F1-184

United States Department of the Interior

U.S. Geological Survey
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Davis Field Station
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University of California
Davis, California 95616

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CALFED Bay-Delta Program Office
1416 Ninth Street, Suite 1155
Sacramento, CA 95814

Attached are ten copies of a proposal, *Mercury in the Cache Creek Ecosystem: Bioaccumulation and Effects on Amphibians and Birds* by Roger L. Hothem and Steven E. Schwarzbach, in collaboration with Larry D. Thompson, Mark R. Jennings, and Walter J. Sadinsky.

This proposal is submitted for your consideration in response to the Request for Proposals, 1997 Category III, Ecosystem Restoration Projects and Programs.

Sincerely,

Roger L. Hothem
Wildlife Biologist (Research)

Attachments

F1-184

Mercury in the Cache Creek Ecosystem: Bioaccumulation and Effects on Amphibians and Birds

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Co-Investigators:
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I. EXECUTIVE SUMMARY

A. Project Title: Mercury in the Cache Creek Ecosystem: Bioaccumulation and Effects on Amphibians and Birds

Applicants: Roger L. Hothem and Steven E. Schwarzbach, in collaboration with Larry D. Thompson, Mark R. Jennings, and Walter J. Sadinsky.

B. Project Description and Primary Biological/Ecological Objectives: This project will contribute to restoration of the ecological health of the San Francisco Bay-Delta by helping to improve water quality, and it will establish baseline data essential for the evaluation of future remedial actions. Mercury, a major stressor originating in the Cache Creek Watershed and transported to the Bay-Delta, especially during flood events, is the focus of this work. Mercury is potentially toxic to priority species of fish and wildlife in most priority habitats, both within the watershed and in the downstream Bay-Delta area. The objectives of this project are: **1)** Further identify point sources of bioavailable mercury in the Cache Creek watershed using residues accumulated in biota; **2)** Evaluate accumulation pathways for mercury in Cache Creek biota; and **3)** Evaluate adverse effects mercury may have on amphibians and swallows, and predict the risk to piscivorous birds.

C. Approach/Tasks/Schedule: This is a two-year field study (plus one year write-up). The first year of the study (1997) was a scoping study designed to evaluate mercury bioaccumulation in reaches of Cache Creek and its tributaries and to document point sources of bioavailable mercury. Data from samples collected in the first year (macro-invertebrates, fish, amphibians, and swallow eggs) will be used to select sample sites to be used the second year. In 1998, we will continue our sampling of biota to further evaluate point sources of mercury and to evaluate site-specific bioaccumulation within the watershed. Besides mercury, we will conduct metal scans of selected samples from each site to detect other contaminants, including nickel, cobalt, boron, and chromium. Amphibians and swallows will be evaluated for their suitability as biomonitors of mercury contamination.

D. Justification for Project and Funding by CALFED: The project focuses on the impacts of mercury, a primary stressor within the Cache Creek Watershed and a toxic metal known to be transported from Cache Creek to the Yolo Bypass, Sacramento/San Joaquin Delta, and San Francisco Bay, where it is a pollutant of great concern. All priority species and most of the priority habitats within the Bay-Delta are potentially adversely affected by mercury. Documentation of mercury levels in biota and identification of point sources of bioavailable mercury in the Cache Creek watershed are necessary to identify and rank potential remediation sites. These baseline data can then be compared with post-remediation data to assess the effectiveness of cleanup efforts. Another benefit from the study will be the evaluation of the adverse effects that mercury may have on fish, amphibians, and swallows. By collecting samples from different trophic levels, we will be able to evaluate accumulation pathways for mercury in the Cache Creek food web. This will facilitate risk determinations for threatened species and species of special concern within the watershed. Finally, mercury accumulations in swallow eggs and amphibians will suggest the applicability of their use in biomonitoring for mercury in other areas, and our assessment of genetic damage in

amphibians may reveal a non-lethal biomarker useful for identifying mercury exposures across broader geographical regions of California.

E. **Budget Costs and Third Party Impacts:** This project is in its first year (1997) of a three-year study of mercury in the Cache Creek Watershed. About one-half of the funding for 1997 was provided by "off-refuge environmental contaminants" funding through Region One of the U.S. fish and Wildlife Service (USFWS); the other half was from U.S. Geological Survey (USGS) base funds. A proposal to extend funding for the second and third years of the study has been submitted to USFWS, but no alternate source of matching funds has been obtained by USGS. Funding for salary and benefits for the principal investigator will be provided by USGS, but additional funds are needed to conduct chemical analyses of biota from the watershed (See Table 2). Estimated total costs for the 1998 field study and 1999 writeup of findings is about $180,000. Of that, $68,549 (38%) is USFWS matching funds, and $34,718 (19%) is USGS base funds. The remaining $88,010, requested from CALFED, will cover salaries for technical assistance, chemical analyses, equipment and supplies and 12% overhead. No third party impacts have been identified or are expected.

F. **Applicant Qualifications**: The applicants and co-investigators have strong backgrounds in environmental toxicology, including effects of mercury and other metals and trace elements on avian reproduction (Hothem and Schwarzbach), contaminants and their effects in fish and invertebrates (Jennings and Thompson), amphibian ecology (Jennings), and effects of contaminants on amphibians (Sadinsky). Each researcher has conducted studies related to the goals of this project, and Hothem, Schwarzbach, Jennings, and Sadinsky have all done extensive work in the San Francisco Bay Estuary.

G. **Monitoring and Data Evaluation**: In 1998, concentrations of mercury, methyl mercury and metals will be estimated for specified trophic levels of the Cache Creek ecosystem. These data will be compared with those collected in 1997, with reference sites, and with data from the scientific literature. All data will be entered into a comprehensive database, coordinated closely with other research efforts focused on water, sediments, and other trophic levels. Manuscripts will be subjected to extensive peer review within agencies (USFWS and USGS) before submission to the appropriate journal.

H. **Local Support/Coordination with other Programs/compatibility with CALFED objectives**: During the first year of this project, we have cooperated with BLM, Yolo County Parks, California Department of Fish and Game, California Department of Transportation, Central Valley Regional Water Control Board (CVRWQCB), Water Resources Division of USGS, Cache Creek Conservancy, the Yolo County Community Development Agency, and the University of California, Department of Wildlife, Fish, and Conservation Biology. Data collected from Bear Creek will be shared with the American Land Conservancy, a group in the process of acquiring part of the Bear Creek Watershed. Data and field sites are being or will be shared with other researchers and managers as the project progresses. This study will benefit other CALFED program objectives, particularly the provision of good water quality and the improvement of aquatic habitats.

II. TITLE PAGE

Mercury in the Cache Creek Ecosystem:
Bioaccumulation and Effects on Amphibians and Birds

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Co-Investigators:
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Type of Organization and Tax Status: Federal Agency (U.S. Department of the Interior), tax exempt (Federal Tax Exemption Number: 84-1024566)

Tax Identification Number:

Technical and Financial Contact person(s): Roger L. Hothem and Steven E. Schwarzbach

Participants/Collaborators in Implementation: Larry D. Thompson, Mark R. Jennings, and Walter J. Sadinsky.

RFP Project Group Type(s): Other services

III. PROJECT DESCRIPTION

A. PROJECT DESCRIPTION AND APPROACH

This project is designed to contribute to the restoration of the ecological health of the San Francisco Bay-Delta by helping to improve water quality. It will also establish baseline data essential for the evaluation of future remedial actions. Mercury, a major stressor originating from abandoned mercury mines and thermal springs in the Cache Creek Watershed and transported to the Bay-Delta, especially during flood events, is the focus of this work. This metal is potentially toxic to priority species of fish and wildlife in most priority habitats, both within the watershed and in the downstream Bay-Delta area.

Invertebrates

Both immature and adult forms of aquatic macro-invertebrates are important components in the diets of many fish, amphibians, and riparian-dwelling birds, which may biomagnify the mercury concentrated in these foods. Methyl mercury, even at low concentrations in sediments, may be bioaccumulated by benthic macro-invertebrates that inhabit the sediments and ingest allochthonous materials or detritus for food (Gillespie and Scott 1971; Schwarzbach and Hofius 1996). Thus, invertebrates have been used as indicators of mercury accumulation in experimental (Saouter et al 1993) and field studies (Steingraeber and Wiener 1995; Beauvais et al 1995; Slotton et al. 1997).

Fish

Mercury bioaccumulation in Cache Creek fish has not been well documented. Factors that influence bioaccumulation of methyl mercury in fish include feeding habits, biomagnification in food webs, fish age and longevity, water temperature, acid-neutralizing capacity, and flooding of new impoundments (Wiener and Spry 1996). Measurements of total mercury concentrations in the axial muscle tissue of fish provide data useful for evaluating methyl mercury bioaccumulation, because nearly 99% of the mercury in this tissue is methyl mercury (Bloom 1992). Our study results can be interpreted in the context of other studies and compared with residue criteria in fish-consumption advisories, which are also based on axial muscle data. In addition, concentrations of mercury in fish may be used to estimate risk to piscivorous birds such as the bald eagle (*Haliaeetus leucocephalus*).

Amphibians

There is evidence that populations of some amphibians, especially true frogs and toads in the western United States, are declining or have disappeared (Blaustein et al. 1994, Jennings and Hayes 1994). Although habitat changes and the introduction of non-native predators can explain the loss of many amphibian species in the low to mid elevations in California (Hayes and Jennings 1988; Jennings 1988, 1996; Fisher and Shaffer 1996), many of these declines remain unexplained (Hayes and Jennings 1990; Fellers and Drost 1993; Drost and Fellers 1996). The role of contaminants in these declines is unclear (Hayes and Jennings 1986; Jennings 1988), but they are often a viable explanation (Stebbins and Cohen 1995). In the Coast Range, for example, localized declines of native amphibians, including foothill yellow-legged frogs (*Rana boylii*), a species of special concern, may be linked to mercury contamination. The Cache Creek

watershed is also within the range of the California red-legged frog (*Rana aurora draytonii*), a species recently listed as threatened.

Amphibian larvae may be useful bioindicators of contaminants because they often bioaccumulate them (Cooke 1981). Amphibians have been found to be especially sensitive to metals such as mercury (Jayaprakash and Madhyastha 1987), and many studies of amphibians have documented teratogenic and lethal effects (Dial 1976; Chang et al. 1974; Punzo 1993).

Research is needed to assess mercury in Cache Creek amphibians and to learn its effects on populations in the watershed and elsewhere in the Sacramento Valley. From this information, alternatives may be developed for the recovery and management of remaining amphibian populations.

Birds

Mercury toxicity may be acute or chronic in birds (Eisler 1987). Symptoms of methyl mercury poisoning in adult birds include reduced food intake, weight loss, progressive muscle weakness, lack of muscle coordination, and difficulty with standing and locomotion (Scheuhammer 1987). However, dietary concentrations of methyl mercury required to produce significant reproductive impairment are about 1.5 times less than those required to produce overt toxicity in adult birds of the same species (Scheuhammer 1991). Symptoms of chronic mercury exposure in mallards (*Anas platyrhynchos*) include eggshell thinning, reduced clutch size, more eggs laid outside the nest, and aberrant juvenile behavior (Heinz 1979). Loons (*Gavia immer*) were not successfully reared in waters where mercury concentrations in prey exceeded 0.4 ppm (Barr 1986).

Elevated concentrations of mercury have been detected in fishes in local lakes and streams (Suchanek et al. 1993), putting piscivorous birds, including the bald eagle, a federally-listed (threatened) species, at risk (Fimreite 1974; Hesse et al. 1975). Riparian insectivorous birds bioaccumulate nonessential toxic elements such as mercury and may be suitable bioindicators of contamination (Nyholm 1995). Powell (1983) reported mercury concentrations in rough-winged swallows (*Stelgidopteryx serripennis*) that were potentially high enough to impair reproduction. Two riparian insectivores found in the Cache Creek Watershed are cliff swallows (*Hirundo pyrrhonota*) and bank swallows (*Riparia riparia*), a federally-listed (threatened) species (U.S. Army Corps of Engineers 1995).

Objectives

The objectives of this project are: **1)** Further identify point sources of bioavailable mercury in the Cache Creek watershed using residues accumulated in biota; **2)** Evaluate accumulation pathways for mercury in Cache Creek biota; and **3)** Evaluate adverse effects mercury may have on amphibians and swallows, and predict the risk to piscivorous birds such as bald eagles.

We propose to conduct a two-year field study (plus one year write-up) to achieve these objectives. The first year of the study (1997) was a scoping study designed to evaluate mercury bioaccumulation in reaches of Cache Creek and its tributaries and to document point sources of bioavailable mercury. Specific collection sites within the watershed were selected based on our prior knowledge of mercury contamination, site accessability, and presence of appropriate study organisms. Data collected in the first year's scoping study (macro-invertebrates, fish,

amphibians, and cliff swallow eggs) will be used to select at least five sample sites within the Cache Creek watershed and a reference site to be used the second year (1998). In 1998, we will continue our sampling of biota further to evaluate point sources of mercury. For cliff swallows, a surrogate species for the threatened bank swallow, we will collect eggs and chicks to estimate mercury accumulation rates for each site. This method will show locally acquired mercury compared with mercury potentially acquired on wintering grounds or during migration. Besides mercury, elevated concentrations of nickel, cobalt, boron, and chromium have also been detected in water and sediment from the watershed (J. Rytuba, USGS, pers. commun.). Therefore, we will conduct metal scans of selected samples from each site to detect other potentially hazardous contaminants.

Amphibians (bullfrogs [*Rana catesbeiana*], foothill yellow-legged frogs, and/or Pacific treefrogs [*Hyla regilla*]), macro-invertebrates and fish (species to be determined) will be collected from the same sites as the swallows. This will enable us to evaluate site-specific bioaccumulation within the watershed. Amphibians in the watershed have not been previously analyzed for mercury residues, but they may be suitable biomonitors of mercury contamination.

In 1998, we will add an investigation of genetic damage in selected frogs/tadpoles collected in the Cache Creek drainage. Foothill yellow-legged frogs and bullfrogs occur in unaffected sub-watersheds and in sites believed to be extremely contaminated by mercury. We propose to measure and compare the extent of genetic damage in populations that have and have not been exposed to elevated levels of mercury. Aspects of genetic damage include chromosomal aberrations as a result of disruption of the spindle apparatus (as in aberrant ploidy), clastogenicity (micronuclei), and the equivalent at the molecular level, strand breaks in DNA. Methyl mercury and mercuric chloride have both been shown in controlled laboratory exposures to induce chromosome breaks in larvae of the newt *(Pleurodeles waltl)* and also produce high levels of microculeated red blood cells (Zoll et al. 1988). This portion of the project will be conducted in collaboration with Dr. Walter Sadinsky, a postgraduate researcher experienced in amphibian genetics work at the University of San Francisco. This technique may be useful as a non-lethal biomonitoring technique for rare or endangered species.

B. LOCATION AND/OR GEOGRAPHIC BOUNDARIES OF PROJECT

The Cache Creek Watershed is in California's Coast Range and drains eastward to the Yolo Bypass of the Sacramento River, near Woodland (Fig. 1). Samples will be collected from this watershed to evaluate bioaccumulation of mercury by biota from Cache Creek and its various tributaries. Samples were collected from 26 sites in 1997 (Table 1, fig. 1). Cliff swallow eggs were collected in 1997 from bridges and buildings at critical locations throughout the watershed. Amphibians, fish, and macro-invertebrates were collected at these and other sites. Analysis of mercury residues in 1997 samples will allow us to select the most appropriate sampling sites for a more detailed characterization of mercury bioaccumulation in 1998.

C. EXPECTED BENEFITS(S)

The project focuses on the impacts of mercury, a primary stressor within the Cache Creek Watershed and a toxic metal known to be transported from Cache Creek to the Yolo Bypass, Sacramento/San Joaquin Delta, and San Francisco Bay, where it is a pollutant of great concern.

All priority species and most of the priority habitats within the Bay-Delta are potentially adversely affected by mercury. By documenting levels of mercury in biota, this study will help identify point sources of bioavailable mercury in the Cache Creek watershed. This information is necessary to identify and rank potential remediation sites. An added benefit is that these baseline data can then be compared with post-remediation data to assess the effectiveness of cleanup efforts.

Another benefit from the study will be the evaluation of the possible adverse effects that mercury may have on fish, amphibians, and swallows. By collecting samples of components of the Cache Creek food web, we will be able to evaluate accumulation pathways for mercury. This will facilitate risk determinations for species of special concern within the watershed, including amphibians (red-legged and foothill yellow-legged frogs), bank swallows, and bald eagles. Finally, mercury accumulations in swallow eggs and amphibians have not previously been determined in Cache Creek or neighboring watersheds. Results from this study will suggest the applicability of their use in biomonitoring for mercury in other areas. Our assessment of genetic damage in amphibians may reveal a non-lethal biomarker useful for identifying mercury exposures across broader geographical regions of California.

This study will benefit other CALFED program objectives, particularly the provision of good water quality and the improvement of aquatic habitats.

D. BACKGROUND AND BIOLOGICAL/TECHNICAL JUSTIFICATION

California has abundant geologic sources of mercury and a long history of mercury contamination associated with mercury mining, particularly in the Coast Ranges. Since 1976, the State of California's Toxic Substances Monitoring Program has consistently reported high mercury concentrations in Cache Creek (California Department of Fish and Game 1988). During the 1995 and 1997 floods in Northern California, very high mercury concentrations were measured in water samples in lower Cache Creek, the Yolo Bypass, and the Sacramento Delta (Chris Foe, CVRWQCB, pers. commun.). These data show that large-scale, downstream movements of mercury are occurring in the Cache Creek watershed. According to Davis et al. (1991), mercury is a priority pollutant in the San Francisco Bay Estuary, and biotic resources, including priority fish species and migratory birds, may be threatened by mercury transport or deposition from upstream sources, including Cache Creek.

Point sources of bioavailable mercury within the watershed have not been well identified. Clear Lake, whose outfall flows into Cache Creek, is clearly one major source (Suchanek et al. 1995), as is Davis Creek Reservoir (Gill and Bruland 1990), whose outfall also flows into Cache Creek. Analyses of mercury residues in benthic macro-invertebrates (Slotton et al. 1997) and in water and sediments (J. Rytuba, USGS, pers. commun.) from the Bear Creek drainage and other tributaries indicate that there are multiple sources of mercury in the watershed.

Elevated mercury concentrations in a water body or its sediments do not necessarily result in excessive accumulations in the resident biota or their associated riparian areas. However, where environmental conditions favor conversions of inorganic mercury to organometallic forms, which are more easily accumulated, high residue concentrations in biota are observed. Upon entering food webs, methyl mercury is biomagnified through trophic levels and this

magnification has been documented in zooplankton communities (Watras and Bloom, 1992), fishes (Wiener and Spry 1996), and birds (Fimreite 1974).

The CVRWQCB has designated Cache Creek a high priority watershed in the State's new Watershed Management Initiative, i.e., ranked high for restoration due to scenic and recreational value and the need to mitigate for large scale in- and off-stream gravel mining (U.S. Army Corps of Engineers 1995 and Chris Foe, CRWQB, pers. commun.). Disturbances and eutrophication have been shown to enhance the methylation of elemental mercury (Zillioux et al. 1993). Therefore, gravel mining and agricultural uses along Cache Creek could be negatively affecting the biota by increasing the fraction of bioavailable mercury and raising exposures. The USFWS and other agencies are considering several habitat restoration options along Cache Creek, including stream bank stabilization, flooding of off-stream abandoned gravel mines to create wetlands, and constructing a new dam to provide water for restoration and other uses (U.S. Army Corps of Engineers 1995). Certain of these options may result in environments attractive to fish and wildlife. However, if exposure to methyl mercury is increased, these options may pose chemical threats. The bioaccumulation data from this study will be useful in formulating the final plans for riparian restoration and habitat enhancement.

This project is a two-year field study to document bioaccumulation, evaluate possible adverse effects of mercury, and pinpoint sources of mercury in the Cache Creek Watershed. The budget for the first year (1997) of the study was $68,000. The USFWS and USGS are sharing the lead in study design, field work, data analysis, catalog preparation, sample shipment and project write-up. The Habitat Alliance & Wildlife Keepers (Hawk) Americorps Program has shown an interest in participating in this study. To optimize research dollars and effort, we are coordinating sampling sites and collections with the CVRWQCB, the Water Resources Division of USGS, and the University of California Davis. Data and field sites are being shared. In addition, the Cache Creek Stakeholders has begun holding regular meetings to discuss the future of the watershed. This effort is assisted by an outside facilitator hired by the Regional Board with grant money from the U.S. Environmental Protection Agency (EPA). We are participating in the Cache Creek Stakeholders meetings, and we have found many opportunities for networking and collaborating with other investigators through these ongoing meetings.

E. PROPOSED SCOPE OF WORK

Preliminary visits to the Cache Creek Watershed began in 1996 during the early phase of cooperation with the USFWS. A proposal for "off-refuge contaminants" funding was approved by the USFWS in the Fall of 1996, and work on the project began in March 1997. Funding provided by USGS was from base funds. Essential characterization of the fauna of the watershed, a necessary step before samples could be collected, was begun using synoptic surveys, especially for amphibians and reptiles, in 1997. It became evident that current funding was insufficient to achieve the stated objectives the second year of the study, and CALFED funding is thus requested. The second year of the study (1998) will be more focused, concentrating on sites found to be especially critical sources for bioavailable mercury. Both larval and adult amphibians will be collected to evaluate bioaccumulation by life stage. Cliff swallow eggs and chicks from the same nest will be collected to evaluate local accumulation of mercury. Foods of these species will be determined and sampled as available to complete the

analysis of bioaccumulation pathways within the food web. A preliminary report of the 1997 findings will be prepared for USFWS in Fall of 1997. The second annual report will document the findings of the two years of the study, but it will not be completed until three months after the receipt of the final chemical analyses results. A final report will include analysis and interpretation of all chemical data and conclusions based on the results of the study. At least one manuscript will be prepared for submission to a peer-reviewed scientific publication within six months of completion of the field work and receipt of results of all chemical analyses.

F. MONITORING AND DATA EVALUATION

In 1998, concentrations of mercury, methyl mercury and metals (metal scan) will be estimated for specified trophic levels of the Cache Creek ecosystem based on sampling of macro-invertebrates, fish, amphibians and cliff swallows. These data will be compared with those collected in 1997 from throughout the watershed, with appropriate reference sites within or outside the watershed, and with data from other studies as reported in the scientific literature. Close cooperation and coordination with other research efforts focused on water, sediments, and other trophic levels will be essential to a comprehensive analysis of the bioaccumulation of mercury and other potentially hazardous contaminants within the Cache Creek Watershed. Manuscripts prepared for scientific journals are required to have undergone extensive peer review within agencies (USFWS and USGS) before submission, and they will be thoroughly reviewed by peers after submission to the journal(s).

G. IMPLEMENTABILITY

All samples will either be collected on public lands (BLM, Yolo County Parks, etc.) or with permission from landowners. Each team member will have the appropriate collecting permits from the California Department of Fish and Game. Permission to collect from bridges will be obtained from the California Department of Transportation or local county public works offices. Requests for access to study sites have thus far met with uniform agreement and support from public land managers, business enterprises, and the general public. The applicants have been participating in meetings of the Cache Creek Stakeholders which have provided many opportunities for networking and collaboration. The study of mercury in the Cache Creek Watershed is greatly enhanced by the CVRWQCB's focus on storm event monitoring of mercury transport. Dr. Jim Rytuba, Water Resources Division of USGS, has a complementary research effort under way investigating the chemical forms and complexes of mercury in mine tailings and hot springs in the watershed. Our study will cooperate with personnel conducting the ecotoxicity study initiated by the Yolo County Department of Environmental Health, led by Dr. Tom To. The Cache Creek Conservancy (Ann Brice) and the Yolo County Community Development Agency (David Morrison) have cooperated by facilitating access to study sites. We have cooperated with the University of California, Department of Wildlife, Fish, and Conservation Biology (Peter Moyle) in fish surveys of the watershed. Data will be shared with the American Land Conservancy, a group in the process of acquiring for public uses a major portion of the Bear Creek Watershed (about 14,000 acres). Data and field sites are being or will be shared with other researchers and managers as the project progresses. This project has begun, the workers are in place, and work can begin on the 1998 phase of the study within a few weeks.

IV. COSTS AND SCHEDULE TO IMPLEMENT PROPOSED PROJECT

A. BUDGET COSTS (See Table 2 for more details)

Project Phase and Task	Direct Labor Hours	Direct Salary and Benefits	Overhead Labor (General, Admin. and fee)	Misc. and other Direct Costs	Total Cost
Field-98	14 mo.	33,233	8,223	35,290	76,746
Writeup -99	3.5 mo.	8,557	1,207	1,500	11,264
Total	17.5 mo.	41,790	9,430	36,790	88,010

This project is in its first year (1997) of a three-year study of mercury in the Cache Creek Watershed. Funding for 1997 was provided by "off-refuge environmental contaminants" funding through Region One of the USFWS. This funding covered about one-half of the costs in 1997; the other half was provided from base funds of the USGS. A proposal to extend funding for the second and third years of the study has been submitted to USFWS, but no alternate source of matching funds has been obtained by USGS. USGS will provide funding for the principal investigator during the study, but additional funds are needed to conduct the necessary, but very expensive, chemical analyses required to adequately characterize the watershed's mercury contamination. Funding of chemical analyses (See Table 2) by CALFED would enable the project to complete many of its objectives. Without additional funding, however, numbers of study sites and numbers of samples per site must be reduced to a minimum, making statistical comparisons more difficult, if not impossible. No other sources of funding are being pursued at this time.

B. SCHEDULE MILESTONES

Collections of biota will continue through September 1998. Most first-year field samples have been collected and will be submitted to the laboratory for analysis by the end of July 1997 and second-year samples by July 1998. Tissue residue data will likely be available by the fall in each year. More specific sampling will occur in FY-98 in areas identified as sites of high bioaccumulation. A preliminary report will be completed in Fall of 1997 and the final report will be submitted within six months of receipt of analytical results from the 1998 sampling. We estimate that a report of study results will be submitted to appropriate peer review journals within a year of receipt of analytical results.

C. THIRD PARTY IMPACTS

None are anticipated.

V. APPLICANT QUALIFICATIONS

Roger L. Hothem received his M.S. in Wildlife Management from Ohio State University in 1972. He has worked for the U.S. Department of the Interior since 1977, and is currently a wildlife research biologist for the Biological Resources Division of the USGS. Since 1984, his primary research emphasis has been measuring, evaluating, and predicting the effects of various environmental contaminants on wildlife, especially birds. Research he conducted on the effects of selenium and other contaminants in irrigation drainwater on avian reproduction in the San Joaquin Valley, California, during 1984-1988, produced 12 coauthored articles in peer-reviewed journals. Since 1989, his research has focused on the impacts of contaminants, especially selenium, mercury and organochlorines, on the reproductive success of wading birds in San Francisco Bay. Three peer-reviewed articles have been published from this work. Other projects have included: effects of cyanide on mammals at gold mines, contaminants in small mammals in San Francisco Bay, dicofol levels in avian eggs and lizards, and contaminants in eggs of western snowy plovers. Recent work has also included studies of contaminants at Edwards Air Force Base in the Mojave Desert and, beginning in the spring of 1997, a study of the effects of mercury on birds and amphibians in the Cache Creek watershed.

Steven E. Schwarzbach received a Ph.D. in Ecology from the University of California, Davis in 1989 and currently serves as Chief of the Environmental Contaminants Division of the Sacramento Field Office, USFWS. He has designed and directed numerous multidisciplinary field studies of environmental contaminant impacts to fish and wildlife in California, including studies in the Klamath Basin, Sacramento Valley, Tulare Basin, San Luis Refuge Complex, and intertidal marshes of San Francisco Bay. Contaminant studies in which Dr. Schwarzbach has been involved have focused on mercury, selenium, organophosphate pesticides, aquatic herbicides, organochlorines, trifluoracetic acid, acid mine drainage, ammonia, and eutrophication effects upon water quality. Dr. Schwarzbach supervises a staff of 10 permanent biologists and administers an annual budget of $1.4 million. His personal scientific interests have recently been focused on mercury and selenium in birds of the San Joaquin Valley, San Francisco Bay, and Cache Creek.

Mark R. Jennings received his Ph.D. in Wildlife and Fisheries Science from the University of Arizona in 1986. For the past 11 years, he has directed 10 projects dealing with the decline and status of amphibians and reptiles in California, especially with native frogs and toads in the Sierra Nevada and Southern California. This work was conducted under contract with the U.S. Fish and Wildlife Service, U.S. Forest Service, U.S. Geological Survey, California Department of Fish and Game, California Department of Parks and Recreation, University of California, Davis, and California Polytechnic State University, San Luis Obispo. This work resulted in dozens of publications in peer-reviewed journals. In 1994, he produced a comprehensive report for the California Department of Fish and Game on the status of the State's herpetofauna that has served as a model for other states in the American West. He currently serves as a member of the USFWS Recovery Team for the San Francisco garter snake, giant garter snake, and the California red-legged frog. He has also written recovery plans for the USFWS on the arroyo toad

and the Santa Cruz long-toed salamander. From 1980-1990, Dr. Jennings studied the effects of selenium and other contaminants on the fishes of the San Joaquin Valley that resulted in three coauthored papers on the subject. He is currently a co-investigator on a mercury assessment study of amphibians and birds in the Cache Creek Watershed.

Larry D. Thompson received a B.S. degree from Southern Oregon State College in 1982 and an M.S. degree from the University of Colorado in 1987. He expects to receive a second M.S. degree (Water Resources/Aquatic Toxicology) in 1997 from the University of Wisconsin, where he researched the effects of landfill leachate contamination and metallic precipitate formation on benthic invertebrate and fish populations. He has held research assistant positions with the Wisconsin Department of Natural Resources and the Upper Mississippi Science Center (USGS-BRD). Mr. Thompson is currently a Fish and Wildlife Biologist with the Environmental Contaminants Division of the Sacramento Field Office, USFWS. He provides expertise in the determination of metal residues in aquatic macro-invertebrates and community-level responses to metal exposures in contaminated streams.

Walter J. Sadinski received his Ph.D. in Ecology from Pennsylvania State University in 1991. He is currently a research fellow at the University of California, San Francisco. Current research includes the design and conduct of studies on molecular mechanisms and bioassays of DNA damage and repair in amphibians and human cell lines exposed to chemical toxicants or ultraviolet radiation. He is conducting an ongoing study to determine the causes of reported declines of populations of amphibians in Yosemite National Park. This work includes: research on the reproductive success of amphibians in relation to environmental parameters such as Ultraviolet-B Radiation, water chemistry, and those related to climate, as well as the relationships among inherent capacities for DNA repair, DNA damage incurred, and hatching success among embryos exposed to ambient ultraviolet-B radiation *in situ*. As a research fellow at Lawrence Berkeley Laboratory, he executed original studies of micronuclei and DNA adducts as measures of sublethal DNA damage and indicators of effects on fitness in larval amphibians exposed to chemical toxicants. He also participated in the designs, executions, and analyses of studies of toxicity and risk assessment in San Francisco Bay and wetlands exposed to urban runoff, in addition to studies of cumulative genetic damage in nematodes exposed to ultraviolet radiation and chemical toxicants.

VI. COMPLIANCE WITH STANDARD TERMS AND CONDITIONS:

Nondiscrimination compliance statement attached.

Terms and conditions are agreeable to and able to be complied with by the applicant.

ATTACHMENT A

LITERATURE CITED

Barr, J.F. 1986. Population dynamics of the common loon (*Gavia immer*) associated with mercury contaminated waters in northwestern Ontario. Occasional Paper 56. Canadian Wildlife Service, Ottawa, Ontario.

Beauvais, S.L., Wiener, J.G., and Atchison, G.J. 1995. Cadmium and mercury in sediment and burrowing mayfly nymphs (*Hexagenia*) in the Upper Mississippi River, USA. Arch. Environ. Contam. Toxicol. 28:178-183.

Blaustein, A.R., D.B. Wake, and W.P. Sousa. 1994. Amphibian declines: Judging stability, persistence, and susceptibility of populations to local and global extinctions. Conserv. Biol. 8:60-71.

Bloom, N.S. 1992. On the chemical form of mercury in edible fish and marine invertebrate tissue. Can.J.Fish.Aq.Sci. 49:1010-1017.

California Department of Fish and Game. 1988. Health Warnings 1988. State Public Information Publication.

Chang, L.W., K.R. Reuhl, and A.W. Dudley, Jr. 1974. Effects of methylmercury chloride on *Rana pipiens* tadpoles. Environ. Res. 8:82-91.

Cooke, A.S. 1981. Tadpoles as indicators of harmful levels of pollution in the field. Environ. Pollut.(Ser.A) 25:123-133.

Davis, J.A., A.J. Gunther, B.J. Richardson, J.M. O'Connor, R.B. Spies, E. Wyatt, E. Larson, and E.C. Meiorin. 1991. Status and trends report on pollutants in the San Francisco Estuary. Report for the San Francisco Estuary Project, U.S. Environmental Protection Agency, San Francisco, Calif. 240pp + appendices.

Dial, N.A. 1976. Methyl mercury: Teratogenic and lethal effects in frog embryos. Teratology 13:327-334.

Drost, C.A. and G.M. Fellers. 1996. Collapse of a regional frog fauna in the Yosemite area of the California Sierra Nevada, USA. Conserv. Biol. 10:414-425.

Eisler, R. 1987. Mercury hazards to fish, wildlife, and invertebrates: A synoptic review. U.S. Fish Wildl. Serv., Biol. Rep. 85(1.10), 90pp.

Fellers, G.M. and C.A. Drost. 1993. Disappearance of the Cascades frog *Rana cascadae* at the southern end of its range, California, USA. Biol. Conserv. 65:177-181.

Fimreite, N. 1974. Mercury contamination of aquatic birds in northwestern Ontario. J. Wildl.Manage. 38(1):120-131.

Fisher, R.N. and H.B. Shaffer. 1996. The decline of amphibians in California's Great Central Valley. Conserv. Biol. 10:1387-1397.

Gill, G.A. and K.W. Bruland. 1990. Mercury speciation in surface freshwater systems in California and other areas. Environ. Sci. Technol. 24:1392-1400.

Gillespie, D.C., and D.P. Scott. 1971. Mobilization of mercury sulfide from sediment into fish under aerobic conditions. J. Fish. Res. Bd. Can. 28:1807.

Hayes, M.P. and M.R. Jennings. 1986. Decline of ranid frog species in western North America: Are bullfrogs (*Rana catesbeiana*) responsible? J. Herpetol. 20:490-509.

Hayes, M.P. and M.R. Jennings. 1988. Habitat correlates of distribution of the California red-legged frog (*Rana aurora draytonii*) and the foothill yellow-legged frog (*Rana boylii*): Implications for management. Pages 144-158 in R.C. Szaro, K.E. Severson, and D.R. Patton (tech. coordinators), *Management of amphibians, reptiles, and small mammals in North America.* Proc. Mountain Forest and Range Experiment Station, Fort Collins, Colorado. Gen. Tech. Rep. (RM-166):1-458.

Hayes, M.P. and M.R. Jennings. 1990. Vanishing amphibians: New mystery in an old pattern. Mainstream 21(3):20-23.

Heinz, G.H. 1979. Methyl mercury: reproductive and behavioral effects on three generations of mallard ducks. J. Wildl. Manage. 43(2):394-401.

Hesse, L.W., R.L. Brown, and J.F. Heisinger. 1975. Mercury contamination of birds from a polluted watershed. J. Wildl. Manage. 39(2):299-304.

Jayaprakash, R.I. and M.N. Madhyastha. 1987. Toxicities of some heavy metals to the tadpoles of frog, *Microhyla ornata* (Dumeril & Bibron). Toxicol. Let. 36:205-208.

Jennings, M.R. 1988. Natural history and decline of native ranids in California. Pages 61-72 in H.F. DeLisle, P.R. Brown, B. Kaufman, and B. McGurty (eds.). Proceedings of the Conference on California Herpetology. Southwestern Herpetologists Society, Spec. Publ. (4):1-143.

Jennings, M.R. 1996. Status of amphibians. Pages 31-1--21-24 in Sierra Nevada Ecosystem Project: Final Report to Congress, Vol. II, Assessments and scientific basis for management options. Center for Water and Wetland Resources, Univ. of California, Davis.

Jennings, M.R. and M.P. Hayes. 1994a. Amphibian and reptile species of special concern in California. California Dept. of Fish and Game, Inland Fisheries Div., Rancho Cordova, CA, 255pp.

Nyholm, N.E.I. 1995. Monitoring of terrestrial environmental metal pollution by means of free-living insectivorous birds. Annals Di Chimica 85:343-351.

Powell, G.V.N. 1983. Industrial effluents as a source of mercury contamination in terrestrial riparian vertebrates. Environ. Pollut. (Ser. B) 5:51-57.

Punzo, F. 1993. Effect of mercuric chloride on fertilization and larval development in the River frog, *Rana heckscheri* (Wright) (Anura: Ranidae). Bull. Environ. Contam. Toxicol. 51:575-581.

Saouter, E., L. Hare, P.G.C. Campbell, A, Boudou, and F. Ribeyre. 1993. Mercury accumulation in the burrowing mayfly *Hexagenia rigida* (Ephemeroptera) exposed to CH_3HgCl or $HgCl_2$ in water and sediment. Water Research 27:1041-1048.

Scheuhammer A.M. 1987. The chronic toxicity of aluminum, cadmium, mercury, and lead in birds: a review. Environ. Pollut. 46:263-295.

Scheuhammer A.M. 1991. Effects of acidification on the availability of toxic metals and calcium to wild birds and mammals. Environ. Pollut. 71:329-375.

Schwarzbach, S. and J. Hofius. 1996. Draft interpretive criteria for mercury residues. Prepared for National Irrigation Water Quality Program. U.S. Fish and Wildlife Service.

Slotton, D.G., S.M. Ayers, J.E. Reuter, and C.R. Goldman. 1997. Cache Creek watershed preliminary mercury assessment, using benthic macro-invertebrates. Final Report for the Central Valley Regional water Quality Control Board and the National Science Foundation, 36pp.

Stebbins, R.C. and N.W. Cohen. 1995. A natural history of the amphibians. Princeton Univ. Press, Princeton, NJ, 316pp.

Steingraeber, M.T. and J.G. Wiener. 1995. Bioassessment of contaminant transport and distribution in aquatic ecosystems by chemical analysis of burrowing mayflies *(Hexagenia)*. Regulated Rivers: Research & Management. 11:201-209.

Suchanek, T.H.., P.J. Richerson, L.A. Woodward, D.G. Slotton, L.J. Holts, and C.E. Woodmansee. 1993. Ecological Assessment Sulphur Bank Mercury mine superfund site Clear Lake, California. Preliminary Lake Study Report. May 25, 1993, 113pp.

Suchanek T.H., P.J. Richerson, L.J. Holts, B.A. Lamphere, C.E. Woodmansee, D.G. Slotton, and L.A. Woodward. 1995. Impacts of mercury on benthic invertebrate populations and communities within the aquatic ecosystem of Clear Lake, California. Water Air Soil Pollut. 80:951-960.

U.S. Army Corps of Engineers. 1995. Northern California Streams: Reconnaissance report Cache Creek Environmental Restoration, California.

Watras, C.J. and N.S. Bloom. 1992. Mercury and methylmercury in individual zooplankton: implications for bioaccumulation. Limnology and Oceanography 37:1313-1318.

Wiener, J.G. and D.J. Spry. 1996. Toxicological significance of mercury in freshwater fish. Pages 297-339 in W.N. Beyer, G.H. Heinz, and A.W. Redmon-Norwood (eds.). *Environmental Contaminants in Wildlife: Interpreting Tissue Concentrations.* Lewis Publishers, Boca Raton, FL, 494pp.

Zillioux E.J., D.B. Porcella, and J.M. Benoit. 1993. Mercury cycling and effects in freshwater wetlands ecosystems. Environ. Toxicol. Chem. 12:2245-2264.

Zoll, Catherine, E. Saouter, A. Boudou, F. Ribeyre, and A. Jaylet. 1988. Genotoxicity and bioaccumulation of methyl mercury and mercuric chloride *in vivo* in the newt *Pleurodeles waltl.* Mutagenesis 3(4):337-343.

Table 1. Collection sites for 1997 mercury study.

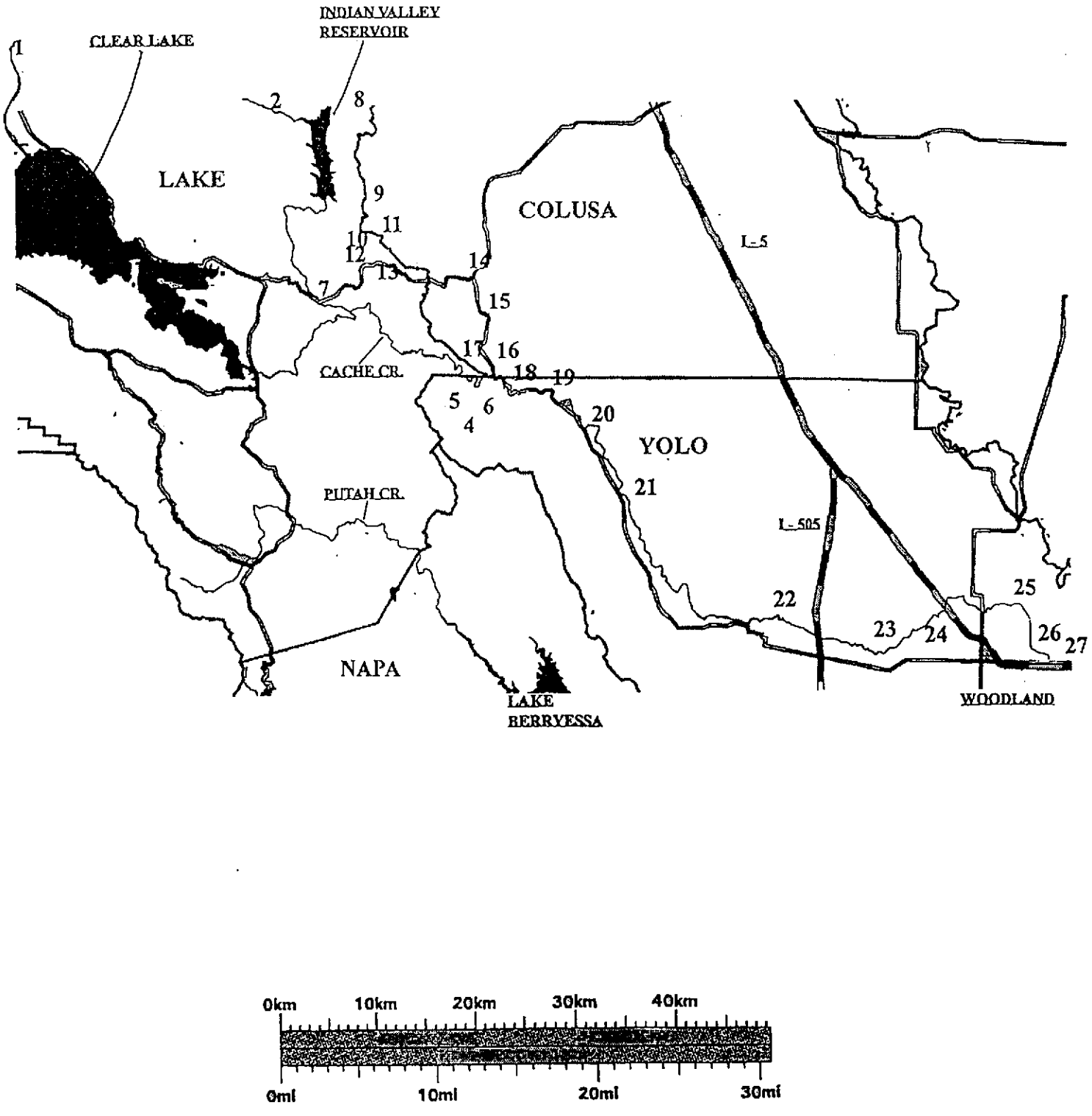
Site #	Location	Bullfrogs Adults	Bullfrogs Tadpoles	Foothill Yellow-Legged Frogs	Pacific Treefrogs	Total Amphibians	Cliff Swallows
1	W. Fork Middle Creek	0	0	3	0	3	12
2	N. Fork Cache Ck., by Spanish Creek	0	0	3	0	3	0
3	Anderson Marsh State Park	0	0	0	0	0	0
4	Davis Creek Reservoir	3	0	0	2	5	12
5	Davis Creek upstream from res.	3	3	3	4	13	0
6	Davis Creek downstream from res.	3	3	3	4	13	0
7	N. Fork Cache Creek at Hwy. 20	0	0	0	0	0	12
8	Mill Creek at Brim Rd.	3	0	3	0	6	12
9	Bear Creek at Hamilton Canyon	3	3	3	3	12	0
10	Sulfur Creek	0	0	3	3	6	12
11	Bear Creek at Sulfur Creek	3	3	3	3	12	12
12	Turkey Run Mine	0	0	1	0	1	0
13	Harley Gulch	0	0	3	3	6	0
14	Bear Creek at Hwy 20	0	3	0	0	3	12
15	Bear Creek Bridge over Hwy 16 (15-37)	0	0	3	0	3	12
16	Bear Creek up from Jct w. Cache	3	0	3	0	6	0
17	Cache Ck up from jct w. Bear Ck.	2	0	2	0	4	0
18	Cache Ck. down from jct w. Bear Ck.	3	0	1	0	4	0
19	Cache Creek Bridge 22-19 (BS Camp)	3	0	0	0	3	12
20	Cache Creek at Rumsey Bridge	0	0	0	1	1	3
21	Cache Creek at Guinda Bridge	3	3	0	0	6	12
22	Cache Creek at Esparto Bridge	3	0	0	0	3	12
23	Cache Creek at Rd. 94B Bridge	3	3	0	0	6	0
24	Cache Creek Conservancy Pond	1	0	0	1	2	0
25	Cache Creek at Rd. 102 Bridge	3	0	0	0	3	12
26	Cache Creek Settling Basin	3	0	0	0	3	0
27	Sacramento River Pumping Station	0	0	0	0	0	4
	Totals	45	21	37	24	127	151

Table 2. BUDGET FOR CACHE CREEK MERCURY STUDY

PERSONNEL(3% COLA/year)		1998 1/98-12/98		1999 1/99-12/99		Both Years
Salary and Benefits(15%)	Rate/ Mo.	Time (mo)	Cost	Time (mo)	Cost	Total Cost
R.L. Hothem*	$5,729	4	22,916*	2	11,802*	34,718*
S.E. Schwarzbach**	$6,053	2	12,106**	1	6,235**	18,341**
L. Thompson**	$3,400	4	13,600**	2.2	7,768**	21,368**
M. Jennings	$4,658	2	9,317	0.5	2,399	11,716
Biol. Tech	$1,993	6	11,958	3	6,158	18,116
Biol. Tech.	$1,993	6	11,958	0	0	11,958
* USGS Base Funds			(22,916)		(11,802)	(34,718)
**USFWS Matching Funds			(25,706)		(14,003)	(39,709)
TOTAL SALARY/BENEFITS			33,233		8,557	41,790
TRAVEL:			2,000		500	2,500
EQUIPMENT: Nest-monitoring camera			3,950		0	3,950
SUPPLIES: jars, bags, chemicals, etc.			1,200**		0	1,200**
COMMUNICATION/PUBLISHING COSTS: Shipping, Graphics, etc.			500		1,000	1,500
Other Costs **CHEMICAL ANALYSES** (Mercury, methyl mercury, & metal scan)			46,880**		0	46,880**
GENOTOXICITY ASSAYS for amphibians			9,600**		0	9,600**
Less Matching Funds (USFWS)			(28,240)		0	(28,240)
TOTAL OTHER			28,240		0	28,240
TOTAL PROJECT COSTS			145,985		35,862	181,847
DIRECT COSTS REQUESTED FROM CALFED			68,523		10,057	78,580
INDIRECT COSTS (12%) REQUESTED FROM CALFED			8,223		1,207	9,430
TOTAL FUNDS REQUESTED FROM CALFED			**76,746**		**11,264**	**88,010**

* These costs are base salary funds provided by applicant.
** 50% of this cost is matching funds from U.S. Fish and Wildlife Service.

Figure 1. Cache CreekWatershed with sampling sites used in 1997 (See Table 1 for site description and samples collected in 1997).



Item

NONDISCRIMINATION COMPLIANCE STATEMENT

COMPANY NAME

U.S. GEOLOGICAL SURVEY, Biological Resources Division, California Science Center

The company named above (hereinafter referred to as "prospective contractor") hereby certifies, unless specifically exempted, compliance with Government Code Section 12990 (a-f) and California Code of Regulations, Title 2, Division 4, Chapter 5 in matters relating to reporting requirements and the development, implementation and maintenance of a Nondiscrimination Program. Prospective contractor agrees not to unlawfully discriminate, harass or allow harassment against any employee or applicant for employment because of sex, race, color, ancestry, religious creed, national origin, disability (including HIV and AIDS), medical condition (cancer), age, marital status, denial of family and medical care leave and denial of pregnancy disability leave.

CERTIFICATION

I, the official named below, hereby swear that I am duly authorized to legally bind the prospective contractor to the above described certification. I am fully aware that this certification, executed on the date and in the county below, is made under penalty of perjury under the laws of the State of California.

OFFICIAL'S NAME

ROGER L. HOTHEM

DATE EXECUTED	EXECUTED IN THE COUNTY OF
July 25, 1997	YOLO

PROSPECTIVE CONTRACTOR'S SIGNATURE

Roger L Hothem

PROSPECTIVE CONTRACTOR'S TITLE

Wildlife Biologist (Wildlife)

PROSPECTIVE CONTRACTOR'S LEGAL BUSINESS NAME

U.S. GEOLOGICAL SURVEY, Biological Resources Division, California Science Center