWR) were used to assess the potential effects of water temperatures in the lower Bear River on fall-run chinook salmon and steelhead trout. These temperatures are collected once monthly associated with DWR's water quality assessment program at the USGS gage station site just downstream of Highway 65 near Wheatland.

What they found:

- The 16 mi of the lower Bear River between Camp Far West and the confluence with the Feather River have limited populations of largemouth bass, bluegill, catfish, and a variety of non-game warm water species including the Sacramento squawfish and Sacramento sucker (SSWD 1980).
- the Bear River was full of salmon and the Indians speared them by the hundreds in the clear water; becoming scarce when the river became muddy from the hydraulic mining. Current information indicates the Bear River, since the late 18001s, has indeed experienced

diminished chinook salmon and steelhead trout populations. The mining damage, followed by the increase in water diversions, continued to damage the fishery and river environment.

- Presently, fall flows in the lower Bear River are not usually high enough to attract salmon to migrate up and spawn. During years where the October- November flows are high, DFG has estimated adult spawning runs as high as 300 fish (Table 1).
    - a flow of 100 cfs measured at the Wheatland gage during the first two weeks of October should provide ample depth and attraction for upstream adult migration and early spawning. A flow of 250 cfs will provide maximum spawning habitat from mid-October through December when the majority of spawning is complete followed by 190 cfs during January through March. Maintaining a flow of no less than 190 cfs during this period throughout the remainder of the spawning and emergence period will prevent dewatering of salmon redds, alevins, and/or stranding of fry. A flow of 100 cfs during April through June will provide maximum juvenile salmon rearing habitat and facilitate their downstream movement. As most fail-run chinook salmon juveniles migrate to the ocean by June, only a minimal flow of 10 cfs from July through September is required
- Chinook Salmon
    - the spawning migration begins in late September and may extend through January with the peak of migration in October and November (DFG 1991) (Table 2). Spawning normally occurs shortly after migration, primarily in October through January and peaks during November and early December. Eggs incubate in the gravel into February, followed by hatching and emergence of fry into March. Fry may emigrate within a few weeks of emergence or may rear to the juvenile stage until June when they emigrate
    - The preferred range for fall-run chinook salmon upstream migration is 44.1-57.5"F1 spawning is 41.0-57.0"~eg~g incubation through fry emergence is 41.0-57.9"~fr~y rearing is 44.6-57.2"F1 and juvenile rearing is 45.1-58.3"~
    - Warm water temperatures near the confluence of the lower Bear and Feather rivers during September and October could delay upstream migration into the Bear River. The likelihood of a delay increases as temperatures rise above about 57.5"F (Table 8). Under existing project operations, conditions suitable for migration are not reached until late October (Figure 6). The preferred temperature range for spawning (41.0-57.0°F) was exceeded at Wheatland until early November shortening the period for spawning that is normally October through January. During the incubation period (October through February), water temperatures generally exceed the optimum only during October. The temperature range for juvenile rearing (45.1-58.3"F) is exceeded during the entire rearing period of April through June.
- Steelhead Trout
    - Steelhead migrate from the ocean to their natal streams to spawn in the fall and winter. Under suitable flow and temperature conditions, the spawning migration begins as early as August, peaks in October and February, and may extend through March. Steelhead spawn in the late winter and early spring months (January through April). Egg incubation and emergence from the gravel extends into May and early June, respectively. Fry remain in the river to rear to juveniles for 1 to 3 years prior to smolting and emigration to the ocean. Emigration generally occurs from March into June. Steelhead mature after 1 to 2 years in salt water and return to their natal stream to spawn.Environmental factors affecting s

- The preferred temperature range for steelhead spawning migration is 46.0-52.0"~while the preferred temperature range for spawning is 39.0-52.0"~a~nd the preferred range for incubation and emergence is 48.0-52.0°F. Fry and juvenile rearing requirements follow with a preferred temperature range of 55.0-60.1"~an d 45.1-60.1°F, respectively
- The warm water temperatures in the lower Bear River generally exceed the steelhead trout spawning migration preferred range (46.0-52.0GF)u ntil December. The expected period of migration is August through March. Water temperatures during the spawning period of January through April were acceptable only during January and February. Egg incubation and emergence extends from January through ,June requiring preferred temperatures of 48.0-52.0°F. This range is generally exceeded during March through June.

Data Gaps:

- There is no discussion of the suitability of the habitat for Steelhead or Chinook outside of temperature, what if there is another limiting factor, such as sediment?
- Therefore, additional temperature studies are needed that should include, but not be limited to: 1) longitudinal river simulations downstream of Camp Far West Reservoir using a range of reservoir outlet temperatures and flows from Camp Far West Reservoir for all months of concern necessary to meet the above temperature recommendations, 2) characterize reservoir elevations drawn upon by the intake structures, 3) characterize the volume of cold water present in upstream reservoirs available for transport downstream, and 4)characterize the reservoir elevations drawn upon by the intake structures.

Kuwabara, J.S., Alpers, C.N., Marvin-DiPasquale, M., Topping, B.R., Carter, J.L., Stewart, A.R., Fend, S.V., Parchaso, F., Moon, G.E., and Krabbenhoft, D.P., 2003, Sediment-water interactions affecting dissolved-mercury distributions in Camp Far West Reservoir, California, U.S. Geological Survey Water-Resources Investigations Report 03-4140, 64 p.

What they did:

- With a wide a range of programmatic decisions to be made related to the improvement of water and fisheries resources in the Bear River, the question posed in this study was, "Are sources and sinks of dissolved total mercury and dissolved methyl-mercury associated with the bottom sediment within Camp Far West Reservoir significant relative to major surface-water inputs from the Bear River?" Therefore, determining whether some fraction of this sediment-associated mercury can remobilize for transport to the overlying water and subsequently to downstream portions of the Bear River is of considerable environmental and ecological significance. Second, elevated concentrations of mercury species in reservoir water, sediment, and fish have prompted a compilation and comparison of dominant contaminant sources so that appropriate remedial strategies can be designed and implemented. Third, changes in oxidizing or reducing (redox) conditions, in pH, and in nutrient availability near the sediment-water interface (for example, during phytoplankton blooms) can dramatically alter the mobility of metals and ligands associated with the bottom sediment as episodic sources of carbon settle out and accumulate
- During two sampling events, two replicate sediment cores (Coring methods; Fig. 2) from each of three reservoir locations (Fig. 1) were used in incubation experiments to provide flux

estimates and benthic biological characterizations. Incubation of these cores provided "snapshots" of solute flux across the sediment-water interface in the reservoir, under benthic, environmental conditions representative of the time and place of collection. Ancillary data, including nutrient and ligand fluxes, were gathered to provide a water-quality framework from which to compare the results for mercury.

- Measured benthic flux of mercury; Scientists and water-quality managers are only beginning to appreciate the importance of benthic flux in many aquatic environments. Within the past decade or two, researchers have gradually realized that there are nonhydrologic processes (for example, benthic flux) that must be incorporated into water-quality models in order to generate physically meaningful information.
- As part of a comprehensive examination of transport processes affecting mercury dynamics in Camp Far West Reservoir, this study focuses on a poorly understood, yet potentially predominant, source of mercury to the reservoir water column: internal recycling, or benthic flux of mercury species and associated ligands. Mobilization, flux, and biological availability of mercury into the water column of the reservoir are affected by physical (for example, advection and diffusion), chemical (that is, oxidation-reduction reactions, complexation and repartitioning) and biological processes (for example, bioirrigation and bioturbation)(Flegal and others, 1991; Kuwabara and others, 1996; Grenz and others, 2000, Topping and others, 2001). Quantifying and understanding the magnitude and variability of these interactions are critical to the accurate assessment of contaminant sources and loads as well as to the development of appropriate water-quality models and remedial programs for this mining-affected system.

What they found:

- Estimates of riverine and benthic flux indicate that sediment sources of dissolved total mercury are seasonally variable, but consistently comparable to or greater in magnitude than riverine sources. Transport of dissolved, bioavailable mercury species between the reservoir bed and water column may therefore be a potentially critical process regulating the fate of mercury species in the reservoir water column
- Similar to methyl-mercury fluxes, dissolved total-mercury fluxes, based on site averages from 2 replicate cores, were generally higher in April than in November 2002
- The reservoir was highly phosphate limited with molar N:P ratios in water column samples ranging from 136 to >5,000 (compared to the Redfield N:P molar ratio of 16; Table 6).
- Because the benthic flux of mercury species may represent a dominant transport process, it also suggests animportant management implication. Remediation efforts and Total Maximum Daily Load (TMDL) allocations along the Bear River have dual objectives of decreasing concentrations and loads to down-gradient systems and reducing bioaccumulation of mercury in fish consumed by humans and wildlife. Using preliminary mercury-flux estimates into the reservoir from the Bear River, our results indicate that with considerable seasonal variability a significant (and possibly predominant) percentage of dissolved mercury in the water column presently comes from the reservoir bed (Mercury flux discussion). If upstream sources are controlled, which is desirable even apart from reservoir effects, the present inflow loads are likely to be compensated in part by increases in benthic flux (Fig. 7). Concentrations of total mercury in the reservoir should be expected to decrease slowly after inflow loads are controlled. A previously developed management tool (Kuwabara and others, 2003) was applied to estimate a benthic response to regulating the riverine inputs of contaminants to the reservoir.

Data Gaps:

- Only took samples at two time of the year, November and April
- There is no data for other water quality parameters for multiple sites along the Bear River
- does benthic flux occur in the river channel

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