B1011

PROPOSAL COVER SHEET

Proposal to: CALFED Bay-Delta Program Office

Submitting Organization:
The Regents of the University of California
University of California
One Shields Avenue
Davis, CA 95616

Title of Proposed Research: Assessing Effects of Fish Screening on Migration of Juvenile Chinook Salmon

Total Amount Requested:	**Proposed Duration:**	**Desired Starting Date:**
$217,206	Two Years	December 1, 1998
Principal Investigator:	**Department:**	**Phone Number:**
G. T. Orlob	CEE	(530) 752-1424

Checks made payable to:
The Regents of the University of California

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Approvals:

6/24/98
Principal Investigator — Date

6/24/98
Department Chair — Date

6/25
Dean, College/School — Date

Other Endorsement — Date

JUN 29 1998
Official Signing for Organization — Date
Sandra M. Dowdy
Contracts and Grants Analyst

I —008476

I-008476

COVER SHEET (PAGE 1 of 2)

May 1998 CALFED ECOSYSTEM RESTORATION PROPOSAL SOLICITATION

Proposal Title:	Assessing Effects of Fish Screening on Migration of Juvenile Chinook Salmon
Applicant Name:	Gerald T. Orlob, Ph.D., P.E.
Mailing Address:	Department of Civil and Environmental Engineering, University of California, One Shields Avenue, Davis, California 95616
Telephone:	(530) 752-1424
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Amount of funding requested: $217,206 for 2 years

Indicate topic for which you are applying:

- ☐ Fish Passage Assessment
- ☐ Floodplain and Habitat Restoration
- ☐ Fish Harvest
- ☐ Watershed Planning/Implementation
- ☐ Fish Screen Evaluations – Alternatives and Biological Priorities
- ☒ Fish Passage Improvements
- ☐ Gravel Restoration
- ☐ Species Life History Studies
- ☐ Education

Indicate geographic area of your proposal (check only one box):

- ☐ Sacramento River Mainstem
- ☒ Delta
- ☐ Suisun Marsh and Bay
- ☐ San Joaquin River Mainstem
- ☐ Landscape (entire Bay-Delta watershed)
- ☐ Sacramento Tributary: _____
- ☐ East Side Delta Tributary: _____
- ☐ San Joaquin Tributary: _____
- ☐ Other: _____
- ☐ North Bay: _____

Indicate the primary species which the proposal addresses (check no more than two):

- ☒ San Joaquin and East Side Delta tributaries fall-run chinook salmon
- ☐ Winter-run chinook salmon
- ☐ Late fall-run chinook salmon
- ☐ Delta smelt
- ☐ Splittail
- ☐ Green sturgeon
- ☐ Migratory birds
- ☐ Spring-run chinook salmon
- ☒ Fall-run chinook salmon
- ☐ Longfin smelt
- ☐ Steelhead trout
- ☐ Striped bass

I-008477

COVER SHEET (PAGE 2 of 2)

May 1998 CALFED ECOSYSTEM RESTORATION PROPOSAL SOLICITATION

Indicate the type of applicant (check only one box):

☐	State agency	☐	Federal agency
☐	Public / Non-profit joint venture	☐	Non-profit
☐	Local government / district	☐	Private party
☒	University	☐	Other: _____

Indicate the type of project (check only one box):

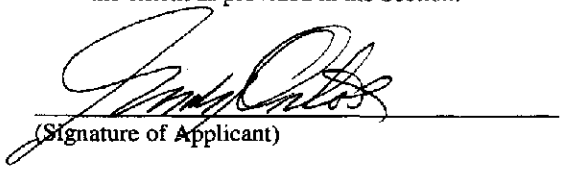
☒	Planning	☐	Implementation
☐	Monitoring	☐	Education
☐	Research		

By signing below, the applicant declares the following:

(1) the truthfulness of all representations in their proposal;

(2) the individual signing the form is entitled to submit the application on behalf of the applicant (if applicant is an entity or organization); and

(3) the person submitting the application has read and understood the conflict of interest and confidentiality discussion in the PSP (Section II.K) and waives any and all rights to privacy and confidentiality of the proposal on behalf of the applicant, to the extent as provided in the Section.



(Signature of Applicant)

I-008478

Executive Summary

ASSESSING EFFECTS OF FISH SCREENING ON MIGRATION OF JUVENILE CHINOOK SALMON

Principal Investigator: Dr. Gerald T. Orlob
Co-Principal Investigator: Dr. Joseph J. Cech, Jr.

Project Description and Primary Ecological Objectives

Past water resources development and management practices have contributed to the decline of Pacific salmon stocks in California's San Francisco Bay-Delta System. Screened and unscreened water diversions, dams, and reservoirs have resulted in changes in flow and temperature that negatively impact migration of juvenile salmonids. While various means have been employed to halt the decline of salmonid populations, improving survival during downstream migration may significantly increase salmon recruitment and prevent extinction.

The objective of the proposed study is to quantify the effects of various water and salmon management strategies as they relate to the out-migration of fall-run chinook salmon in conjunction with the timing and magnitude of Sacramento-San Joaquin Delta diversions proposed in alternative water transfer schemes now under consideration by the CALFED Bay-Delta Program. This objective will be achieved through (1) investigations of migratory readiness as a function of swimming performance of juvenile salmonids, and by (2) simulation of the hydrodynamics of the flow regime in channels approaching screening facilities. Through integration of these two components, the ability of fish to escape impingement and the hydraulic performance of screening facilities will be related. Expected results will enhance out-migration of juvenile salmonids and improve screen designs.

Approach/Tasks/Schedule

During parr-smolt transformation, salmon migrate downstream through the San Francisco Bay Estuary eventually reaching the ocean. Many studies have demonstrated that physiological changes, particularly hormonal fluctuations, accompany this transformation from a freshwater to a salt-water type fish. Studies on both Atlantic and Pacific salmon have indicated that swimming performance increases as parr grow larger, but that a decrease in swimming performance occurs as the transformation from parr to smolt occurs. Decreased swimming performance may be explained by changes in the muscle fibers during smoltification. An understanding of the swimming ability of juvenile salmon can direct water and fish management decisions such as the timing of major water diversions and hatchery smolt releases, and also guide design of fish screening facilities. In the proposed study, the swimming ability of smolting chinook is considered as a criterion for design and operation of a fish screen at the head of a large water diversion facility. If the swimming capability and circadian velocity preferences of juvenile salmon and the local hydrodynamic conditions in the vicinity of screen openings can be determined, diversions may be adjusted accordingly to assure maximum escapement of smolts during downstream migration.

Mathematical models will be designed to simulate potential hydrodynamic conditions experienced by migrating salmon and evaluate hydraulic characteristics of alternative fish screen designs now under consideration by the CALFED Bay-Delta Program. Model simulation capabilities relevant to design considerations include identification of flow stagnation regions where predators converge and sediment is deposited; non-uniformities in flow along the screen face; and the effective exposure time during which fish must swim to avoid entrapment. Results of hydrodynamic model testing will aid screen designers in development of screens that minimize impacts on migrating juvenile chinook salmon. It is expected that the study will be completed within two years from the project inception.

Justification for Project and Funding by CALFED

Temperature-associated changes in muscle function, swimming performance, and velocity preference through smoltification will significantly affect downstream salmonid migrations and susceptibility to entrainment in screened diversions. These effects will also delineate optimal timing of reservoir water and hatchery smolt releases to maximize smolt survival. The proposed study will generate guidelines for setting stream flow and temperature criteria during smolt migration using results of laboratory studies of parr/smolt swimming performance. Results from this study are expected to enhance survival of smolts, increase salmonid recruitment, reduce entrapment mortality, and restore important living components of California's Delta ecosystem.

Variation in swimming performance and muscle development during smoltification may affect the ability of juvenile salmon to avoid impacts of screened diversions. Current fish screen technologies do not provide adequate fish passage at large-scale screened diversion facilities. Characteristics of fish screens such as their orientation or arrangement in the channel, shape and angle of screen face, and location of fish bypass have not been sufficiently investigated and tested to maximize fish passage (see Fish screen characteristics, Appendix C). Although these characteristics can be investigated using physical models, implementation and comparative testing are often cost and time prohibitive. Mathematical models developed in this investigation will be used to evaluate hydraulic characteristics of fish screen designs in a manner that is relatively cost and time efficient.

Budget Costs and Third Party Impacts

The total cost of the proposed study is **$217,206**. Matching contributions valued at **$57,458** include in-kind services of the principal and co-principal investigators and the consultant, plus estimated equipment costs. No negative third party impacts are anticipated.

Applicant Qualifications

Dr. Gerald T. Orlob, Professor Emeritus of Civil and Environmental Engineering at the University of California, Davis, has specialized in the development and application of mathematical models of surface water systems throughout a career spanning 45 years in professional practice, engineering education, and research. He will serve as principal investigator to the proposed study. Dr. Joseph J. Cech, Jr., is a professor of Fish Biology at the University of California, Davis and is a well-recognized authority on the ecological physiology of fishes. Dr. Cech will serve as co-principal investigator to the proposed study. Ian P. King is Professor Emeritus of Civil and Environmental Engineering at the University of California, Davis and will be available as a consultant on the use of the mathematical models. Dr. Orlob, Cech and King will serve at no cost to the project.

Monitoring and Data Evaluation

Results of this study can be evaluated subsequent to implementation of project recommendations by ongoing juvenile fish population monitoring programs (USFWS, CDFG, NMFS).

Local Support/Coordination with other Programs/Compatibility with CALFED Objectives

Extensive local support is available throughout the two-year term of the project. Collection of juvenile salmon will be coordinated with CDFG. Modeling efforts will be partially supported by the EPA Center for Ecological Health Research and an EPA/NSF research grant at UC Davis. Technical advice will be provided by scientists at the CDWR and CDFG who are currently conducting research concerning screened water diversions at the UC Davis hydraulics laboratory. The results of this study will be combined with those of two other salmonid investigations currently underway at UC Davis to enhance understanding of the effects of screened diversions on native Delta fishes. Objectives of this study are consistent with CALFED objectives concerning improvement of San Francisco Bay-Delta anadromous fisheries.

ASSESSING EFFECTS OF FISH SCREENING ON MIGRATION OF JUVENILE CHINOOK SALMON

Principal Investigator:	Dr. Gerald T. Orlob, Professor Emeritus Department of Civil & Environmental Engineering University of California, Davis One Shields Avenue Davis, California 95616 Tel. (530) 752-1424 Fax (530) 752-7872 E-mail: gtorlob@ucdavis.edu
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Type of Organization :	University of California (Public Institution)
Tax Status:	Tax Exempt
Tax Identification Number:	94-603649-W
Participants:	Dept. of Civil & Environmental Engineering, UC Davis Dept. of Wildlife, Fisheries & Conservation Biology, UC Davis
Collaborators:	California Department of Water Resources California Department of Fish and Game U.S. Fish and Wildlife Service Center for Ecological Health Research, UC Davis

IV. PROJECT DESCRIPTION AND APPROACH

a. Project Description and Approach

Past management practices have contributed to the decline of Pacific salmon stocks in California's San Francisco Bay-Delta System. Screened and unscreened water diversions, dams, and reservoirs have resulted in changes in flow and temperature that negatively impact migration of juvenile salmonids (NRC, 1996). While various means have been employed to halt the decline of salmonid populations, improving survival during downstream migration may significantly increase salmon recruitment. During parr-smolt transformation, juvenile salmon migrate downstream through the San Francisco Bay Estuary eventually reaching the ocean. Many studies have demonstrated that physiological changes, particularly hormonal fluctuations, accompany this transformation from a freshwater to a salt-water type fish (Zaugg, 1989; Boeuf, 1993). Studies on Pacific salmon have demonstrated that swimming performance increases as parr grow larger, but that a decrease in swimming performance occurs during the transformation from parr to smolt (Boeuf, 1993).

Decreased swimming performance, when out-migrating smolts are exposed to changing hydrodynamic and water quality conditions increases susceptibility to predation and decreases their ability to avoid physical obstructions caused by channel dredging, re-routing of flows and export pumping in the Delta. Decreased swimming performance during downstream migration may be a result of structural/functional changes in swimming musculature that signal the optimal time for out-migration to the ocean. Changes in muscle proteins and development have been described in hatchery-raised Atlantic salmon (*Salmo salar*) (Higgins, 1990; Higgins and Thorpe, 1990), but these changes were not studied in conjunction with physiological indices of swimming performance or velocity preferences, nor have they yet been related to field conditions.

Hydrodynamic conditions experienced by migrating juvenile salmon in the vicinity of a screened diversion may determine the success of outmigrating salmon. It is proposed that these conditions be simulated using mathematical models to provide a basis for comparative analysis of the hydraulic characteristics of alternative fish screen designs under consideration by government agencies including CDWR (Shawn Mayr, personal communication). Model simulation objectives relevant to screen design include identification of flow stagnation regions where predators converge and where sediment is deposited; non-uniformities in velocities along the screen face; and the effective exposure time during which fish must swim to escape entrainment. Results of hydrodynamic model testing will aid fish screen designers in development of screens that minimize impacts on migrating juvenile chinook salmon.

A specific case of interest treated in this proposal is that of a screened diversion, the design of which should be governed by the physiological responses of juvenile salmon exposed to unusual hydrodynamic conditions that may threaten their survival. In this proposal, the swimming ability of the migrating smolt is considered as a criterion for design of a large scale screening facility at the head of a water diversion facility. For example, if the swimming capacity and daily velocity preferences of juvenile salmon can be determined, then properties of a screening facility, such as limiting velocities normal to and along the face of the screen, and the physical orientation, shape, and bypass arrangement of the screen may be fixed accordingly to assure maximum escapement of smolts during downstream migration.

The objective of the proposed study is to quantitatively evaluate various water and salmon management strategies. The model will be used to assess alternative water transfer schemes within the Sacramento-San Joaquin Delta now under consideration by the CALFED Bay-Delta Program. This

objective would be achieved through integration of swimming performance studies of parr/smolts as a function of migratory readiness, simulation of the hydrodynamics of the flow regime in the vicinity of a screening facility, and comparison of hydraulic characteristics of alternative screen designs.

b. Proposed Scope of Work

The proposed study encompasses two closely related themes: 1) an assessment of the swimming capacity of smolting salmonids and 2) a determination of the hydrodynamic stresses to which juvenile salmon may be subjected in the vicinity of an actual screening facility. Swimming performance of juvenile salmonids during the parr-smolt transformation will be evaluated in terms of critical swimming speeds (U_{crit}) (Brett, 1964), circadian velocity preference, and muscle force/velocity/structure parameters. Laboratory experiments will be performed at two temperatures (14 and 19°C) and a range of velocities experienced by juvenile salmonids.

In conjunction with laboratory studies of parr-smolt swimming performance, investigations will be carried out to estimate properties of actual flow fields (associated with alternative screen designs) to which the outmigrating chinook juveniles may be subjected. These investigations will be accomplished in stages beginning with expansion of an existing set of multidimensional mathematical models to simulate flow fields in the river channel adjacent to the screening device and hydraulic properties of flow through proposed fish screens. The models will be adaptable to the channel bathymetry of proposed screening sites to simulate velocities in the approach channel, "sweeping" velocities along the face of the screen, velocities normal to the screen, and variations in velocity along screen faces. The models, which have already been adapted to simulate the flow and water quality regimes of the Sacramento-San Joaquin Delta, will be extended to represent two and three-dimensional properties of the screen environment.

Activities outlined above will span the proposed two-year project period. Studies during the first year will concentrate on analysis of parr-smolt swimming behavior and performance at times of potential exposure to the influence of a screened diversion and modeling of the general properties of the two-dimensional flow field in the approach channel. Data collection and analysis will be further refined in the succeeding year to include three-dimensional characterization of the flow field in the vicinity of the screens, as additional information on swimming capabilities from laboratory experiments dictates. Candidate models include RMA10 (a finite element model that simulates hydrodynamics) and RMA11 (a general water quality model) (King, 1998). These have already been adapted for study of transport of striped bass larvae in the Central Delta. An advantage of these models is flexibility to represent complex water bodies and fish screen designs over a wide range of spatial scales, particularly at the level of detail required for description of local velocity fields experienced by migrating salmonids. The major product of the project will be a capability to guide design of screening facilities to minimize damage to fish species at risk. Specific tasks for the proposed project are outlined below. A schedule of tasks is included as Appendix B.

Task 1: Define Models To Be Used for Flow Field Simulation. As noted previously, the most appropriate models must be capable of simulating the three-dimensional flow field adjacent to a screening facility under the hydrologic and project operating conditions likely to be experienced if a major off-channel diversion is implemented. Models must also be capable of representing the magnitude and direction of velocities in the vicinity of and through proposed fish screens so that comparative analyses can be made. The primary candidates for this application are available in the RMA suite of models already adapted to the Bay-Delta system. In the vicinity of proposed trans-Delta diversions, the models are presently one-dimensional. They will have to be extended initially to two-dimensions, and later, as studies dictate, to three-dimensions.

Task 2: Assemble Existing Data on Possible Screening Sites. Existing electronic databases supported by a variety of government agencies and compiled by the California Data Exchange Commission (CDEC) will be utilized to develop seasonal estimates of flow in the Sacramento River. Velocity data will be collected during field surveys (e.g., near Hood, California if facilities are sufficiently implemented) and later used in calibration and verification exercises. Velocities will be measured using an acoustic doppler current profiler over a range of flow conditions. It is expected these data will be supplemented by results of fish screen studies currently underway by the WFCB Department at UC Davis and the CDWR at the UC Davis Hydraulics Laboratory. Details of fish screen configurations and channel modifications required in comparative analysis of alternative fish screen designs will be acquired through cooperation with government agencies.

Task 3: Collection and Maintenance of Juvenile Chinook. Fall-run chinook salmon will be collected using minnow seine and Archimedes screw traps from the American and Mokelumne Rivers three times during the March – mid-June stream rearing/smoltification period. Fish will be maintained at 14 and 19°C [temperature fluctuations normally occurring in the stream system during the time of smoltification (D.T. Castleberry et al., 1991)] in circular tanks at swimming speeds no greater than one body-length per second.

Task 4: Critical Swimming Speed Experiments. Critical swimming velocities will be determined, using a recirculating Brett-type swimming flume (Brett, 1964) and standard techniques. All experiments will be videotaped and analyzed with Peak Performance Software for kinematic data such as gait changes and tail-beat frequencies and amplitudes. After each experiment, presumed saltwater readiness (smoltification) will be determined using gill Na^+/K^+ ATPase activity (Zaugg, 1989).

Task 5: Muscle Contraction and Force Generation Experiments. A sub-sample of juvenile chinook from the same size/developmental groups as used by the U_{crit} and Flow Table Experiments will be used to determine development of axial and pectoral muscle force. Strips of abdominal and pectoral swimming muscles will be extracted. Muscle strips will be attached at one end to a force transducer and fixed in position at the other end in a temperature controlled Ringer's saline bath. The optimal length for force generation will be found by varying the length with a micromanipulator and stimulating the muscle at various frequencies according to the kinematic data obtained from the critical swimming speed experiments. Force/velocity relationships will be determined in various measures of muscle kinetics (shortening speed, time to peak tension, time to relaxation) at acclimation temperatures of 14 and 19°C . These experiments are important because the maximum isometric tension (P_o) and maximum contraction velocity (V_{max}) produced by a muscle fiber bundle is a function of both the absolute temperature at which it is tested as well as the acclimation temperature for the fish (Altringham and Johnston, 1984;1988).) produced by a muscle fiber bundle is a function of both the absolute temperature at which it is tested as well as the acclimation temperature for the fish. Muscle power generation (P) will be determined using force/velocity relationships. After the muscle kinetics experiments, sarcomere length (at the peak tension fiber length) will be measured using a low power helium neon laser using Bragg's diffraction equation (Altringham and Johnston, 1994).

Task 6: Histochemistry Experiments. Histochemical stains will be used to identify various morphological and biochemical features of the muscle fibers from a subsample of fish. Trypan blue will be used to identify dead tissue from the muscle preparation (Sosnicki *et al.*, 1989). Cryosections will be prepared to assess enzymatic activity. Nitroblue tetrazolium with cyanide will be used to determine oxidative enzymes (Batty, 1983). Glycogen content will be assessed by the PAS reaction

using Schiff's reagent (Dunn *et al.*, 1989). The volume of each fiber type and structural changes associated with development will be assessed with hematoxylin, eosin, Verhoeff, and van Gieson's stains. Sudan black will be used to examine tissue lipid content and distribution (Squire, 1986). These histological analyses will produce a quantitative assessment of fish condition, potential muscle power generation, including muscle fuel stores for migratory (sustained) and predator escape/prey capture burst activities.

Task 7: Flow Table Experiments. A flow table with a calibrated, horizontal velocity gradients will be used with a video camera and infrared lights to determine juvenile chinook velocity preferences during lighted (and darkened) conditions. Velocity gradients in the flow table will approximate observed field (nose and holding) velocities. The age of individual salmon will be determined according to Na^+/K^+ ATPase activity (Castleberry *et al.*, 1991). Standard length and weight will be measured after all experiments are run.

Task 8: Extend Models to Two Dimensions. The finite element network currently used for Bay-Delta simulations will be modified to include two-dimensional (depth-averaged) characterization of the geometry of screened diversion including off-channel diversion bathymetry and screen geometry. Sufficient detail in the grid will be provided to assure accurate representation of velocities likely to be experienced by migrating salmonids. Field data will be pre-processed for use as initial and boundary conditions, and later in calibration and verification efforts.

Finite element grid modifications will be made to represent fish screen designs being considered by government agencies. Simulations using a variety of screen designs will be evaluated under critical flow and withdrawal scenarios to determine strengths and weaknesses of each design. Designs characteristics such as their orientation or arrangement in the diversion channel (e.g. folded or partially-folded v-shapes, or multiple plate screens along main river channel), the shape and angle of the screen face (e.g, straight or parabolic shapes, and those perpendicular, angled, or parallel to the direction of flow), and the location of the fish bypasses (e.g., "funneling" bypasses downstream of folded v-screens, or use of main river channel as bypass) will be considered to determine their efficacy in fish passage (see Appendix C). From this, preliminary assessment of the environment likely to be encountered by out-migrating juvenile salmon can be made for a variety of screen designs.

Task 9: Extend Simulation Capability to Three Dimensions. Based on laboratory results of juvenile swimming performance, critical velocities, and possible screen configurations, detail in the model grid will be extended and the models run in three-dimensional mode to determine vertical velocities along the face of the fish screen, and consequently resultant velocities likely to be experienced by juveniles. A three-dimensional characterization of flow field will provide a more detailed description of hydraulics characteristics through and adjacent to fish screens.

Task 10: Perform Simulations for Critcial Operating Conditions. A demonstration of the risk aversion approach to combined management of water transfers and fisheries would be performed for a selected set of hydrologic and water diversion scenarios and screen facility designs. Model simulations will be performed under high, normal, and low flow conditions in the Sacramento River in combination with high and low diversion quantities (e.g. 5,000 and 15,000 cfs) and alternative screen designs currently under consideration by government agencies. We will determine "critical operating scenarios" under which migrating juvenile salmon will likely experience stress.

Task 11: Map the Screen Velocity Field and Smolt Risk Zones. Having identified critical (swimming) velocities and the velocity field adjacent to the screen, a "map" of critical zones will be developed to show where local velocities may exceed salmonid capability to avoid entrainment or

impingement. Flow stagnation regions induced by suggested screen designs will also be identified so that predation and sedimentation associated with these regions can be reduced. Such a product would assist screening facility designers in minimizing overall screen-related mortality.

Task 12: Statistical Analysis. Appropriate statistical models will be used to analyze fish experiment data sets. Multiple analyses of variance (MANOVAs) will be used to compare muscle force generation at each frequency and between age classes. A principal component analysis will be used to compare histological differences among age/development groups. MANOVA will be used to compare gait changes, critical swimming velocities, and velocity preferences among age/developmental groups. The results from these studies will be combined in manuscripts for submission to the appropriate scientific journals for review and publication. Management recommendations will be formulated and sent to CDFG, CDWR, USFWS, NMFS, and USBR decision makers for their consideration.

c. Location and Geographic Boundaries of the Project

The project will focus on the efficacy of fish screening facilities contemplated as components of alternative Delta water transfer schemes. Such facilities may include the headworks of the proposed isolated diversion facility on the Sacramento River near Hood, California. Laboratory experiments will focus on juvenile salmon collected in the American and Mokelumne Rivers.

d. Expected Benefits

The proposed study will generate guidelines for stream flow and temperature criteria, especially at screen diversions, during smolt migration. Quantification of swimming performance changes in terms of muscle microstructure and swimming power can be used as diagnostic tools for determining exactly when the smolt are prepared to migrated downstream and furthermore, smolt tolerance for fish screen velocities and magnitudes. Hatcheries that now use Na^+/K^+ ATPase activity to assess smolt status, may be able to use a simple muscle biopsy and staining technique to determine migratory (not just seawater) readiness. Fiber type determinations may also be used to determine screen velocities which smolts can withstand. Potential muscle power generation, and therefore smolt migratory readiness, can be assessed by examining fiber type and distribution. This information can be used to determine the timing and temperature of water release from dams and intake velocity profiles at fish screens, during critical salmonid life history stages. A more accurate method for determining the readiness of smolts to migrate as well as the stream velocity and temperature that optimizes migration should enhance the survival of smolts and increase salmonid recruitment.

Results of fish screens comparisons will benefit developers of large-scale diversion facilities. Flow fields associated with various fish screen designs will identify velocities favorable to fish passage. Facilitating juvenile salmon passage will likely increase chinook salmon populations and benefit commercial and recreational fisheries.

e. Background and Ecological/Biological/ Technical Justification

Uncertainty concerning water management practices used to facilitate migration of wild stocks and to determine the timing of the release of smolts from hatcheries prioritizes the need for in-depth studies on the process of smoltification (ERPP Executive Summary, p. 9). This project combines powerful techniques for determining muscle performance and power in migrating fish and for estimating the potential for entrainment at water diversion sites (ERPP Executive summary, p. 18). The proposed study will increase the numbers of viable wild and hatchery adult fall-run chinook returns to the Sacramento-San Joaquin Watershed resulting in improved sport and commercial fisheries (ERPP Executive Summary, p. 12). Our model will integrate knowledge of swimming performance

limitations during smoltification with predicted environmental conditions along fish screen faces to protect juvenile salmonids from entrainment at screened diversions (ERPP Executive Summary, pp. 10, 15). Swimming performance of developing juveniles at different temperatures and velocities can be directly related to the magnitude and timing of water release from dams to improve smolt survival and migration (ERPP Executive Summary, pp. 27, 31, 32, 33, 35, 39). The development of a histological technique to assess swimming capability and migratory readiness will contribute to hatchery fish survival (ERPP Executive Summary, p. 17). The development of guidelines for optimal flow near a fish screen will not only prevent death due to impingement, but will additionally mitigate for predation on stunned/damaged post-screen fish (ERPP Executive Summary, pp. 30, 39, 41).

At present, fish screen technologies do not provide adequate fish passage at large-scale screened diversion facilities. Characteristics of fish screens such as their orientation or arrangement in the diversion channel, the shape and angle of the screen, and the location of the fish bypass, have not been sufficiently investigated and tested to improve fish passage (see Appendix C). Although these characteristics can be tested using physical models, implementation and comparative testing are often cost and time prohibitive. In contrast, mathematical models developed in this investigation will provide comparative analyses of fish screen designs in a manner that is relatively cost and time efficient. A strength of finite element models is the ability to represent complex geometric arrangements relatively easily, adding detail where it is most appropriate.

f. Monitoring and Data Evaluation

Data required for modeling purposes will be obtained through field collection and acquisition using existing electronic databases such as CDEC. Three-dimensional velocity data will be collected with an acoustic doppler current profiler. It is expected information describing velocity patterns near fish screens can be investigated in coordination with existing screen studies at UC Davis.

Quarterly reports will be sent to the CALFED Bay-Delta Program as well as to CDFG, USFWS, NMFS, and USBR for review. All project accomplishments will be documented in a final report to CALFED.

g. Implementability

Extensive local support is available for the two year term of this project. Funding for fish biology preliminary studies has been provided by the Granite Bay Flyfishers Society ($1000) and the Jastro-Shields Fellowship ($1500). Fish collection will be assisted by the Department of Fish and Game and the East Bay Municipal Utility District. Models proposed for investigation of screen hydrodynamics are product of the Center for Ecological Health Research at UCD. Collaboration with government agencies including the U.S. Army Corps of Engineers involving channel modifications in the vicinity of fish screen facilities, the California Department of Water Resources involving fish screen designs, and the U.S. Bureau of Reclamation regarding operation of upstream hydroelectric facilities are expected with the proposed research.

UC Davis is well known for its strong and diverse programs in the biological and hydrologic sciences. Seventeen professors at UCD are specialists in the field of fish biology. David Hinton, a professor in the veterinary school, will provide technical support for the histological studies. Steve Bennett in the Wildlife, Fish and Conservation Biology Department will provide the hardware and software support. Further advice will be provided by scientists at the Department of Water Resources and the Department of Fish and Game who are currently working with Dr. Cech's laboratory on research concerning water diversions and fish screens. Presentation of results will be made at appropriate workshops and professional meetings.

V. COSTS AND SCHEDULE TO IMPLEMENT PROPOSED PROJECT

a. Budget Costs

Table 5.1 catalogues costs associated with tasks of the proposed study. The 2 year total project cost is **$217,206**. The matching contribution for available in-house equipment costs is $12,000. This estimate includes minnow beach seines, Archimedes screw traps, a recirculating Brett-type swimming flume, a flow table, and all computer software and hardware required for modeling tasks. Equipment use is effectively being provided at no cost to the project. Supply and travel costs reflect those related to field reconnaissance: fish collection using beach seines, boat and equipment rentals required to collect velocity measurements. Overhead calculations are based on salary, benefit, supply, and travel costs. The fees grouped with the cost category *Overhead* in Table 5.1 are tuition and fee remission costs for the two research assistants.

Table 5.1 Cost Breakdown By Task

Project Task	Cost Category			Total Per Task, $
	Personnel, $ *	Equipment, Supplies, & Travel, $	Overhead & Fees, $	
1. Define Model Requirements	5,000	1,000	6,618	12,618
2. Assemble Model Data	6,000	8,000	6,618	20,618
3. Fish Collection/Maintenance	1,000	3,217	6,863	11,080
4. Critical Swimming Speed	12,170	3,217	6,863	22,250
5. Muscle Contraction	12,170	3,217	6,863	22,250
6. Muscle Histochemistry	12,170	3,217	6,863	22,250
7. Flow Table Experiments	12,170	3,217	6,863	22,250
8. Extend Model to 2-D	12,000	2,000	6,618	20,618
9. Extend Model to 3-D	14,000	3,000	6,618	23,618
10. Simulations for Critical Operation	5,835	1,000	6,618	13,453
11. Map Screen Velocity Field	8,000	1,000	6,618	15,618
12. Statistical Analysis	500	3,217	6,863	10,580
Subtotal per category	*101,014*	*35,302*	*80,891*	
2 YEAR TOTAL				**217,206**

** Note: Personnel costs are detailed in Table 5.2*

Table 5.2 details personnel costs associated with the proposed study. The matching contributions associated with salaries and fringe benefits of the principal and co-principal investigators are based on 5% equivalent time of their academic salaries. Total value of personnel and equipment matching contributions is **$57,458** (see Appendix A).

Table 5.2 Personnel (Salary and Benefit) Cost Details

Cost Items	Year 1 Total, $	Year 2 Total, $	Matching Contribution, $
Salaries and Wages			
Principal Investigator: 12 mo. @ 5% academic salary			14,722
Co-Principal Investigator: 12 mo. @ 5% academic salary			12,184
Consultant: 12 mo. @ 5% academic salary			14,722
Student Research Assistants			
1 RA: 50% for 9 mo. @ $2253/mo., 100% for 3 mo. @ $2253/mo.	16,898	17,235	
1 RA: 50% for 9 mo. @ $2253/mo., 100% for 3 mo. @ $2253/mo.	16,898	17,235	
3 UG Assistants IV: 9 mo. @ $400/mo. Each	10,800	11,016	
Technical Assistant	3,184	3,235	
Fringe Benefits			
2 Principal Investigators and Consultant @ 9.2%			3,830
2 RA's and 3 UG Assistants @ 4.4%	1,487	1,517	
Technical Assistant @ 23.5%	748	760	
Subtotal	*50,014*	*50,999*	
2 YEAR PERSONNEL COST TOTAL		**101,014**	***45,458***

b. Schedule Milestones

Table 5.3 Schedule of Project Milestones

Date	Milestone
December 1998	• Project is funded • Experiments using flow table and rectangular swimming chamber for Brett-type flume begin • Apparatus for measuring muscle force/velocity is built • Field data collection and modeling investigations begin
February 1999	• Lab equipment is calibrated and preliminary experiments carried out to perfect techniques • Quarterly progress report is submitted
March 1999	• Chinook parr are obtained from the field and all laboratory experiments are conducted • Samples are collected for histological data
May 1999	• Transitional (parr to smolt) chinook are obtained from the field • All laboratory experiments are conducted • Samples are collected for histological data • Quarterly progress report is submitted
April 1999	• Two-dimensional model development commences
June 1999	• Chinook smolts are obtained from the field and all laboratory experiments are conducted • Samples are collected for histological analysis
July 1999	• Histological samples are analyzed
August 1999	• Three-dimensional model development begins • Quarterly progress report is submitted
November 1999	• Annual report for 1999 is submitted
February 2000	• Quarterly progress report is submitted
April 2000	• Chinook parr are obtained from the Mokelumne and American Rivers • All laboratory experiments are conducted • Samples are collected for histological data

April 2000 (continued)	• "Critical operation" model simulations are performed
May 2000	• Chinook smolts are obtained from the Mokelumne and American Rivers • All laboratory experiments are conducted • Samples are collected for histological data • Quarterly progress report is submitted
June 2000	• Chinook smolts are obtained from the Mokelumne and American Rivers • All laboratory experiments are conducted • Samples are collected for histological data
July 2000	• Histological samples are analyzed and results are compared between years for wild fish • Velocity field and smolt risk zones are "mapped"
August 1999	• Quarterly progress report is submitted
November 2000	• Final report is submitted, funding ends

c. Third Party Impacts

We anticipate no negative third party impacts. The proposed studies will generate guidelines for stream temperature and dam/water diversion flow criteria during smolt migration as well as a histological diagnostic tool for determining downstream migratory readiness. The implementation of these guidelines will result in enhanced smolt survival and increased salmonid recruitment. Increased chinook salmon populations would also benefit commercial and recreational fisheries, their related economies and would maintain an integral part of the California Native American cultural heritage.

VI. APPLICANT QUALIFICATIONS

The principal investigators for the proposed project have formed a team with special qualifications in the disciplines required to address issues concerning the effects of screening facilities on the migration of juvenile salmonids. It includes expertise in the physiological responses of subject fish to environmental stress and in the characterization of the stress domain itself, the hydrodynamic field encountered by migrants. The qualifications and roles of key participants are summarized briefly below.

PRINCIPAL INVESTIGATOR: GERALD T. ORLOB

Education

B. S. in Civil Engineering (cum laude), University of Washington, 1948
M. S. in Environmental Engineering, University of Washington, 1949
Ph.D. in Hydraulic Engineering, Stanford University, 1959

Professional Career

6/49 to 6/52, Survey Supervisor, Washington Pollution Control Commission
Field investigation of water pollution as basis for control actions
7/52 to 6/65, Professor, University of California, Berkeley
Teaching and research in environmental and water resources engineering
7/65 to 4/74, President and CEO, Water Resources Engineers, Inc.
Research, development and application of mathematical models
9/74 to 6/78, Principal, Resource Management Associates, Inc.
7/68 to 6/92, Professor, University of California, Davis
Teaching, research and administration in civil engineering

(Gerald T. Orlob, continued)

Consulting in water resource systems analysis and management

7/92 to present, Professor Emeritus, University of California, Davis

Research in mathematical analysis of surface water systems

Professional Achievements

Founder and CEO of consulting firms pioneering development of mathematical models for simulation of hydrodynamics and water quality in rivers, estuaries, lakes, reservoirs, and coastal waters. Consultant to U.S. agencies and international organizations. Panel of Experts in Environmental Management, U. N.; International Science Advisory Committee, WRI, Technion, Israel; Commissioner, Mamala Bay Study Commission, Honolulu, HI.

Engineering Activities

Registered Civil Engineer, California, ASCE Water Resource Advisor to Technical Council for Water Resource Planning and Management; member and chair of Water Resource Systems Committee; Research and Education Committee; journal paper reviewer; conference session organizer; member various task committees; principal advisor for thesis and dissertation research for more than 40 students; CE Department Chair.

Publications

More than 150 contributions to technical journals and books, including:

Eddy Diffusion in Homogeneous Turbulence, J. Hydraulics Div., ASCE, Vol. 85, No. HY9, 1959 (ASCE Hilgard Prize, Hydraulics)

"Temperature Variations in Deep Reservoirs," J. Hydraulics Div., ASCE, Vol. 96, No. HY2, pp. 391-410, (with L. G. Selna)

"An Alternative to the Peripheral Canal," J. Water Resources Planning and Management Div., ASCE, Vol. 108, No. WR1, 1982, pp. 123-141.

Water Quality Modeling--Streams, Lakes and Reservoirs, IIASA, State of the Art Services, G. T. Orlob, ed., Wiley Interscience Publ. Co., N. Y., 1983, 518 p.

"Decision Support for Estuarine Water Quality Management," J. WRPM Div., ASCE, Vol. 115, No. 6, pp. 775-792, (with U. Arnold), (Outstanding Research Paper Award, 1991)

"Impacts of Climate Change on Water Quality," In Water Resources Management in the FAce of Climatic and Hydrologic Uncertainties, Z. Kaczmarek, ed., IIASA State of the Art Series, Kluwer Publ. Co., Amsterdam, 1995, pp. 70-105.

Honors and Awards

National Academy of Engineering, 1992

American Society of Civil Engineers, Honorary Member, 1997

The karl Emil Hilgard Hydraulic Prize, 1963; The Rudolph Herring Medal, 1963;

Julian Hines Award, 1987; Outstanding Research Paper, WRPM Division, 1991

American Academy of Environmental Engineers, Diplomat, 1966; Honor Award for Excellence in University Research, 1991; Gordon Maskew Fair Award, 1998

Water Pollution Control Federation; Harrison Prescott Eddy Award, 1970

American Geophysical Union; Hydrology Award, 1957

American Water Works Association; Resources Division Award, 1956

Fullbright-Hayes Lectureship, Yugoslavia, 1973

International Water Resources Association, Fellow and Charter Member, 1970

CO-PRINCIPAL INVESTIGATOR: JOSEPH J. CECH, JR.

Education

B. S. in Zoology, University of Wisconsin, Madison, 1966

(Joseph J. Cech, Jr., continued)

M. A. in Zoology, University of Texas, Austin, 1970
Ph.D. in Zoology, University of Texas, Austin, 1973

Professional Career

1965-66, Resident Zoologist, Sea Search I, R/V Dante Deo, Caribbean Sea
1966-72, Research and Teaching Assistant, Univ. of Texas, Austin
1973-75, Research Associate, Research Inst. Gulf of Maine, Portland-Gorham
1981-87, Associate Professor of Fisheries Biology, Univ. of California, Davis
1991-1994, Associate Editor, Transactions of the American Fisheries Society
1992-97, Chair, CUD Dept. of Wildlife, Fish and Conservation Biology
1987-present, Professor of Fisheries Biology, University of California, Davis

Awards and Honors

1970-73, NIH Pre-doctoral Fellow
Member: Phi Sigma, Phi Kappa Phi, Sigma XI
1979 Invited participant; NATO Advanced Study Institute on "Environmental Physiology of Fish"
1985 NATO Advanced Workshop on "Evolutionary Biology of Primitive Fisheries"
1986 IUPS Discussion Panel on "Controversies: Circulation and Respiration"
1990 Organizer, 2nd Biennial International Symposium on "Fish Physiology, Toxicology, and Water Quality Management" Nanjing, PRC
1992 Elected fellow of the American Institute of Fishery Research Biologists
1992 Honorable Mention, "Most Significant Paper" in Transactions of American Fisheries Society
1993 Outstanding Faculty Advisor Award, College of Agriculture and Environmental Sciences
1994 Plenary Speaker, First International Fish Physiology Symposium
1995 Excellence in Fisheries Education Award (with P. B. Moyle), American Fisheries Society
1997 Elected Fellow, American Association for the Advancement of Science

Selected Publications

Publications selected from more than 90 peer-reviewed articles and books:

Cech, J. J. Jr. 1990, Respirometry, pp. 335-362, In: C. B. Schreck and P. B. Moyle, Eds, Methods for Fish Biology, AFS.

Cameron, J. N., and J. J. Cech, Jr., Lactate kinetics in exercised channel catfish, Physiol. Zoology, 63: 909-920.

Sanderson, S. L., Cech, J. J. Jr., and Patterson, M., 1991, Fluid dynamics in suspension feeding blackfish, Science 251: 1346-1348.

Cech, J. J. Jr., R. G. Schwab, W. C. Coles, and B. B. Bridges, 1992 Mosquitofish reproduction: effects of photoperiod and nutrition, Aquaculture, 101: 361-369.

Cech, J. J. Jr., and M. J. Massingill, 1995 Tradeoffs between respiration and feeding in Sacramento blackfish, Env, Biol. Fish, 44: 157-163.

Cech, J. J. Jr., S. D. Bartholow, P. S. Young and T. E. Hopkins, 1996, Striped exercise and handling and handling stress in freshwater: physiological responses to recovery environment, Trans. Amer. Fish. Soc., 125: 308-320.

Crocker, C. E. and J. J. Cech, Jr., 1997, Effects of environmental hypoxia on oxygen consumption rate and swimming activity in juvenile white sturgeon, *Acipenser transmontanus*, in relation to temperature and life intervals, Env. Biol. Fish. 50: 383-389.

Cech, J. J. Jr. B. W. Wilson and D. G. Crosby, 1998 Multiple stresses in ecosystems, Lewis/CRC Publ. Boca Raton.

CONSULTANT: IAN P. KING

Ian P. King is Emeritus Professor of Civil and Environmental Engineering at the University of California at Davis. He holds advanced degrees in civil engineering and engineering mechanics. He is internationally recognized for his pioneering developments of numerical methods for solution of hydrodynamics and water quality problems. He is the creator of a number of mathematical models that are now being applied world-wide, including the two-and three-dimensional RMA models that would be used in the proposed project to simulate the flow field in the vicinity of a screening facility. He will be available as a consultant on the use of the models at no cost to the project.

GRADUATE RESEARCH ASSISTANT: SHANA KATZMAN

Ms. Katzman holds a Master of Arts degree in Biology from UCLA, where she studied fish swimming under Professor Malcolm Gordon's supervision. She has had extensive research experience with field and laboratory work including histological sectioning, fish kinematic and swimming performance studies, fish behavior near a fish screen, estuarine biodiversity surveys and marine fish diversity surveys. She is a member of the American Fisheries Society and Physiological Zoology as well as a recipient of the Jastro-Shields Fellowship and the Granite Bay Flyfisher's Award.

GRADUATE RESEARCH ASSISTANT: CURTIS LOEB

Mr. Loeb is a graduate student/researcher in the Water Resources and Environmental Modeling Group of the Department of Civil and Environmental Engineering at UC Davis. He has been responsible for constructing, calibrating, and applying multi-dimensional finite element models of the Sacramento-San Joaquin Delta and the Sacramento River in a project sponsored by the Center for Environmental Health. The models are currently being used in studies of the influence of hydrodynamics and water quality (temperature and salinity) on the fate of striped bass larvae in the Delta channel system. These models will be extended in the proposed project to characterize the two- and three dimensional flow fields in the vicinity of a screened diversion facility.

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Altringham, J.D. and Johnston, I.A. (1985). The effects of temperature on ATPase activity and force generation in skinned muscle fibers from the Pacific blue marlin (*Makaira nigricans*). *Experientia.* **41**,1532-1533.

Altringham , J.D. and Johnston, I.A. (1988). Muscle contraction in polar fishes: experiments with demembranated muscle fibers. *Com. Biochem. Physiol.* **3**, 547-555.

Altringham , J.D. and Johnston, I.A. (1994). Intact and demembranated muscle fibers. In *Biochemistry and Molecular Biology of Fishes vol. 3* (eds. P.W. Hochachka and T.P. Mommsen), Amsterdam: Elsevier Science Publishers, pp. 108-117.

Anderson, J. D., D. W. Huston, C. J. Loeb, G. T. Orlob, and I. P. King. (1998). A mechanistic approach to assessing aquatic ecosystem response to stress: case study-evaluation of juvenile salmon survival and migration in the Sacramento River and San Francisco Bay-Delta System. ASCE Wetlands Engineering and River Restoration Conference.

Batty, R.S. (1983). Development of swimming movements and musculature of larval herring (*Clupea harengus*). *J. exp. Biol.* **110**, 217-229.

Boeuf, G. (1993). Salmonid smolting: a pre-adaptation to the oceanic environment. In *Fish Ecophysiology* (eds. J.C. Rankin and F.B. Jensen), London: Chapman and Hall, pp. 105-125.

Brett, J.R. (1964). The respiratory metabolism and swimming performance of young sockeye salmon. *J. Fish Res. Board Can.* **21**:1183-1226.

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Castleberry, D.T., J.J. Cech, Jr., M.K. Saiki, and B.A. Martin. (1991). Growth, condition, and physiological performance of juvenile salmonids from the lower American River: February through June, 1991 Draft Report. U.S. Fish and Wildlife Service. Dixon, CA.

Dunn, J.F., S.D. Archer, and I.A. Johnston. (1989). Muscle fiber types and metabolism in post-larval and adult stages of nototheniod fish. *Polar Biol.* **9**, 213-223.

Higgins, P.J. (1990). The histochemistry of muscle in juvenile Atlantic salmon, *Salmo salar* L. *J. Fish Biol.* **37**, 521-529.

Higgins, P.J. and J.E. Thorpe. (1990). Hyperplasia and hypertrophy in the growth of skeletal muscle in juvenile Atlantic salmon, *Salmo salar* L. *J. Fish Biol.* **37**, 505-519.

Houston, A. H. (1990). Blood and circulation. In *Methods for Fish Biology* (eds. C.B. Schreck and P.B. Moyle), Bethesda: American Fisheries Society, pp. 273-322.

Huston, D. W., C. J. Loeb, J. D. Anderson, and G. T. Orlob. (1997). Preliminary calibration of hydrodynamic and water quality models of the Sacramento River-San Francisco Bay-Delta System, Proc. AGU Fall Meeting, San Francisco, CA, 1p. Abstract.

King, I. P. (1998). A finite element model for stratified flow, RMA-10 user's guide, version 6.5. Department of Civil and Environmental Engineering (unpublished).

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Squire, J.M. (1986). Muscle Design, Diversity and Disease. The Benjamin/ Cummings Publishing Company, Menlo Park, California.

Zaugg, W.S. (1989) Migratory behavior of underyearling *Oncorhynchus tshawytscha* and survival to adulthood as related to prerelease (Na^+-K^-)-ATPase development. *Aquaculture.* **82,** 339-353.

APPENDIX A:
Summary of Costs of Proposed Study

Budget Summary Table

COST CATEGORY ITEMS	Year 1 Total, $	Year 2 Total, $	Total Matching Contribution, $
Personnel Salaries and Benefits			
Principal Investigator: 12 mo. @ 5% of academic salary			$14,722
Co-Principal Investigator: 12 mo. @ 5% of academic salary			$12,184
Consultant: 12 mo. @ 5% of academic salary			$14,722
Student Research Assistants			
1 RA: 50% for 9 mo. @ $2253/mo., 100% for 3 mo. @ $2253/mo.	$16,898	$17,235	
1 RA: 50% for 9 mo. @ $2253/mo., 100% for 3 mo. @ $2253/mo.	$16,898	$17,235	
3 Undergraduate Assistants IV: 9 mo. @ $400/mo. each	$10,800	$11,016	
Technical Assistance	$3,184	$3,235	
Fringe Benefits			
2 Principal Investigators and Consultant at 9.2%			$3,830
2 Research Assistants at 4.4%	$1,487	$1,517	
1 Technical Assistant at 23.5%	$748	$760	
Personnel Subtotal	*$50,014*	*$50,999*	*$45,458*
Other Direct Costs			
Equipment			$12,000
Supplies			
Chinook Swimming Performance	$8,601	$8,701	
Data Collection in Support of Modeling	$7,000	$7,000	
Travel	$2,000	$2,000	
Direct Costs Subtotal	*$17,601*	*$17,701*	*$12,000*
Miscellaneous Costs			
Fee Remission: 2 Research Assistants @ 4,800/yr/student	$9,600	$9,600	
Overhead, 44.5% year 1, 46% year 2 (based on personnel, supplies, travel)	$30,089	$31,602	
Miscellaneous Costs Subtotal	*$39,689*	*$41,202*	
Yearly Subtotal	*$107,304*	*$109,902*	
2 YEAR TOTAL		**$217,206**	**$57,458**

I-008496

APPENDIX B:

Schedule of Proposed Tasks

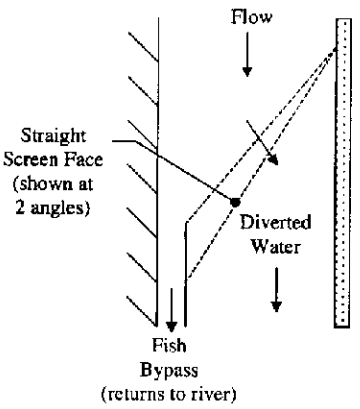
Task and Schedule List

Task	Description	Schedule
1	Define Model Requirements for Flow Field Simulation	December 1998 through March 1999
2	Assemble Existing Data on Possible Screening Sites	April through July 1999
3	Collection and Maintenance of Juvenile Chinook	March through June 1999 and 2000
4	Critical Swimming Speed Experiments	March through June 1999 and 2000
5	Muscle Contraction and Force Generation Experiments	March through June 1999 and 2000
6	Histochemical Analysis	July through February 1999 and 2000
7	Flow Table Experiments	March through June 1999 and 2000
8	Extend Models to Two Dimensions	August through November 1999
9	Extend Simulation Capability to Three Dimensions	December 1999 through March 2000
10	Perform Simulations for Critical Operating Conditions	August through November 2000
11	Map the Screen Velocity Field and Impingement Risk Zones	April through July 2000
12	Statistical Analysis of Fish Swimming Experiments	July through February 1999 and 2000

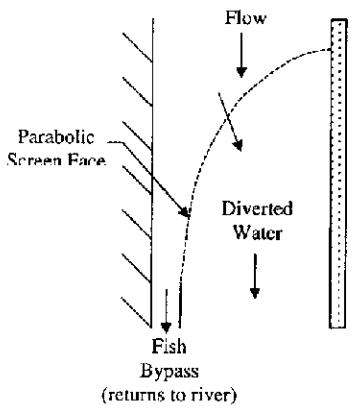
Appendix C

Screen Configurations Being Considered by Government Agencies

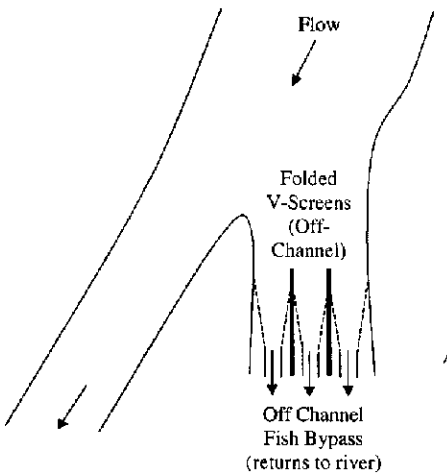
Detail of Partial Folded V-Screen



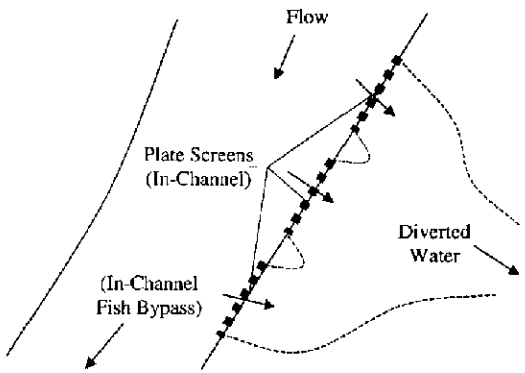
Detail of Partial Parabolic Screen



Multiple Off-Channel Folded V-Screens



Multiple In-Channel Plate-Screens



ref: (Shawn Mayr, personal communication)

U.S. Department of the Interior

Certifications Regarding Debarment, Suspension and Other Responsibility Matters, Drug-Free Workplace Requirements and Lobbying

Persons signing this form should refer to the regulations referenced below for complete instructions:

Certification Regarding Debarment, Suspension, and Other Responsibility Matters - Primary Covered Transactions - The prospective primary participant further agrees by submitting this proposal that it will include the clause titled, "Certification Regarding Debarment, Suspension, Ineligibility and Voluntary Exclusion - Lower Tier Covered Transaction," provided by the department or agency entering into this covered transaction, without modification, in all lower tier covered transactions and in all solicitations for lower tier covered transactions. See below for language to be used or use this form for certification and sign. (See Appendix A of Subpart D of 43 CFR Part 12.)

Certification Regarding Debarment, Suspension, Ineligibility and Voluntary Exclusion - Lower Tier Covered Transactions - (See Appendix B of Subpart D of 43 CFR Part 12.)

Certification Regarding Drug-Free Workplace Requirements - Alternate I. (Grantees Other Than Individuals) and Alternate II. (Grantees Who are Individuals) - (See Appendix C of Subpart D of 43 CFR Part 12)

Signature on this form provides for compliance with certification requirements under 43 CFR Parts 12 and 18. The certifications shall be treated as a material representation of fact upon which reliance will be placed when the Department of the Interior determines to award the covered transaction, grant, cooperative agreement or loan.

PART A: Certification Regarding Debarment, Suspension, and Other Responsibility Matters - Primary Covered Transactions

CHECK X IF THIS CERTIFICATION IS FOR A PRIMARY COVERED TRANSACTION AND IS APPLICABLE.

(1) The prospective primary participant certifies to the best of its knowledge and belief, that it and its principals:

(a) Are not presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded by any Federal department or agency;

(b) Have not within a three-year period preceding this proposal been convicted of or had a civil judgment rendered against them for commission of fraud or a criminal offense in connection with obtaining, attempting to obtain, or performing a public (Federal, State or local) transaction or contract under a public transaction; violation of Federal or State antitrust statutes or commission of embezzlement, theft, forgery, bribery, falsification or destruction of records, making false statements, or receiving stolen property;

(c) Are not presently indicted for or otherwise criminally or civilly charged by a governmental entity (Federal, State or local) with commission of any of the offenses enumerated in paragraph (1)(b) of this certification; and

(d) Have not within a three-year period preceding this application/proposal had one or more public transactions (Federal, State or local) terminated for cause or default.

(2) Where the prospective primary participant is unable to certify to any of the statements in this certification, such prospective participant shall attach an explanation to this proposal.

PART B: Certification Regarding Debarment, Suspension, Ineligibility and Voluntary Exclusion - Lower Tier Covered Transactions

CHECK__IF THIS CERTIFICATION IS FOR A LOWER TIER COVERED TRANSACTION AND IS APPLICABLE.

(1) The prospective lower tier participant certifies, by submission of this proposal, that neither it nor its principals is presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from participation in this transaction by any Federal department or agency.

(2) Where the prospective lower tier participant is unable to certify to any of the statements in this certification, such prospective participant shall attach an explanation to this proposal.

DI-2010
June 1988
(This form replaces DI-1953, DI-1954, DI-1955, DI-1956 and DI-1960)

PART C: Certification Regarding Drug-Free Workplace Requirements

CHECK X IF THIS CERTIFICATION IS FOR AN APPLICANT WHO IS NOT AN INDIVIDUAL.

Alternate I. (Grantees Other Than Individuals)

A. The grantee certifies that it will or continue to provide a drug-free workplace by:

(a) Publishing a statement notifying employees that the unlawful manufacture, distribution, dispensing, possession, or use of a controlled substance is prohibited in the grantee's workplace and specifying the actions that will be taken against employees for violation of such prohibition;

(b) Establishing an ongoing drug-free awareness program to inform employees about–
(1) The dangers of drug abuse in the workplace;
(2) The grantee's policy of maintaining a drug-free workplace;
(3) Any available drug counseling, rehabilitation, and employee assistance programs; and
(4) The penalties that may be imposed upon employees for drug abuse violations occurring in the workplace;

(c) Making it a requirement that each employee to be engaged in the performance of the grant be given a copy of the statement required by paragraph (a);

(d) Notifying the employee in the statement required by paragraph (a) that, as a condition of employment under the grant, the employee will –
(1) Abide by the terms of the statement; and
(2) Notify the employer in writing of his or her conviction for a violation of a criminal drug statute occurring in the workplace no later than five calendar days after such conviction;

(e) Notifying the agency in writing, within ten calendar days after receiving notice under subparagraph (d)(2) from an employee or otherwise receiving actual notice of such conviction. Employers of convicted employees must provide notice, including position title, to every grant officer on whose grant activity the convicted employee was working, unless the Federal agency has designated a central point for the receipt of such notices. Notice shall include the identification number(s) of each affected grant;

(f) Taking one of the following actions, within 30 calendar days of receiving notice under subparagraph (d)(2), with respect to any employee who is so convicted –
(1) Taking appropriate personnel action against such an employee, up to and including termination, consistent with the requirements of the Rehabilitation Act of 1973, as amended; or
(2) Requiring such employee to participate satisfactorily in a drug abuse assistance or rehabilitation program approved for such purposes by a Federal, State, or local health, law enforcement, or other appropriate agency;

(g) Making a good faith effort to continue to maintain a drug-free workplace through implementation of paragraphs (a) (b), (c), (d), (e) and (f).

B. The grantee may insert in the space provided below the site(s for the performance of work done in connection with the specific grant:

Place of Performance (Street address, city, county, state, zip code)

_____

_____

_____

Check___if there are workplaces on file that are not identified here.

PART D: Certification Regarding Drug-Free Workplace Requirements

CHECK__IF THIS CERTIFICATION IS FOR AN APPLICANT WHO IS AN INDIVIDUAL.

Alternate II. (Grantees Who Are Individuals)

(a) The grantee certifies that, as a condition of the grant, he or she will not engage in the unlawful manufacture, distribution, dispensing, possession, or use of a controlled substance in conducting any activity with the grant;

(b) If convicted of a criminal drug offense resulting from a violation occurring during the conduct of any grant activity, he or she will report the conviction, in writing, within 10 calendar days of the conviction, to the grant officer or other designee, unless the Federal agency designates a central point for the receipt of such notices. When notice is made to such a central point, it shall include the identification number(s) of each affected grant.

DI-2010
June 1988
(This form replaces DI-1963, DI-1964, DI-1965, DI-1966 and DI-1967)

PART E: Certification Regarding Lobbying
Certification for Contracts, Grants, Loans, and Cooperative Agreements

CHECK X IF CERTIFICATION IS FOR THE AWARD OF ANY OF THE FOLLOWING AND THE AMOUNT EXCEEDS $100,000: A FEDERAL GRANT OR COOPERATIVE AGREEMENT; SUBCONTRACT, OR SUBGRANT UNDER THE GRANT OR COOPERATIVE AGREEMENT.

CHECK __ IF CERTIFICATION IS FOR THE AWARD OF A FEDERAL LOAN EXCEEDING THE AMOUNT OF $150,000, OR A SUBGRANT OR SUBCONTRACT EXCEEDING $100,000, UNDER THE LOAN.

The undersigned certifies, to the best of his or her knowledge and belief, that:

(1) No Federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of an agency, a Member of Congress, and officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, "Disclosure Form to Report Lobbying," in accordance with its instructions.

(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers (including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements) and that all subrecipients shall certify accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by Section 1352, title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

As the authorized certifying official, I hereby certify that the above specified certifications are true.

THE REGENTS OF THE UNIVERSITY
OF CALIFORNIA

Sandra M. Dowdy — JUN 2 9 1998

SIGNATURE OF AUTHORIZED CERTIFYING OFFICIAL

Sandra M. Dowdy
Contracts and Grants Analyst

TYPED NAME AND TITLE

DATE

DI-2010
June 1995
(This form replaces DI-1952, DI-1954, DI-1956, DI-1960 and DI-19631

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I-008501

Figure 1

Standard Form 424

APPLICATION FOR FEDERAL ASSISTANCE

OMB Approval No. 3348-0043

1. TYPE OF SUBMISSION: Application / Preapplication; ☐ Construction / ☐ Construction; ☒ Non-Construction / ☐ Non-Construction	2. DATE SUBMITTED: 7/1/98	Applicant Identifier: N/A
	3. DATE RECEIVED BY STATE: N/A	State Application Identifier: N/A
	4. DATE RECEIVED BY FEDERAL AGENCY:	Federal Identifier:

5. APPLICANT INFORMATION

Legal Name: The Regents of the Univ. of Calif.

Organizational Unit: College of Engr; CEE

Address (give city, county, state, and zip code): Office of the Vice Chancellor for Research, 410 Mrak Hall, University of California, One Shields Avenue, Davis, CA 95616

Name and telephone number of person to be contacted on matters involving this application (give area code): Sandra Dowdy, Contract & Grant Analyst, (530) 752-2075

6. EMPLOYER IDENTIFICATION NUMBER (EIN): 94-6036494

7. TYPE OF APPLICANT: (enter appropriate letter in box) I

A. State; B. County; C. Municipal; D. Township; E. Interstate; F. Intermunicipal; G. Special District; H. Independent School Dist.; I. State Controlled Institution of Higher Learning; J. Private University; K. Indian Tribe; L. Individual; M. Profit Organization; N. Other (Specify)

8. TYPE OF APPLICATION:

☒ New ☐ Continuation ☐ Revision

If Revision, enter appropriate letter(s) in box(es): ☐ ☐

A. Increase Award; B. Decrease Award; C. Increase Duration; D. Decrease Duration; Other (specify):

9. NAME OF FEDERAL AGENCY: U.S. Bureau of Reclamation (CALFED Bay-Delta Program)

10. CATALOG OF FEDERAL DOMESTIC ASSISTANCE NUMBER: ☐☐ - ☐☐☐

TITLE: N/A

11. DESCRIPTIVE TITLE OF APPLICANT'S PROJECT:

12. AREAS AFFECTED BY PROJECT (Cities, Counties, States, etc.): United States

13. PROPOSED PROJECT: Start Date 12/1/98; Ending Date 11/30/00

14. CONGRESSIONAL DISTRICTS OF: a. Applicant III; b. Project III

15. ESTIMATED FUNDING:

a. Federal	$ 107,304.00
b. Applicant	$ 20,591.00
c. State	$ .00
d. Local	$ .00
e. Other	$ .00
f. Program Income	$ .00
g. TOTAL	$ 127,995.00

16. IS APPLICATION SUBJECT TO REVIEW BY STATE EXECUTIVE ORDER 12372 PROCESS?

a. YES. THIS PREAPPLICATION/APPLICATION WAS MADE AVAILABLE TO THE STATE EXECUTIVE ORDER 12372 PROCESS FOR REVIEW ON: DATE _____

b. NO. ☒ PROGRAM IS NOT COVERED BY E.O. 12372 ☐ OR PROGRAM HAS NOT BEEN SELECTED BY STATE FOR REVIEW

17. IS THE APPLICANT DELINQUENT ON ANY FEDERAL DEBT? ☐ Yes If "Yes," attach an explanation ☐ No

18. TO THE BEST OF MY KNOWLEDGE AND BELIEF, ALL DATA IN THIS APPLICATION/PREAPPLICATION ARE TRUE AND CORRECT, THE DOCUMENT HAS BEEN DULY AUTHORIZED BY THE GOVERNING BODY OF THE APPLICANT AND THE APPLICANT WILL COMPLY WITH THE ATTACHED ASSURANCES IF THE ASSISTANCE IS AWARDED.

a. Type Name of Authorized Representative	b. Title: Sandra M. Dowdy, Contracts and Grants Analyst	c. Telephone Number: (530) 752-2075
d. Signature of Authorized Representative: Sandra M Dowdy		e. Date Signed: JUN 29 1998

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Figure 2

Standard Form 424A

BUDGET INFORMATION - Non-Construction Programs

OMB Approval No. 0348-0044

SECTION A - BUDGET SUMMARY

Grant Program Function or Activity (a)	Catalog of Federal Domestic Assistance Number (b)	Estimated Unobligated Funds		New or Revised Budget		
		Federal (c)	Non-Federal (d)	Federal (e)	Non-Federal (f)	Total (g)
1. CALFED		$	$	$ 107,305	$ 20,691	$ 127,996
2. CALFED				109,901	20,690	130,591
3.						
4.						
5. Totals		$	$	$ 217,206	$ 41,381	$ 258,587

SECTION B - BUDGET CATEGORIES

6. Object Class Categories	GRANT PROGRAM, FUNCTION OR ACTIVITY (1)	(2)	(3)	(4)	Total (5)
a. Personnel	$ 47,780	48,721	$	$	$ 96,501
b. Fringe Benefits	2,235	2,277			4,512
c. Travel	2,000	2,000			4,000
d. Equipment					
e. Supplies	15,601	15,701			31,302
f. Contractual					
g. Construction					
h. Other	9,600	9,600			19,200
i. Total Direct Charges (sum of 6a-6h)	77,216	78,299			155,515
j. Indirect Charges	30,089	31,602			61,691
k. TOTALS (sum of 6i and 6j)	$ 107,305	$ 109,901	$	$	$ 217,206
7. Program Income	$	$	$	$	$

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Prescribed by OMB Circular A-102

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Figure 2

Standard Form 424A (cont'd.)

SECTION D - OTHER NON-FEDERAL RESOURCES

(a) Grant Program	(b) Applicant	(c) State	(d) Other Sources	(e) TOTALS
8.	$ 41,381	$	$	$ 41,381
9.				
10.				
11.				
12. TOTAL (sum of lines 8 - 11)	$ 41,381	$	$	$ 41,381

SECTION E - FORECASTED CASH NEEDS

	Total for 1st Year	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
13. Federal	$ 107,305	$ 26,827	$ 26,826	$ 26,826	$ 26,826
14. NonFederal	20,691	5,172	5,173	5,173	5,173
15. TOTAL (sum of lines 13 and 14)	$ 127,996	$ 31,999	$ 31,999	$ 31,999	$ 31,999

SECTION F - BUDGET ESTIMATES OF FEDERAL FUNDS NEEDED FOR BALANCE OF THE PROJECT

(a) Grant Program	FUTURE FUNDING PERIODS (Years)			
	(b) First	(c) Second	(d) Third	(e) Fourth
16.	$	$	$	$
17.				
18.				
19.				
20. TOTAL (sum of lines 16-19)	$	$	$	$

SECTION G - OTHER BUDGET INFORMATION

21. Direct Charges: yr 1 = $107,305; yr 2 = $109,901

22. Indirect Charges: yr 1 = 44.5% and yr 2 = 46% of MTDC

23. Remarks:

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Standard Form 424A (Rev. 4-92) Page 2

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Figure 3

Standard Form 424B

OMB Approval No. 0348-0040

ASSURANCES — NON-CONSTRUCTION PROGRAMS

Public reporting burden for this collection of information is estimated to average 15 minutes per response, including time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding the burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to the Office of Management and Budget, Paperwork Reduction Project (0348-0040), Washington, DC 20503.

PLEASE DO NOT RETURN YOUR COMPLETED FORM TO THE OFFICE OF MANAGEMENT AND BUDGET, SEND IT TO THE ADDRESS PROVIDED BY THE SPONSORING AGENCY.

NOTE: Certain of these assurances may not be applicable to your project or program. If you have questions, please contact the awarding agency. Further, certain Federal awarding agencies may require applicants to certify to additional assurances. If such is the case, you will be notified.

As the duly authorized representative of the applicant I certify that the applicant:

1. Has the legal authority to apply for Federal assistance and the institutional, managerial and financial capability (including funds sufficient to pay the non-Federal share of project cost) to ensure proper planning, management and completion of the project described in this application.

2. Will give the awarding agency, the Comptroller General of United States, and if appropriate, the State, through any authorized representative, access to and the right to examine all records, books, papers, or documents related to the award; and will establish a proper accounting system in accordance with generally accepted accounting standards or agency directives.

3. Will establish safeguards to prohibit employees from using their positions for a purpose that constitutes or presents the appearance of personal or organizational conflict of interest, or personal gain.

4. Will initiate and complete the work within the applicable time frame after receipt of approval of the awarding agency.

5. Will comply with the Intergovernmental Personnel Act of 1970 (42 U. S. C. §4728-4763) relating to prescribed standards for merit systems for programs funded under one of the nineteen statutes or regulations specified in Appendix A of OPM's Standards for a Merit System of Personnel Administration (5 C. F. R. 900, Subpart F).

6. Will comply with all Federal statutes relating to nondiscrimination. These include but are not limited to: (a) Title VI of the Civil Rights Act of 1964 (P.L. 88-352) which prohibits discrimination on the basis of race, color or national origin; (b) Title IX of the Education Amendments of 1972, as amended (20 U. S. C. §1681-1683, and 1685-1686), which prohibits discrimination on the basis of sex; (c) Section 504 of the Rehabilitation Act of 1973, as amended (29 U. S. C. §794), which prohibits discrimination on the basis of handicaps; (d) the Age Discrimination Act of 1975, as amended (42 U. S. C. §6101-6107), which prohibits discrimination on the basis of age; (e) the Drug Abuse Office and Treatment Act of 1972 (P. L. 92-255), as amended, relating to nondiscrimination on the basis of drug abuse; (f) the Comprehensive Alcohol Abuse and Alcoholism Prevention, Treatment and Rehabilitation Act of 1970 (P.L. 91-616), as amended, relating to nondiscrimination on the basis of alcohol abuse or alcoholism; (g) §§523 and 527 of the Public Health Service Act of 1912 (42 U.S.C. 290 dd-3 and 290 ee-3), as amended, relating to confidentiality of alcohol and drug abuse patient records; (h) Title VIII of the Civil Rights Act of 1968 (42 U.S.C. §3601 et seq.), as amended, relating to nondiscrimination in the sale, rental or financing of housing; (i) any other nondiscrimination provisions in the specific statute(s) under which application for Federal assistance is being made; and (j) the requirements of any other nondiscrimination statute(s) which may apply to the application.

7. Will comply, or has already complied, with the requirements of Titles II and III of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 (P.L. 91-646) which provide for fair and equitable treatment of persons displaced or whose property is acquired as a result of Federal or federally assisted programs. These requirements apply to all interests in real property acquired for project purposes regardless of Federal participation in purchases.

8. Will comply, as applicable, with provisions of the Hatch Act (5 U.S.C. §§1501-1508 and 7324-7328) which limit the political activities of employees whose principal employment activities are funded in whole or in part with Federal funds.

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Prescribed by OMB Circular A-102

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Figure 3

Standard Form 4248 (cont'd.)

9. Will comply as applicable, with the provisions of the Davis-Bacon Act (40 U.S.C. §§276a to 276a - 7), the Copeland Act (40 U.S.C. §§276c and 18 U. S. C. §§874), and the Contract Work Hours and Safety Standards Act (40 U.S.C. §§327-333), regarding labor standards for federally assisted construction subagreements.

10. Will comply, if applicable, with flood insurance purchase requirements of Section 102(a) of the Flood Disaster Protection Act of 1973 (P.L. 93-234) which requires recipients in a special flood hazard area to participate in the program and to purchase flood insurance if the total cost of insurable construction and acquisition is $10,000 or more.

11. Will comply with environmental standards which may be prescribed pursuant to the following: (a) institution of environmental quality control measures under the National Environmental Policy Act of 1969 (P.L. 91-190) and Executive Order (EO) 11514; (b) notification of violating facilities pursuant to EO 11738; (c) protection of wetlands pursuant to EO 11990; (d) evaluation of flood hazards in floodplains in accordance with EO 11988; (e) assurance of project consistency with the approved State management program developed under the Coastal Zone Management Act of 1972 (16 U.S.C. §§1451 et seq.); (f) conformity of Federal actions to State (Clear Air) Implementation Plans under Section 176(c) of the Clear Air Act of 1955, as amended (42 U.S.C. §§ 7401 et seq.); (g) protection of underground sources of drinking water under the Safe Drinking Water Act of 1974, as amended, (P.L. 93-523); and (h) protection of endangered species under the Endangered Species Act of 1973, as amended, (P.L. 93-205).

12. Will comply with the Wild and Scenic Rivers Act of 1968 (16 U.S.C. §§1271 et seq.) related to protecting components or potential components of the national wild and scenic rivers system.

13. Will assist the awarding agency in assuring compliance with Section 106 of the National Historic Preservation Act of 1966, as amended (16 U.S.C. 470), EO 11593 (identification and protection of historic properties), and the Archaeological and Historic Preservation Act of 1974 (16 U.S.C. 469a-1 et seq.).

14. Will comply with P.L. 93-348 regarding the protection of human subjects involved in research, development, and related activities supported by this award of assistance.

15. Will comply with the Laboratory Animal Welfare Act of 1966 (P.L. 89-544, as amended, 7 U.S.C. 2131 et seq.) pertaining to the care, handling, and treatment of warm blooded animals held for research, teaching, or other activities supported by this award of assistance.

16. Will comply with the Lead-Based Paint Poisoning Prevention Act (42 U.S.C. §§ 4801 et seq.) which prohibits the use of lead based paint in construction or rehabilitation of residence structures.

17. Will cause to be performed the required financial and compliance audits in accordance with the Single Audit Act of 1984 or OMB Circular No. A-133, Audits of Institutions of Higher Learning and other Non-profit Institutions.

18. Will comply with all applicable requirements of all other Federal laws, executive orders, regulations and policies governing this program.

SIGNATURE OF AUTHORIZED CERTIFYING OFFICIAL	TITLE
Sandra M. Dowdy	Sandra M. Dowdy Contracts and Grants Analyst
APPLICANT ORGANIZATION THE REGENTS OF THE UNIVERSITY OF CALIFORNIA	DATE SUBMITTED JUN 2 9 1998

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