F1-019

I. Executive Summary

a. Project Title and Applicant Name: Toxic Effects in Juvenile Chinook Salmon Following Simulated Long-term Exposure to Ambient Concentrations of Copper, Cadmium, and Zinc in Water and Forage Organisms from the Sacramento River; Michael K. Saiki.

b. Project Description and Primary Biological/Ecological Objectives: This study will determine if juvenile chinook salmon (Oncorhynchus tshawytscha) reared under laboratory conditions simulating those found in metal-contaminated reaches of the Upper Sacramento River exhibit poor growth, impairment of parr-smolt transformation, and other biochemical changes or physiological afflictions that adversely affect survival during downstream migration through the Delta and San Francisco Bay. Specific objectives are to determine if long-term (90-day) exposure of fish to metal-contaminated water and forage organisms at relevant concentrations result in measurable toxic effects and, if so, to determine the relative importance of these two routes of metal exposure.

c. Approach/Tasks/Schedule: The general approach is to collect aquatic invertebrates from selected reaches of the Sacramento River and its tributaries that are either exposed or unexposed to heavy metal contamination from acid-mine drainage. The invertebrates will be used to prepare test diets that are then be fed to juvenile chinook salmon for 90 days in the laboratory. In addition to dietary treatments, the fish will be exposed to water treatments that mimic conditions in the Sacramento River. Toxic endpoints will include measurements of fish survival, growth, swimming performance, gill Na-K ATPase activity, serum and mucus lysozyme activities, liver metallothionein level, and whole-body concentrations of copper, cadmium, and zinc. Field collections of aquatic invertebrates will be completed by March 1998, formulation of experimental diets will be completed by December 1998, test animals will be obtained by February 1999, the laboratory exposures will be completed by June 1999, the associated biological or toxicological measurements will be completed by September 1999, the chemical analyses of water and tissue samples will be completed by December 1999, and the final report summarizing the study results will be completed by September 2000.

d. Justification for Project and Funding by CALFED: Fish kills associated with heavy metal toxicity have historically occurred in the Sacramento River at or below the mouth of Spring Creek, a small tributary that receives acid-mine drainage from Iron Mountain Mine. The fish kills included anadromous salmonids such as chinook salmon, which use the San Francisco Bay/Delta as a migratory corridor to the Pacific Ocean. Within the last 20 years, remedial actions at Iron Mountain Mine and elsewhere in the Spring Creek watershed have reduced metal concentrations entering the Sacramento River and virtually eliminated the massive fish kills. However, dissolved concentrations of copper, cadmium, and zinc still occasionally exceed concentrations predicted to cause some mortality in juvenile salmonids. A recent field study in the Sacramento River also

identified elevated concentrations of copper, cadmium, and zinc in aquatic invertebrates that serve as forage for juvenile salmonids. The possibility exists that foodborne exposure to metals may adversely affect juvenile chinook salmon in the Sacramento River and exacerbate toxicity from dissolved metals. In addition, juvenile salmonids exposed to sublethal concentrations of metals in the Sacramento River could arrive in the San Francisco Bay-Delta with impaired disease resistance (immune system dysfunction) and a diminished capacity to tolerate physiological stresses associated with the parr-smolt transformation and entry into saline waters. CALFED priorities addressed by this proposal include instream aquatic habitats in the Sacramento River that receive metal-contaminated acid-mine drainage, and winter-run and spring-run chinook salmon that may experience toxic effects from metal exposure.

e. Budget Costs and Third Party Impacts: The amount requested from CALFED to complete this study is $374,870. If the study contributes toward enhancing habitat restoration efforts and fostering increased production of chinook salmon, third party impacts could include more fishing opportunities for anglers in the Sacramento River, San Francisco Bay-Delta, and coastal waters of northern California. Indirectly, the local economy may benefit from a healthy recreational fishing industry.

f. Applicant Qualifications: The Principal Investigator (Dr. Michael K. Saiki) has nearly 20 years of working experience in aquatic contaminant issues affecting chinook salmon and other fishes in the Sacramento and San Joaquin river systems. His past work includes field and laboratory studies similar to the work described in this proposal. Since 1991, Dr. Saiki has received more than $750,000 in competitive grants and contracts to support his research program. Results from his studies have appeared in 21 peer-reviewed publications.

g. Monitoring and Data Evaluation: Standard techniques (e.g., analysis of variance) will be used to summarize and compare the data for statistical significance. Data interpretation will integrate, contrast, and verify findings from this work with relevant results from other published studies. Working hypotheses generated by this study will reassess contaminant threats to juvenile chinook salmon in the Sacramento River, and suggest new or revised habitat restoration goals that further reduce or eliminate adverse effects from such threats.

h. Local Support/Coordination with other Programs/Compatibility with CALFED objectives: This proposed study will complement and extend findings from past and current monitoring and research studies on acid-mine drainage and anadromous fishery resources by the U.S. Geological Survey, the U.S. Fish and Wildlife Service, and other federal or state agencies in the Sacramento River and the San Francisco Bay-Delta. The U.S. Fish and Wildlife Service has voiced strong support for this study because it will help evaluate the protectiveness of proposed cleanup activities at the Iron Mountain Mine Superfund site.

II. Title Page

a. Title of Project: Toxic Effects in Juvenile Chinook Salmon Following Simulated Long-term Exposure to Ambient Concentrations of Copper, Cadmium, and Zinc in Water and Forage Organisms from the Sacramento River.

b. Name of applicant/principle investigator(s); address; phone/fax/E-mail; organizational, institutional or corporate affiliations of applicant/principle investigator(s): Michael K. Saiki; Northwest Biological Science Center-Dixon Duty Station, 6924 Tremont Road, Dixon, California 95620; tel. (916) 756-1946 x617, fax (916) 678-5039, E-mail michael_saiki@nbs.gov; U.S. Geological Survey, Biological Resources Division.

c. Type of Organization and Tax Status: U.S. Government, tax exempt.

d. Tax Identification Number and/or Contractor license, as applicable: Not available.

e. Technical and Financial Contact person(s), address, phone/fax/E-mail (if different from above): Michael K. Saiki.

f. Participants/Collaborators in Implementation: Daniel F. Woodward, U.S. Geological Survey, Environmental and Contaminants Research Center, Jackson Field Research Station, P.O. Box 1089, Jackson, Wyoming 83001; Thomas W. May, U.S. Geological Survey, Environmental and Contaminants Research Center, 4200 New Haven School Road, Columbia, Missouri 65201; and Alec G. Maule, U.S. Geological Survey, Northwest Biological Science Center, Columbia River Field Station, 5501-A Cook-Underwood Road, Cook, Washington 98605.

g. RFP Project Group Type(s) (Construction; Acquisition; Other Services): Other Services.

III. Project Description.

a. Project Description and Approach: This study will determine if juvenile chinook salmon reared in the Upper Sacramento River are adversely affected by long-term (90 days) exposure to ambient concentrations of dissolved metals in water and consumption of metal-contaminated forage organisms. Specific objectives are to determine if measurable toxic effects are present in exposed fish and, if so, to determine the relative importance of waterborne and foodborne routes of metal exposure. The general approach is to expose fish to eight treatments consisting of two levels of dissolved metals and four levels of metal-contaminated forage during a 90-day exposure period to detect toxic responses such as reduced growth and survival, impaired physiological condition, and curtailed development of the parr-smolt transformation. Each treatment will be replicated four times, and each replicate will contain 25 fish. Thus, 32 test chambers and 800 fish will be required for this study. The two levels of dissolved metals will consist of (i) undetectable concentrations of copper, cadmium, and zinc, and (ii) concentrations of copper, cadmium, and zinc equivalent to the 75th percentile for measurements made over the past year in the Sacramento River at Keswick Dam. The four levels of metal-contaminated forage will consist of a control diet obtained from a commercial source (i.e., Biodiet®) and three diets formulated with aquatic invertebrates collected from selected reaches of the Sacramento River and one of its tributaries: a reference diet containing aquatic invertebrates from a tributary with no history of metal contamination (e.g., Battle Creek); a test diet containing aquatic invertebrates from the Sacramento River at Redding (a known metal-contaminated site); and a second test diet containing aquatic invertebrates from the Sacramento River at Meridian (a site downstream from Redding where metal contamination is reduced by dilution from uncontaminated tributaries). The three diets formulated from aquatic invertebrates will be supplemented with appropriate amounts of essential vitamins and minerals to approximate the amounts present in Biodiet®. Fish survival will be monitored daily, whereas growth (increase in length or weight) will be measured at monthly intervals. Following termination of the test after 90 days, 1/4 of surviving fish in each treatment will be subjected to a swimming performance test (an index of general health and stress); 1/4 will be subjected to a 24-hr seawater challenge test (a direct measure of adaptation to ionoregulatory stress); 1/4 will be used for measurements of gill Na-K ATPase activity (a measure of the extent to which smoltification has progressed), serum and mucus lysozyme activity (a general measure of immune competence), and liver metallothionein level (a measure of the fish's adaptive ability to tolerate metal exposure); and 1/4 will be used for determination of whole-body concentrations of copper, cadmium, and zinc.

b. Location and/or geographic boundaries of project: This study will assess the toxic effects of heavy metals in acid-mine drainage on chinook salmon reared in the Sacramento River below Keswick Reservoir within the Sacramento River Watershed Region. Aquatic invertebrates will be collected from the reach of Sacramento River extending from Redding (Shasta County) downstream to Meridian (Sutter County). In

addition, aquatic invertebrates will be collected from at least one tributary (e.g., Battle Creek) within this reach of the Sacramento River. Results from the study are applicable to the San Francisco Bay-Delta, which serves as the sole migratory corridor for all anadromous salmonids in the Sacramento River.

c. Expected benefit(s): This study focuses on chinook salmon that spawn and rear in in-stream aquatic habitat of the Sacramento River below Keswick Reservoir. Although fall-run fish will be used in laboratory tests because they are most readily available from local hatcheries, results will be directly applicable to winter-run and spring-run chinook salmon. This study will specifically attempt to determine if existing concentrations of copper, cadmium, and zinc dissolved in water and bioaccumulated in fish-forage invertebrates are toxic to juvenile salmon. The study is especially significant to CALFED because it will provide baseline information for assessing the effectiveness of current and future remedial actions aimed at reducing heavy metal pollution from Iron Mountain Mine (including water release schedules from Shasta Dam to dilute flows of acid-mine drainage from the Spring Creek Debris Dam). In addition, results from the study will be useful for evaluating the severity of environmental damage to chinook salmon stocks that contribute to recreational fishing opportunities in the San Francisco Bay-Delta.

d. Background and Biological/Technical Justification: For over a century, fish kills from metal pollution have occurred in the Sacramento River at or below the mouth of Spring Creek, a small tributary that receives acid-mine drainage from Iron Mountain Mine. Major kills of □25,000 fish were documented in 1955, 1957, and 1967. The last recorded kill, which involved unknown numbers of trout (species not identified), occurred in Keswick Reservoir in January 1978.

In 1963, the Spring Creek Debris Dam (which forms Spring Creek Reservoir) was constructed partly to control the flow of acid-mine drainage into Keswick Reservoir, an afterbay for Shasta Dam on the Sacramento River. Copper cementation plants were also installed in the Spring Creek drainage to help remove this metal from the drainage water. Flow from the Debris Dam is regulated in accordance with discharge from Shasta Dam specifically to avoid heavy metal concentrations in the Sacramento River that are acutely toxic to juvenile salmonids.

Efforts to alleviate the toxic effects of metals on fishes in the Sacramento River have focused primarily on chinook salmon because this species is especially important to the socioeconomic welfare of people in California. In 1963, the California Department of Fish and Game attempted to estimate safe levels for total copper from 96-hr acute toxicity tests with chinook salmon fingerlings. In 1978-80, the California Department of Fish and Game conducted additional tests that included cadmium and zinc. The new tests employed embryos, larvae, and fingerlings of chinook salmon and steelhead (Oncorhynchus mykiss), and were conducted for up to 83 days. Based on these tests, the State of California adopted and the U.S. Environmental Protection Agency (USEPA) approved the following site-specific water quality objectives (standards) for the

Sacramento River below Keswick Dam (values are dissolved concentrations for receiving waters where total hardness is 40 mg/L as $CaCO_3$): copper, 0.0056 mg/L; cadmium, 0.00022 mg/L; and zinc, 0.016 mg/L. The USEPA Superfund Program recently implemented major pollution control measures at Iron Mountain Mine to reduce the volume of contaminated runoff entering Spring Creek. In spite of these past and current efforts, potentially toxic concentrations of dissolved metals still occur in the Sacramento River during heavy rainfall when releases from Shasta Dam and the Spring Creek Power Plant are inadequate for diluting uncontrolled flood-stage flows that overtop the Spring Creek Debris Dam.

Heavy metal pollution in aquatic ecosystems is often more markedly reflected by high metal levels in sediments, macrophytes, and benthic animals than by elevated concentrations in water. Under these circumstances, fish could be endangered if they ingest sediment-dwelling invertebrates. In 1990, the National Biological Survey (now known as the Biological Resources Division of the U.S. Geological Survey) conducted a field survey of metal concentrations in water, sediment, particulate organic detritus, waterweed (Elodea canadensis), immature aquatic insects, and fishes (including juvenile chinook salmon) sampled during July-September (low flow period) from two sites in the Sacramento River downstream from Keswick Dam (at Redding and at Jellys Ferry Road, about 40 km downstream from Redding) and from one site each in two nearby tributary streams (Battle and Cottonwood creeks) with no history of exposure to acid-mine drainage. Samples from the Sacramento River (especially waterweed and insects) contained higher concentrations of copper, cadmium, and zinc than did samples from the tributaries. In the Sacramento River, mean concentrations (expressed as dry weight) in aquatic insects (48-200 mg copper/kg, 8.3-23 mg cadmium/kg, and 430-1,600 mg zinc/kg) were as much as 1-2 orders of magnitude higher than in whole fish (5.3-11 mg copper/kg, 0.78-1.4 mg cadmium/kg, and 130-210 mg zinc/kg), indicating that these metals did not undergo biomagnification through the food chain. However, the toxic threshold in fishes subsisting on metal-contaminated foods has not been determined. Until such data are available, the ecological significance of elevated metal burdens in fish-forage organisms will remain poorly understood.

Researchers from the Oregon Department of Fish and Wildlife reported that juvenile coho salmon (Oncorhynchus kisutch) exposed to sublethal mixtures of dissolved copper, cadmium, and zinc suffered from suppressed Na-K ATPase activity in gills, and deaths occurred when fish were challenged with seawater. More recently, other researchers have shown that gill Na-K ATPase activity in chinook salmon parr was unaffected by exposure to sublethal dissolved copper concentrations, whereas significant inhibition occurred in smolts. These observations suggest that the Na-K ATPase enzyme associated with chloride cells in gills of smolts is susceptible to inhibition by dissolved copper, thus explaining the lack of enzyme inhibition found in parr. Similar studies involving foodborne exposure to these metals have not been conducted.

The National Marine Fisheries Service (Seattle, Washington) has shown that aromatic hydrocarbons and polychlorinated biphenyls can reduce the immune competence and, presumably, the disease resistance of juvenile chinook salmon.

Although we are not aware of similar studies where chinook salmon was exposed to heavy metals, other researchers have demonstrated that rainbow trout (the resident form of steelhead) fingerlings become more susceptible to pathogens such as infectious hematopoietic necrosis virus and the bacterium, Yersinia ruckeri, following exposure to sublethal concentrations of dissolved copper. The possible effect of foodborne exposure to metals on the fish immune system has not been investigated.

The purpose of this study is to determine if juvenile chinook salmon exposed to ambient concentrations of dissolved metals and reared on metal-contaminated forage organisms in the Upper Sacramento River experience toxic effects that could adversely affect survival and the recreational fishery for this species in the San Francisco Bay-Delta. Results from this study will serve as a baseline to establish the effectiveness of current and future restoration efforts aimed at reducing heavy metal pollution in the Upper Sacramento River from acid-mine drainage originating at Iron Mountain Mine. The results will also contribute toward an assessment of the severity of damage to the anadromous salmonid fishery in the Bay-Delta.

e. Proposed Scope of Work: This work will be accomplished in two phases. In Phase I, data from ongoing water quality monitoring programs at Keswick Dam will be summarized to establish target levels for major ion and heavy metal concentrations in test waters. The test waters will mimic conditions during the time periods that winter-run chinook salmon (July-March) and spring-run chinook salmon (November-May) are rearing in the Upper Sacramento River. Phase I will also be used to compile and review recently completed and ongoing studies that survey the heavy metal content of food chain organisms from various reaches of the Upper Sacramento River and its tributaries. Results from this compilation will be used to identify or verify reaches from where aquatic invertebrates will be collected to create test diets for this study. Aquatic invertebrates used to formulate the test diets will also be collected during the time period that winter-run and spring-run chinook salmon are rearing in the river. In Phase II, test animals (juvenile chinook salmon) will be exposed under laboratory conditions to appropriate concentrations of heavy metals in water and food for 90 days. Toxic responses in test animals will be recorded daily or at other specified time intervals. Progress reports summarizing significant accomplishments and current level of expenditures will be submitted within 90 days of the completion of each significant milestone of work. In addition, a final completion report that summarizes the entire study, including data interpretations, will be submitted at the end of this study.

f. Monitoring and Data Evaluation: Percent survival, growth, swimming performance, gill Na-K ATPase activity, serum and mucus lysozyme activity, liver metallothionein level, and whole-body concentrations of copper, cadmium, and zinc will be statistically evaluated using analysis of variance. Percent data will be angular transformed before analysis. The experiment will be treated as a completely randomized, two-factor, split-plot design with four replicates. The statistical model includes dissolved metal concentration as the main-plot treatment effect and dietary metal concentration and the

interaction of aqueous and dietary metals as subplot effects. Means will be compared using Tukey's multiple means comparison test. Statistical significance for all tests will be assigned at the P □0.05 level. Data interpretation will attempt to integrate, contrast, and verify findings from this work with relevant results from other published studies. The intent of such comparisons is to develop working hypotheses that can be used to better assess the threats posed by heavy metal contamination to juvenile chinook salmon, and to suggest new or improved habitat restoration goals that reduce or eliminate adverse effects from such threats. The final completion report will be subjected to approval by the NBSC internal peer review process (the same approval process used for manuscripts) prior to submittal to CALFED.

g. Implementability: Scientific Collector's Permits to take aquatic invertebrates from proposed study sites will need to be obtained from the State of California for each federal employee involved with field collections. Special permits will not be needed for possessing chinook salmon used as test animals in the proposed work because all fish will be obtained from federal or state fish hatcheries. Access to field sampling sites will occur at public right-of-ways or on public lands after securing the written permission of the public land manager.

IV. Costs and Schedule to Implement Proposed Project.

a. Budget Costs: The total cost of this project is $449,870, of which $374,870 is requested from CALFED. The remainder ($75,000) is in-kind support from the U.S. Geological Survey for salary-and-benefits of the Principal Investigator (50% time) and value of preexisting equipment and supplies. Service Contracts will consist of $14,000 for preparation of the test diet; $35,000 for chemical analyses of water, test diet, and fish samples; $25,000 for measurements of gill Na-K ATPase activity, and serum and mucus lysozyme activities; and $25,000 for analysis of liver metallothionein levels.

Project Phase and Task	Direct Labor Hours	Direct Salary and Benefits	Overhead Labor (General, Admin. and fee)	Service Contracts	Material and Acquisition Contracts	Miscel. and other Direct Costs	Total Cost
Phase I	960	11,384	24,139	15,000	3,000	10,000	63,523
Phase II	3,600	64,035	118,312	84,000	15,000	30,000	311,347
Grand Total requested from CALFED							374,870

b. Schedule Milestones: The proposed work assumes a start date of December 1, 1997, and a completion date of September 30, 2000. Billings will be submitted to CALFED at quarterly intervals rather than according to completion of milestones.

Milestone	Completion Date
Prepare study plan and protocols	December 1997
Hire personnel and purchase equipment/supplies	December 1997
Collect macroinvertebrates for fish diets	March 1998
Formulate fish diets	December 1998
Complete laboratory exposures	June 1999
Complete biological/toxicological measurements	September 1999
Complete chemical analyses	December 1999
Summarize and interpret data	April 2000
Prepare and revise final report	September 2000

c. Third Party Impacts: Habitat restoration or mitigation efforts that occur in response to findings from this project may result in third party benefits such as increased numbers of chinook salmon available to recreational and commercial fishermen, and fewer restrictions on bag limits and length of the open season. Additional third party impacts may include increased revenues from sale of fishing and boating equipment and supplies; lodging, transportation, and related costs; and other expenditures associated with a thriving recreational fishing industry.

V. Applicant Qualifications.

The Principal Investigator (Dr. Michael K. Saiki) will be responsible for all phases of this proposed work, including supervision of research staff, scheduling research activities, and approving the expenditure of funds. Mr. Daniel F. Woodward of the Environmental and Contaminants Research Center will assist with the laboratory portion of the proposed work, and oversee the preparation of test diets and measurements of liver metallothionein level. Mr. Thomas W. May of the Environmental and Contaminants Research Center will collaborate by conducting chemical determinations of copper, cadmium, and zinc in biological and water samples from this proposed work. Dr. Alec G. Maule of the Northwest Biological Science Center will collaborate by measuring gill Na-K ATPase activity, and serum and mucus lysozyme activities.

Biosketch of the Principal Investigator (Michael K. Saiki):
Education:

Ph.D., 1976. University of Arizona, Tucson. Major: Biology, Minor: Botany.
M.S., 1973. University of Arizona, Tucson. Major: Fishery Biology.
B.A., 1971. University of Hawaii, Honolulu. Major: Zoology.

Experience:

Fishery Biologist (Research), October 1994-present. National Biological Service/U.S. Geological Survey-Biological Resources Division, California Science Center/Northwest Biological Science Center, Dixon Duty Station, 6924 Tremont Road, Dixon, CA 95620. Serves as Project Leader for the Northwest Biological Science Center, Dixon Duty Station. Supervises 1-2 full-time research biologists and 1-5 technicians and aids. Responsible for identifying research needs and conducting ecological and contaminant studies on inland and estuarine fishery resources. Project manager and principal investigator for laboratory and field studies on the tolerance of endangered Lost River and shortnose suckers from the Klamath River system to high temperature, pH, and ammonia concentration, and low dissolved oxygen concentration (1992-present). Project manager and principal investigator for a field survey of tidewater goby and other aquatic vertebrates in Mugu Lagoon (1993-1994). Principal investigator for a field survey (abundance and distribution) of the endangered tidewater goby in estuaries and lagoons of coastal California (1995-present).

Fishery Biologist (Research), March 1978-September 1994. U.S. Fish and Wildlife Service/ National Biological Service, Midwest Science Center, Field Research Station-Dixon, 6924 Tremont Road, Dixon, CA 95620. Served as Leader for the Midwest Science Center's Field Research Station in Dixon. Supervised 1-2 full-time research biologists and 1-5 technicians and aids. Responsible for identifying research needs and conducting ecological and contaminant studies on inland and estuarine fishery resources.

Completed a field study that assessed the ecological effects of irrigated land-use on bluegill populations and fish communities in the San Joaquin River system (1980-83). Completed field and laboratory studies on the toxicity of selenium, boron, molybdenum, and other elements in subsurface agricultural drainwater from the San Joaquin Valley floor. Research focused on toxic responses in fish (chinook salmon and striped bass) and the bioaccumulation of elements by aquatic food chains (1983-90). Completed a field survey of selenium and other elements accumulated by fishes in the Salton Sea (1985). Completed a field study that assessed the effects of heavy metals in acid-mine drainage on reproductive success and early survival of chinook salmon in the upper Sacramento River system (1990-1994). Served as Project manager and co-investigator for a field study on the effects of flow and temperature on growth, condition, and physiological performance of juvenile chinook salmon and juvenile steelhead in the lower American River (1991-1994). Appointed as Associate in the Agricultural Experiment Station, University of California-Davis (1984-1990). Completed the FWS Upper Level Management Development Program (1992-1993).

Publications: Dr. Saiki has authored or co-authored a total of 21 refereed articles in scientific journals and technical books, and about 20 unrefereed manuscripts in "grey" literature such as symposium/workshop proceedings and contract completion reports. Two examples of relevant articles are as follows:

Saiki, M.K., M.R. Jennings, and R.H. Wiedmeyer. 1992. Toxicity of agricultural subsurface drainwater from the San Joaquin Valley, California, to juvenile chinook salmon and striped bass. Transactions of the American Fisheries Society 121:78-93.

Saiki, M.K., D.T. Castleberry, T.W. May, B.A. Martin, and F.N. Bullard. 1995. Copper, cadmium, and zinc concentrations in aquatic food chains from the upper Sacramento River (California) and selected tributaries. Archives of Environmental Contamination and Toxicology 29:484-491.

Grants, Contracts, and Research Awards: Since 1991, Dr. Saiki has received a total of $757,944 in contracts and grants to support his research program. A summary of these contracts and grants is as follows:

Anadromous Salmonid Studies in the Lower American River, 1991-1993; FWS Reimbursable Agreement Nos. 14-16-0009-91-1845 ($69,300), 14-16-0009-92-1840 ($100,000), and 14-48-0009-93-1872 ($25,000) with East Bay Municipal Utility District, Oakland, CA. Total award, $194,300. Contact: Alan L. Thompson, tel. (510) 287-1185.

Water Quality Tolerances of Lost River and Shortnose Suckers, 1992-1995; NBS/FWS Reimbursable Agreement Nos. 14-48-0009-92-1902 ($24,999) and 14-48-0009-92-1904 (1992, $66,000; 1993, $111,121; 1994, $119,383; 1995, $64,079) with U.S. Bureau of

Reclamation, Klamath Falls, OR. Total award, $385,582. Contact: Mark Buettner, tel. (503) 883-6935.

Bioassay Support for the BEST Klamath Pilot Project, 1993; Permission received to charge expenses to FWS Region 1 Account No. 10120-1130-1031. Total award, $10,000. Contact: James Coyle, tel. (503) 231-6223.

Fish Survey at Mugu Lagoon, 1993; Military Interdepartmental Purchase Request No. N6312693MP73364 from the Naval Air Warfare Center Weapons Division, Point Mugu, CA. Total award, $30,000. Contact: Thomas Keeney, tel. (805) 989-8389.

NBS Quick Response Activities Project (Tolerance of Lost River and Shortnose Suckers to Ambient Water Quality in Upper Klamath Lake: A Field Toxicity Study), 1994; Amendment to the Midwest Science Center's FY-94 Work Activity Advice. Total award, $49,020.

Fishery Proposals for the San Francisco Bay/Estuary Program, 1995; NBS Reimbursable Agreement No. 14-48-0001-95542. Total award, $15,542. Contact: Richard Morat, tel. (916) 979-2113.

Status of Tidewater Goby, 1995; NBS Competitive Grants Program. Total award, $73,500.

Professional Memberships:

American Fisheries Society (Certified Fisheries Scientist, Certificate # 1,891)
American Institute of Fishery Research Biologists (Member)
Society of Environmental Toxicology and Chemistry (Regular Member)

References:

1. Ms. Susan Finger, Research Coordinator, U.S. Geological Survey, Environmental and Contaminants Research Center, Columbia, MO. Tel. (573) 875-5399.

2. Dr. Joseph Skorupa, Fish and Wildlife Biologist, U.S. Fish and Wildlife Service, Sacramento, CA. Tel. (916) 979-2110.

3. Dr. A. Dennis Lemly, Fishery Biologist (Research), U.S. Forest Service, c/o Virginia Tech. University, Blacksburg, VA. Tel. (540) 231-6663.

VI. Compliance with Standard Terms and Conditions.

All terms and conditions stated in the CALFED RFP are agreeable to and able to be complied with by the applicant.