F1-003

United States Department of the Interior

TAKE PRIDE IN AMERICA

GEOLOGICAL SURVEY

Water Resources Division MS496
345 Middlefield Rd.
Menlo Park, CA 94025

July 22, 1997

Kate Hansel
CALFED Bay-Delta Program
1416 Ninth St., Suite 1155
Sacramento, CA 95814

Dear Ms. Hansel,

Enclosed here are ten copies of a proposal in response to the CALFED Category III RFP. Title of the proposal is "Assessment of the Sacramento-San Joaquin River Delta as Habitat for Production of the Food Resources that Support Fish Recruitment". This project is designed as a three-year assessment to give a definitive answer to the question of whether food-limitation is a stressor to recruitment of the fish species that rear in the Delta. This assessment will also provide the information required to define how specific restoration actions will impact the secondary production of the food resources used by early-stage fishes. Our objective is to fill an important gap in the scientific knowledge required to design an effective longterm restoration plan for the Delta. The proposal fits in your RFG Group #3, Other Services.

Please note that this proposal is a collobarative project between the USGS (Menlo Park), University of California-Davis, Stanford University, and the Virginia Institute of Marine Science. Although we are submitting one integrated proposal, each institution has a separate budget. From a funding perspective, this may be viewed as a bundling of four separate proposals. However, it is important to understand that this project is designed as a comprehensive assessment that integrates results of five different tasks. Rigorous assessment of this complex issue will require the integration of multiple approaches, and we hope that reviewers of this proposal will appreciate the need for each of the tasks included in our assessment design.

In recent years there has been intense speculation and debate about the issue of food-limitation as a potential stressor to fish recruitment. We view the CALFED Category III program as an opportunity to support the measurements and analyses required to resolve this debate. Resolution of this issues is a critical step in the design of a program to restore fish stocks in the Delta to levels observed in past decades.

Would you please send a brief acknowledgement of receipt of this proposal. On behalf of my colleagues, we thank CALFED agencies for their consideration of this proposal.

Sincerely,

James E. Cloern

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F1 · 003

Assessment of the Sacramento-San Joaquin River Delta as Habitat for Production of the Food Resources that Support Fish Recruitment

James Cloern (coordinator), Michael Brett, Elizabeth Canuel, Brian Cole, Alan Jassby, Jeffrey Koseff, Stephen Monismith, and Dörthe Müller-Navarra

This proposal describes a comprehensive assessment of the production, import, utilization, and export of the organic matter that serve as food for small aquatic organisms, such as copepods and mysid shrimp, that are the food resource for fish in their early life stages. The transfer of nutritive material among the biota at the lower trophic levels, from phytoplankton and detritus to small invertebrates and immature fish, represents one of the most critical sets of ecosystem functions in the Sacramento-San Joaquin Delta. These functions ultimately determine, and potentially limit the population growth of fishes in the Delta. Our project is designed to provide the scientific basis for judging how specific restoration actions can improve these ecosystem functions. It is motivated by the perspective of Herbold et al.[15] *"Developing an understanding of the estuary as an ecosystem is important to restore the healthy fisheries that the estuary has supported in the past. Development of a general, descriptive model of the aquatic habitats and resources of the Bay and Delta is necessary for coordinated and comprehensive management."* Our goal is to provide the information required to understand how different Delta habitats support the growth (secondary production) of the small aquatic invertebrates that are forage for the priority species of fish such as Delta smelt, longfin smelt, Sacramento splittail, and young striped bass. This information will be developed through completion of five related tasks that include: measurements of food quantity/quality and sources, compilation of budgets of food production and losses, analysis of long-term IEP measures of plankton populations, development of a numerical model of phytoplankton and nutrient dynamics in the Delta, and development of a synthesis of results to define the capacity of Delta habitats for supporting secondary production, with estimates of how that capacity would be changed by specific restoration actions.

Justification

The 1994 Bay-Delta accord was prompted by concerns about the dramatic declines of living resources that have occurred in the Sacramento-San Joaquin River Delta in recent decades. Progressive population declines of striped bass, white catfish, threadfin shad, longfin smelt, and Sacramento splittail have been observed since the 1970's. Some migratory (Chinook salmon) and resident (Delta smelt) fish have reached alarmingly small population levels, prompting protection under state and federal laws for endangered species. The green sturgeon is designated a species of concern by DFG. Two once-abundant species, the Sacramento perch and thicktail chub, are now extinct. The simultaneous and large declines of so many different species is now interpreted as a compelling "*indicator of broad problems with the estuarine environment, especially in the Delta*"[3]. CALFED agencies now face the complex challenge of implementing a long-term restoration program to solve these problems. One goal is to identify a suite of restoration actions to enhance the likelihood that populations of these living resources will return to levels observed in prior decades. Our project was designed to provide the scientific basis for restoration actions that can be taken to promote the production of the small lower-trophic-level invertebrate organisms that are utilized as forage by these fish at some period of their life cycles.

Budget

This project is planned as a three-year cooperation between the U.S. Geological Survey (USGS), University of California-Davis (UCD), Stanford University, and Virginia Institute of Marine Science (VIMS). CALFED support will be supplemented by the USGS, with cost-sharing as follows:

	1998	1999	2000
Request to CALFED	517K	490K	393K
USGS Contribution	244K	283K	220K

Applicant Qualifications

This project is a team effort between investigators having a long history of involvement in Bay-Delta issues, and young investigators who are pioneering new techniques for assessing food quality and utilization in aquatic ecosystems. Project coordinator is James Cloern, a USGS biologist who has studied diverse aspects of the Bay-Delta ecosystem for over two decades. Dr. Michael Brett is Research Associate at UCD with expertise in plankton foodwebs. Dr. Elizabeth Canuel is Assistant Professor at VIMS, with expertise in the use of biomarkers to identify sources of organic matter in estuaries. Brian Cole is a USGS biologist who has studied plankton ecology of San Francisco Bay for over two decades. Dr. Alan Jassby is a Professional Research Ecologist at UCD, with expertise in mathematical tools for identifying patterns and causes of ecosystem variability. Dr. Jeffrey Koseff is Professor and Chair of the Department of Civil Engineering, Stanford University, with expertise in environmental fluid mechanics. Dr. Stephen Monismith is Associate Professor in the same department, with expertise in lake and estuarine hydrodynamics. Dr. Dörthe Müller-Navarra is Research Associate at UCD with expertise in techniques for assessing linkages between primary and secondary production. Drs. Cloern, Jassby, and Monismith are members of the Science Advisory Group to the IEP. This team has a rich history of collaborative science and publication. Examples include:

Canuel, E.A., Cloern, J.E., Ringelberg, D., Guckert, J., and Rau, G., 1995, Molecular and isotopic tracers used to understand sources of organic matter and trophic relationships in the San Francisco Bay estuary: Limnology and Oceanography, v. 40, p. 67-81.

Cole, B.E., and Cloern, J.E., 1984. Significance of biomass and light availability to phytoplankton productivity in San Francisco Bay: Marine Ecology- Progress Series, v. 15, page 15-24.

Jassby, A.D., W.J. Kimmerer, S.G. Monismith, C. Armor, J.E. Cloern, T.M. Powell, J.R. Schubel, and T.J. Vendlindski. 1995 Isohaline position as a habitat indicator for estuarine populations. Ecological Applications 5:272-289.

Koseff, J.R., Holen, J.K., Monismith, S.G., and Cloern, J.E.. 1993.The effects of vertical mixing and benthic grazing on phytoplankton populations in shallow turbid estuaries. Journal of Marine Research, 51: 1-26, 1993.

Data Evaluation

Data and model analyses and interpretations will be subjected to the rigorous peer-review required for publication in international scientific journals, such as those listed above.

Local Support/Coordination with other Programs

This project will utilize laboratory and computing facilities and logistical support provided by the USGS in Menlo Park, Division of Environmental Studies at UC-Davis, and Department of Civil Engineering at Stanford University. Sampling will be coordinated with the IEP compliance monitoring. Proposed new measurements will complement those made with support from the USGS Toxic Substances Hydrology Program and IEP Contaminants Work Team. Model development will build upon numerical models supported by grants to Stanford from NSF.

Assessment of the Sacramento-San Joaquin River Delta as Habitat for Production of the Food Resources that Support Fish Recruitment

-- a proposal to the CALFED Bay-Delta Program, by --

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Type of Organization: Federal Agency (USGS) and Universities (College of William and Mary, Stanford University, and University of California-Davis)

Tax ID numbers:	**USGS**: 805003683	**UCD**: 94-6036494
	Stanford: 94-1156365	**VIMS**: 54-6001-802

Financial Contacts:

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UCD: Jo Clare Peterman, Business Contracts Office, 453 Mrak Hall, University of California, Davis, CA 95616, (916) 752-2426, (FAX)752-2553, jcpeterman@ucdavis.edu
Stanford: Ruth Kaempf, Sponsored Projects Office, Stanford University, Stanford, CA 94305-4125 ph: (415) 723-4740, fax: (415) 723 0810
VIMS: Jane Lopez, Virginia Institute of Marine Sciences, College of William and Mary, POB 1346, Gloucester Point, VA 23062

RFP Group: #3, Services

PROJECT DESCRIPTION AND APPROACH

This proposal is based on the premise that the capacity of Delta habitats to sustain populations of upper-trophic-level organisms, including priority fish species, is partly dependent on the quantity and quality of the food resource available to the lower-trophic-level organisms. The importance of food transfers from the lower to upper trophic levels has been recognized implicitly in much of the work done in the Delta and Suisun Bay. However, large gaps remain in our knowledge of the sources and chemical forms (quality) of organic matter, and variability of this component of Delta habitats for the production of invertebrate animals (secondary production). We propose a focused assessment of the capacity of different Delta habitats to support the nutritional requirements of the invertebrate biota that sustain populations at the upper-trophic-levels. This assessment is an integral step in the search for effective actions to promote recovery of those living resources which have experienced large declines in recent decades.

LOCATION

This project applies to the Sacramento-San Joaquin River Delta (see attached map), including the Delta Basin, Yolo Basin, Suisun Marsh, and inputs from the Sacramento River, San Joaquin River, and East Side Delta tributaries.

EXPECTED BENEFITS

CALFED agencies are actively engaged in the search for strategies to restore and protect the 'health' of the Bay-Delta ecosystem. Although there is vigorous debate about the concept of system 'health', there is a developing consensus that this concept is strongly linked to the functions or services provided by ecosystems, and that restoration efforts should be guided toward actions that will optimize those functions or services. Our project will fill critical gaps in knowledge about one important set of ecosystem functions -- the production, delivery, utilization, and export of organic matter required as food for the production of animal biomass. A second objective is to explain the variability of these ecosystem functions, with focus on the natural variability in river flow, anthropogenic variability caused by management of water projects, and potential actions that can be taken by CALFED agencies to restore physical habitats or hydrologic regimes that promote secondary production. This information is required to assess the trophic linkages that directly or indirectly support recruitment of striped bass, white catfish, threadfin shad, longfin smelt, Sacramento splittail, Chinook salmon, Delta smelt, green sturgeon and other species in decline. This project will provide to CALFED agencies:

1. The first comparison of the capacity of different Delta habitats to support secondary production, including the first systematic measures of primary production in the Delta.
2. The scientific basis for understanding how that capacity will expand (or contract) in response to restoration actions such as hydrograph alterations, operations of new conveyance facilities, or habitat reconstruction.
3. A framework for understanding the importance of ecosystem functions at the lower trophic levels as forces that can cause variability of fish recruitment.
4. Protocols for new food-quality assays that can be incorporated into monitoring programs as indicators of the ecosystem services provided by lower-trophic-level biota.
5. A new numerical model to describe the couplings between transports, nutrient cycling, and primary production in the Delta -- a tool for predicting responses of these functions to different scenarios of restoration action.

BACKGROUND AND JUSTIFICATION

Our proposed assessment is based on analyses showing that most species of fish within the Delta have poor survival through the first year of life -- i.e., fish in the Delta are *recruitment limited*[3]. Although there is uncertainty about the importance of food limitation as a mode of recruitment limitation, we do know that declines of fish stocks have occurred in an era of intense disruption of the lower foodweb. The introduced clam *Potamocorbula amurensis* has caused an unprecedented five-fold reduction of primary production in Suisun Bay[1]. Primary production has not been measured in the Delta, so the magnitude of this food source is unknown there. However, seasonal phytoplankton cycles have been altered in the Delta, and exports appear to be a significant loss of biomass from the Delta[17]. The zooplankton community has changed drastically in recent years; a particular concern is decline of the copepod *Eurytemora affinis*, an important dietary component for larval fish. Total zooplankton abundance has declined, suggesting that food might be less available to larval fish during their critical first-feeding stage. Parallel declines of the mysid shrimp *Neomysis mercedis* are of concern because this species is a key dietary component for juvenile fishes. Riverine input is an importnat source of organic matter[16], so manipulation of flows[2] has likely changed the input of organic matter to the Delta.

These foodweb disturbances suggest that the capacity of the Delta to support production of invertebrate animals has been degraded in recent decades. However no assessment has been made of the quality and quantity of the food resource required by these consumer animals. Laboratory studies show a correlation between copepod production and phytoplankton biomass over the range of chlorophyll concentrations between 0 and 10 µg/liter. Since 1987, chlorophyll concentrations in the lower Sacramento River and Suisun Bay have consistently been less than 10 µg/liter, suggesting that the *phytoplankton* food resource is suboptimal for copepod growth. Phytoplankton food quality varies among species, and the highest nutritional value is provided by species rich in highly unsaturated fatty acids (HUFA) -- essential dietary components for animal production. Freshwater zooplankton are limited when the HUFA content of seston is less than 1 µg/liter[23], and the HUFA dietary content is a strong predictor of marine copepod production[29]. The few measurements made in the Delta show HUFA concentrations are generally below limiting levesl[7], suggesting that zooplankton production in the Delta is usually food-limited.

Of course the ultimate question here is whether the food resource for early-stage fish is sufficient to support optimal growth and survival in all Delta habitats. Some observations suggest that the food resource is one of several factors that limits fish recruitment. Larval striped bass grow more slowly in the Bay/Delta than in other estuaries[3]. Since slow growth prolongs the period in which larvae are vulnerable to predation, factors which influence growth (including food-limitation) can be important sources of mortality[3]. Other priority species, such as Delta smelt, are directly susceptible to starvation in their larval stages; declines of this species may be related to declines in the abundance of rotifers, the preferred food resource[21]. In their review, Bennett and Moyle[3] note that the fish species in decline reside in the Delta and "*exhibit some degree of food sensitivity*". With these observations as background, we believe that effective habitat restoration requires a definitive assessment of those ecosystem functions that support secondary production of invertebrates that provide forage for fish during early life stages.

PROPOSED SCOPE OF WORK

Although the Sacramento-San Joaquin Delta is one of the best-studied estuarine ecosystems with respect to water quality and stocks of selected species of fish, fundamental questions remain about the feeding ecology and nutritional condition of the lower-trophic-level animals. These questions persist because there has been no integrated assessment of the Delta to:

measure primary production; determine whether zooplankton or other invertebrates are food-limited; measure the inputs, exports, and assimilation of organic matter; or to establish the trophic linkages underlying the strong statistical associations between salinity (flow) and recruitment of biota at different trophic levels[18]. To address these gaps of knowledge, we propose a three-year project composed of five related tasks:

Task #1: Compare the Quantity and Quality of the Food Resource Available to Support Secondary Production in Different Habitats of the Sacramento-San Joaquin Delta

This task is to initiate a new sampling program to measure the quantity and quality of the organic matter available to the lower-trophic-level consumer organisms. Sampling is designed to measure spatial variability across a network of sites (see following map and Table 1 of the Appendix), and temporal variability by sampling across a range of hydrologic and biological conditions in which the strength of the different food sources varies (Table 2, Appendix). Objectives are to compare food quantity/quality among the different habitat types of the Delta, and to measure changes in the food resource in response to pulse inputs of river-derived organic matter and seasonal changes in Delta primary production. This assessment includes four components:

A. Bulk Chemical Measures (USGS) -- Our concept of trophic transfer places emphasis on the particulate organic matter (POM), which is a complex mixture of mineral particles with organic coatings, living microbes, and detrital particles of diverse origin. The following methods can be used to assess the quantity/quality of the POM food resource:

1. Ratio of Carbon to Nitrogen -- The ratio of carbon to nitrogen is a useful indicator of the nutritional quality of the POM, and this can be derived from measured concentrations of particulate C and N with an elemental analyzer[9].

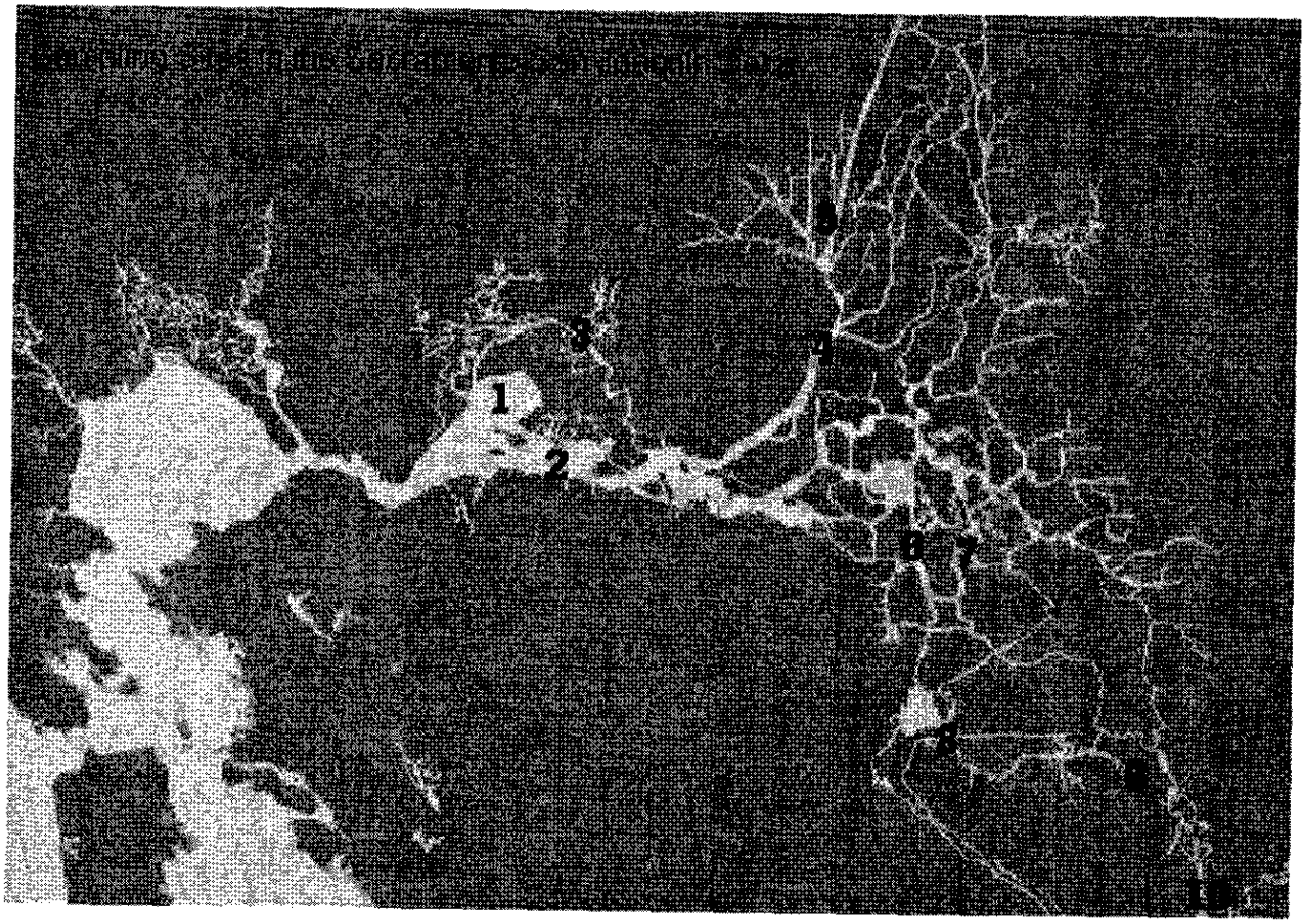
2. The Algal Component -- we can estimate the algal component as chlorophyll concentration, multiplied times the ratio of carbon to chlorophyll in the algal biomass[10]. The ratio of algal-carbon to total particulate carbon is an index of food quality, which generally increases as the algal component increases[11].

3. Total Seston -- will be determined by measuring the weight of particles retained on filters, as a measure of the abundance of total suspended solids (mineral and organic).

B. Biochemical Markers (VIMS) -- No single chemical tracer can give a complete description of the quality and origin of organic matter, so we will use several different indicators. Surficial sediments and suspended particles will be collected at five sites and analyzed for total lipid[5], carbohydrate[25], protein[24], and biomarker compounds as indicators of the origins of organic matter. We will target the lipid biomarkers (fatty acids and sterols) because these can distinguish organic matter derived from phytoplankton, seagrasses, land/marsh plants, and sewage. These analyses will be supplemented with measures of the isotopic composition (ratio of carbon13 to carbon12), another indicator of the origin of organic matter. This multiple-indicator approach is necessary in complex estuarine ecosystems which have a spectrum of potential food sources[6,7].

C. Dissolved Organic Matter (USGS) -- The largest pool of organic matter in the Delta is the dissolved organic matter (DOM). However, the fraction of the dissolved pool that can be assimilated into the foodweb is unknown. We define this labile component as the fraction that can be metabolized within the time of transport across the Delta -- i.e., within days or weeks. This labile fraction of DOM can be measured with five-day BOD incubations of filtered water.

D. Zooplankton Production Assay (UCD) -- Since the secondary production of invertebrates is determined by food quantity and quality, we can use assays of zooplankton production to assess directly the nutritional quality of the food resource in Delta habitats. Recent studies have shown that phytoplankton with the best nutritional quality for copepods are rich in



Task: Measurements	STATION 1	2	3	4	5	6	7	8	9	10
1A: Bulk Chemical Measures	X	X	X	X	X	X	X	X	X	X
1B: Biochemical Markers		X	X	X		X				X
1C: Dissolved Organic Matter	X	X		X		X		X		X
1D. Zooplankton Production Assay		X	X	X		X				X
2A: River Inputs and Exports				X		X		X		X
2B: Primary Production	X	X		X		X		X		X

highly unsaturated fatty acids (HUFA). Results from freshwater systems also show that HUFA content of organic particles is strongly correlated with food quality[23]. Because phytoplankton HUFA play an important role in herbivore nutrition, the availability of essential fatty acids can limit the rate at which primary production is converted to animal production[4]. The most important essential fatty acids are eicosapentaenoic acid and docosahexaenoic acid, which are critical limiting compounds for crustaceans, mollusks, and a wide variety of fish species[4]. These compounds will be measured in Task 1B. We will also use copepod egg-production assays to measure zooplankton production and food quality, and to determine if food quality is correlated with fluctuations in essential fatty acids. These bioassays will be conducted by feeding laboratory-reared copepods the natural seston collected from five Delta locations, and then monitoring copepod survival, egg production, and egg viability. These are modifications of food-quality bioassays used in nutritional studies of estuarine copepods[20] and freshwater cladocerans[23]. Our final report will include recommendations of how these assays could be used as ecological indicators of food-limitation of secondary production within monitoring programs.

Task #2: Identify the Important Sources of Food that Fuel Secondary Production

Three sources dominate the supply of food for lower-trophic-level consumers in the Delta: riverine inputs of DOM, riverine inputs of POM, and phytoplankton primary production within the Delta. We propose to measure each source across a range of hydrologic/biological conditions.

A. Riverine Inputs and Exports (USGS, VIMS) -- Accurate measurement of inputs is difficult because loadings fluctuate strongly with river flow[28]. We can estimate the riverine food source by making flow-weighted measurements of particulate C and N, chlorophyll, carbohydrates, proteins, lipid biomarkers, and BOD in the Sacramento River at Rio Vista and in the San Joaquin River at Vernalis. Discharge is measured continuously at both locations, so inputs to the Delta can be calculated as flow multiplied times the concentration of each constituent. Exports can be estimated from concentrations and flows measured in the central Delta at Old River and at the intake of Clifton Court Forebay (see the map of sampling sites).

B. Phytoplankton Primary Production (USGS) -- Primary production will be measured at six sites with the standard incubation method used to measure primary production in San Francisco Bay[12]. From these measurements we will determine if a simple regression equation of primary production can be developed, following the approach used[13] for San Francisco Bay. If primary production by Delta phytoplankton can be predicted from measures of chlorophyll and light availability, then this equation can be used to estimate primary production from measurements included in the IEP monitoring program. This equation can also be used to calculate historic changes in primary production in the Delta over the period of IEP monitoring.

Task #3: Construct Budgets for the Food-Resource Indicators in the Delta (UCD, USGS)

With simultaneous measurements of primary production, river loadings, and exports, we can construct simple budgets of particulate carbon and nitrogen, algal biomass, essential fatty acids, and labile DOM to determine the relative importance of these sources and sinks of the Delta food resource. The difference between river loadings and exports will measure the net ecosystem function of the Delta as a producer (or consumer) of organic matter. Comparison of loadings with primary production will measure the relative importance of the external and internal food sources. Budgets for the labile DOM will identify the importance of dissolved organic matter to the production of animal biomass in the Delta. Measurement of exports will tell the fraction of the food resource lost from the Delta under current practices of flow regulation.

Task #4: Develop Models for Describing Nutrient-Phytoplankton Dynamics in the Delta
Phytoplankton blooms are significant biological events that directly impact the ecosystem services of primary production, nutrient cycling, and supply of high-quality drinking water through the creation of taste and odor problems and formation of trihalomethanes (THM). Although the mechanisms of Delta blooms are not well known, they appear to result from the interaction of variable river flow, diversions, and nutrient loading from wastewater treatment plants and agricultural drainage[17]. Our poor understanding of how flow, diversion, and nutrient inputs interact to control algal blooms is a limitation to the efforts at Delta-habitat restoration. Without this knowledge, restoration actions that change the physical structure or flow regime of the Delta can have unforeseen consequences, such as establishment of transport paths that would lead to the reoccurrence of the harmful blooms that occurred in the southern Delta in the 1970's. We propose two different approaches to provide tools for understanding blooms and predicting the impacts of actions that would change nutrient inputs, flow paths, or habitat distributions. The first (statistical) approach uses historical data to identify the main mechanisms of variability in phytoplankton abundance; the second (numerical) approach uses a computer model to describe the connections between transport, algal growth, and nutrient cycling.

A. Use Historic Water-Quality Data to Build a Statistical Model of Phytoplankton Blooms (UCD): We propose to use the extensive IEP dataset to (1) identify the patterns and causes of bloom formation in the Delta; (2) develop a statistical model relating bloom magnitude to hydrologic, nutrient and biotic factors; and (3) use the model to examine a range of flow scenarios that would accompany different restoration strategies. The datasets include Dayflow; IEP compliance monitoring of phytoplankton, nutrients, physical variables and benthos; and the IEP *Neomysis*-zooplankton data. The approach to data analysis[19] identifies the main processes responsible for year-to-year variability of phytoplankton, such as outflow, diversion and/or nitrogen loading, and quantifies the relative importance of each process. This information is then used in specifying a descriptive model. The analysis provides a predictive statistical model for describing how changes in, for example, diversions, flow patterns and nitrogen loading will affect phytoplankton blooms and therefore drinking water quality for people and food availability for higher trophic levels.

B. Develop a Numerical Model of Transport and Nutrient-Phytoplankton Dynamics in the Delta (Stanford, USGS): As a complementary approach, we propose to develop a hydrodynamic/phytoplankton/nutrient model to explain how potential changes in Delta geometry, nutrient loadings, or flows will affect blooms. The basic "chassis" of the model is TRIM2D, a depth-averaged, two dimensional circulation model[8], which gives accurate descriptions of tidal currents, water level variations, and transport patterns in South San Francisco Bay[14]. To apply TRIM2D to the Delta and Suisun Bay, we will grid the region extending from the Golden Gate to the Sacramento River and the San Joaquin River, including Montezuma Slough and the pumping plants in Tracy. Steps of model calibration will include comparisons with flow and depth measurements made by the USGS in the Delta[26].

The hydrodynamic model by itself can be used to predict changes in salinity intrusion and transport patterns that will result from physical modifications to the Delta or changes in operational strategies. Because of the direct coupling to physical (transport) processes, our effort will focus on the bottom of the foodweb: First, given distributions of the constituents measured in Tasks 1 and 2, we will use model-derived flowfields to calculate the fluxes of these food-resource indicators from the Delta to Suisun Bay and the pumps, and determine the flow paths that these materials follow. Clear identification of transport paths is essential for development of operational strategies involving channel closures or modifications. Secondly, we will develop a biogeochemical model to be run in parallel with TRIM2D for describing coupled processes of nutrient uptake and recycling, bloom development, and primary production. This model will include transport equations to describe the biomass variability of phytoplankton, the concentrations of dissolved nitrogen and phosphorus, and dissolved oxygen. The required parameters of phytoplankton growth and photosynthesis will be measured in Task 2B of the sampling program. A simple version of this model has been used with TRIM2D for modeling phytoplankton blooms in South San Francisco Bay[22].

The main results from coupling the nutrient-phytoplankton model to a spatially-detailed hydrodynamic model are: (1) A prediction of the spatial structure of primary production in the Delta, at scales that are impossible to measure (i.e. identify regions and habitat-types of the Delta that are especially productive). (2) An estimate of how the transport into Suisun Bay of organic carbon produced in the Delta depends on hydrodynamic conditions, both historical ones and those resulting from actions proposed as part of the CALFED restoration program. (3) An assessment of the effect of increased shallow water habitat on system primary production; (4) A tool for quantifying the role of nutrient deliveries in regulating the development of blooms and production of high-quality POM required by secondary producers.

Task #5 Synthesis

Results of the measurement/modeling projects will be synthesized in a report to CALFED agencies that provides a comprehensive assessment of the ecosystem functions that support secondary production in the Delta, with commentary about how specific restoration actions will influence those functions. This synthesis will: (1) Compare the quantity/quality of the food resource for secondary producers among the different habitat-types of the Delta, including **tidal marsh, tidal river channel, seasonal wetland**, and **shallow-water habitats**. (2) Identify seasons and habitats where (if) secondary production is limited by the food resource, and determine which habitat types sustain secondary production at higher rates than others. (3) Compare the important sources of food that fuel secondary production in the Delta. (4) Determine the fate of the food resource delivered to and produced within the Delta (i.e., determine the percentages assimilated by animals, lost to exports, and transported to San Francisco Bay). (5) Identify the mechanisms of algal-bloom development in the Delta, with explanation of how those mechanisms would be influenced by specific restoration actions. And (6) identify the biogeochemical role of the Delta as an ecosystem that assimilates nutrients and transforms them into plant and animal biomass.

MONITORING AND DATA EVALUATION

Data and model analyses and interpretations will be subjected to the rigorous peer-review required for publication in international scientific journals, such as those listed below.

IMPLEMENTABILITY

This project will utilize laboratory and computing facilities and logistical support provided by the USGS in Menlo Park (including ship operations), the Division of Environmental Studies at UC-Davis, the Virginia Institute of Marine Sciences, and the Department of Civil Engineering at Stanford University. Sampling will be coordinated with the IEP compliance (D1485) monitoring (see attached letter of support from DWR in the Appendix). The new measurements proposed here will complement the ongoing measurement program in the Bay-Delta supported by the USGS Toxic Substances Hydrology Program and the IEP Contaminants Work Team. Model development will build upon numerical models supported by grants to Stanford University from the U.S. National Science Foundation. The zooplankton growth assays will follow protocols being implemented at UC-Davis with grant support from the National Science Foundation.

Budget Costs

This project includes new measurements, analyses, and model-development that will build from a history of collaboration between USGS, UC-Davis, VIMS, and Stanford University. The USGS request includes salary support for a postdoctoral associate who will take responsibility for Tasks 1A, 1C, and 2A. The UC-Davis budget includes half-time salary for a postdoctoral associate and half-time support for a technician to complete Task 1D, and five months support/year for A. Jassby to complete tasks 3 and 4A. The VIMS request includes half-time salary for a laboratory specialist and half-time support for a graduate student who will use results from Tasks 1B and 2A as the basis for a doctoral thesis. The Stanford University budget includes salary support for a postdoctoral associate, who will develop the submodel of coupled phytoplankton-nutrient dynamics, and a graduate student who will include these dynamics into the TRIM2D hydrodynamic model as applied to the Delta; this task will also be the basis for a doctoral dissertation. Budget summaries, by year and institution are shown here (itemized budgets for each institution are included in the Appendix):

Institution	Principal Investigators	Tasks	1998	1999	2000
U.S. Geological Survey	J. Cloern B. Cole	1A, 1C, 2A, 2B, 4B, 5	149,725	167,142	153,344
Virginia Institute of Marine Science	E. Canuel	1B, 2A, 5	69,772	87,020	75,775
Stanford University	S. Monismith J. Koseff	4B, 5	155,359	117,029	40,733
University of California-Davis	A. Jassby M. Brett D. Müller-Navarra	1D, 2A, 3, 4A, 5	142,552	118,567	123,575
TOTAL			517,408	489,758	393,427

Cost-Sharing: Logistical support for the field components of this project will be provided by USGS; this includes 40 days of shipboard sampling from the R/V Polaris and a 28' shallow-draft boat. We request from CALFED 25% of the costs for ship/boat operations; the remaining 75% will be supported by the USGS Water Resources Division-National Research Program and the Toxic Substances Hydrology Program. The USGS will also contribute supplies plus two months/year salary support for J. Cloern, B. Cole, J. Edmunds, and six months/year for a hydrologic technician and a field technician. The yearly contributions from USGS are:

1998	1999	2000
243,483	283,262	220,082

The new tasks proposed here will be integrated with: an NSF-funded study of the nutritional ecology of freshwater zooplankton (Brett and Müller-Navarra); NSF-funded program of hydrodynamic-ecological model development in estuaries (Monismith and Koseff); the IEP compliance monitoring program; and (if funded) a USGS proposal to CALFED to assess mercury contamination in the Bay-Delta.

Schedule Milestones (by year and quarter):

We propose a start date of January 1998, with completion of Tasks 1-4 by December 2000. The following table shows the timelines for each task. In April of 1999 and 2000, the project coordinator will submit to CALFED agencies a report summarizing the progress and results from the previous year. By April 2001, the coordinator will submit a final report to CALFED with a comprehensive assessment of Delta habitats that support secondary production; definitive statements on the role of food-limitation as a stressor; and recommendations about specific restoration actions that can be taken to remediate this stressor if it impacts fish recruitment. Individual investigators will also give progress reports at annual meetings of the IEP, Bay-Modeling Forum, the State-of-the-Estuary Conference, and other public meetings relevant to the status of the Bay-Delta Ecosystem.

Task	Description	98-1	98-2	98-3	98-4	99-1	99-2	99-3	99-4	00-1	00-2	00-3	00-4
1A-1D	Methods Development	X	X										
1A-1D	Field Sampling (Number of Ship Days)		X 5	X 5	X 5	X 5	X 5	X 5	X 5	X 5			
1A-1D	Laboratory Analyses				X	X	X	X	X	X	X	X	
2A	Measure River Inputs		X	X	X	X	X	X	X	X	X		
1, 2	Data Analysis, Synthesis					X	X	X	X	X	X	X	X
2B	Measure Primary Productivity		X	X	X	X	X	X	X	X	X		
3	Construct Budgets of Food Sources, Sinks									X	X	X	X
4A	Statistical Model of Delta Algal Blooms	X	X	X	X	X	X	X	X	X	X	X	X
4B	Develop Coupled Model of Transport and Nutrient-Phytoplankton Dynamics	X	X	X	X	X	X	X	X				
4B	Numerical Experiments with the Nutrient-Phytoplankton Model				X	X	X	X	X	X	X		
5	Synthesis - Annual Progress Reports					X				X			
5	Synthesis - Journal Articles									X	X	X	X

This project is designed to answer two critical questions for restoring the Bay-Delta ecosystem: Is secondary production limited by the food resource in the Delta? And, how can specific restoration actions provide ecosystem benefits by enhancing the food supply that fuels secondary production? These are complex questions that require consideration of hydrodynamic processes, organic geochemistry, phytoplankton dynamics, and nutritional ecology of secondary producers. These areas of expertise are included in the team of university and agency investigators that will work together on this project. The team has a record of successful collaborations, and it includes members who have been working on critical Bay-Delta issues for over twenty years. Each member has recent experience directly relevant to the tasks included in the project:

James Cloern is a biologist with the U.S. Geological Survey in Menlo Park who will coordinate the overall project, supervise Tasks 1A, 1C, 2A, and 5, and contribute to Tasks 3 and 4. Dr. Cloern received an M.S. in zoology from the University of Wisconsin in 1973 and Ph.D. in zoology from Washington State University in 1976. He has directed a team-study of the ecology of San Francisco Bay for over twenty years, with emphasis on plankton ecology. He has served on numerous science-advisory panels to regulatory/management programs, including the IEP, Florida Bay Program, and Bay of Brest (France) Restoration Program. He received a Fulbright Research Fellowship to support a sabbatical year at the Centre d'Océanologie de Marseille, was Distinguished Visiting Scientist at the National Institute of Water and Atmospheric Research of New Zealand, received the U.S. Department of Interior Award for Meritorious Service, and served as member of the editorial board of the journals *Limnology and Oceanography* and *Estuaries*.

Michael Brett and Dörthe Müller-Navarra are Research Associates in the Division of Environmental Studies, University of California-Davis, who will share responsibility for Task 1D. Dr. Brett received a Ph.D. in Limnology from Uppsala University (Sweden) in 1990 and M.Sc. in zoology from the University of Maine in 1985. He received a Fulbright Graduate Student Fellowship, and has expertise in foodweb structure and linkages between primary and secondary production in freshwater systems. Dr. Müller-Navarra received a Ph.D. from Christian-Albrechts University (Germany) in 1993 for work at the Max-Planck Institute für Limnolgie, and then completed fellowships at Scripps Institute of Oceanography and the Oceanographic Laboratory of Biochemistry and Ecology at Villefranche (France). Her expertise is in the study of food quality and food-limitation of zooplankton, with focus on the importance of essential fatty acids.

Brian Cole is an oceanographer with the USGS who will assume primary responsibility for Task 2B. Brian received an M.A. in biology from California State University-Humboldt in 1974, and has worked as a member of the USGS San Francisco Bay program since 1975. He has expertise in plankton ecology, with experience measuring primary productivity in lakes, tidal rivers, estuaries, and Antarctic coastal waters. He has done the definitive study of primary production in San Francisco Bay and Tomales Bay, and has advised IEP staff on techniques for measurement of production.

Elizabeth Canuel is Assistant Professor in the School of Marine Science of the College of William & Mary. She will direct work to complete Tasks 1B and 2A. Dr. Canuel received a Ph.D. in Marine Sciences from the University of North Carolina in 1992, and then worked for two years as National Research Council Postdoctoral Fellow at the USGS in Menlo Park. Her expertise is marine organic geochemistry, with special interest in use of lipid biomarkers to identify the source and quality of organic matter in estuaries. Her Postdoctoral Fellowship was used to conduct the first application of these biomarker tools in San Francisco Bay. In 1995 she was awarded a

National Science Foundation CAREER grant.

Alan Jassby is a Professional Research Ecologist in the Division of Environmental Studies, University of California-Davis. He will direct work to complete Tasks 3 and 4A. Dr. Jassby received a Ph.D. in ecology from the University of California-Davis in 1973, and B.S. in mathematics from the Massachusetts Institute of Technology in 1969. His areas of expertise are limnology; estuarine ecology; water quality; lake and reservoir restoration and management; statistical analysis and modeling. Dr. Jassby is a member of the IEP Science Advisory Group, and recipient of the Hugo B. Fischer Award of the Bay-Delta Modeling Forum for his innovative approaches to identify linkages between salinity variation and recruitment of biota in the Delta-Suisun Bay.

Jeffrey Koseff is Professor and Chair and Stephen Monismith is Associate Professor in the Department of Civil Engineering, Stanford University. They will jointly supervise model development and applications of Task 4B. Dr. Koseff received a Ph.D. in civil engineering from Stanford University in 1983, and M.S. in civil engineering from Stanford University in 1978. His expertise is in the dynamics of estuarine systems, including turbulence in stratified environments, numerical techniques for simulating estuarine and geophysical flows, and the hydrodynamics of benthic grazing by bivalve feeders. Dr. Koseff received the Robert T. Knapp Award of the American Society of Mechanical Engineers in 1985, and was Gledden Visiting Senior Fellow, University of Western Australia, in 1991. Dr. Monismith received a Ph.D. in civil engineering from the University of California-Berkeley in 1983, and M.S. in civil engineering from the University of California-Berkeley in 1979. His research interests include the behavior of turbulence in stratified fluids, flows and turbulence under wind waves, field and modelling studies of mixing and circulation in estuaries, and hydrodynamic processes in marine ecology. Stephen was Postdoctoral Research Fellow at the Centre for Water Research, University of Western Australia from 1983-86, and given the prestigious NSF award as Presidential Young Investigator in 1989. He is a member of the Bay Delta Modeling Forum steering committee, IEP Science Advisory Committee, and Technical Advisory Committee of the San Francisco Estuary Project.

We list here a selected set of recent publications from this team that are relevant to the proposed project:

Alpine, A.E., and Cloern, J.E., 1992, Trophic interactions and direct physical effects control phytoplankton biomass and production in an estuary: Limnology and Oceanography, v. 37, p. 946-955.

Brett, M.T., and C.R. Goldman. 1996. A meta-analysis of the freshwater trophic cascade. Proceedings of the National Academy of Sciences, USA 93: 7723-7726.

Brett, M.T., and D.C. Müller-Navarra. 1997. The role of essential fatty acids in aquatic food web processes. Freshwater Biology (in press).

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Cloern, J.E., 1996. Phytoplankton bloom dynamics in coastal ecosystems: A review with some general lessons from sustained investigation of San Francisco Bay, California: Reviews of Geophysics, Vol. 34 , No. 2 , p. 127-168.
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Jassby, A.D., J. Koseff, and S. Monismith. 1996 Processes underlying phytoplankton variability in San Francisco Bay. In: San Francisco Bay: the ecosystem, edited by J.T. Hollibaugh, p. 325-350, Pacific Division, American Association for the Advancement of Science, San Francisco, California.
Koseff, J.R., Holen, J.K., Monismith, S.G., and Cloern, J.E. 1993. The effects of vertical mixing and benthic grazing on phytoplankton populations in shallow turbid estuaries," J. Marine Res. 51:1-26
Monismith, S.G., Burau, J. and M. Stacey. 1996. Stratification Dynamics and Gravitational Circulation in Northern San Francisco Bay. In San Francisco Bay: The Ecosystem, ed. T. Hollibaugh, pp. 123-153, AAAS.
Monismith, S.G. and D.A. Fong. 1996. A simple model of mixing in stratified tidal flows. J. Geophys. Res. (Oceans) 101, pp. 28583-28597.
Müller-Navarra, D.C. 1995. Evidence that a highly unsaturated fatty acid limits Daphnia growth in nature. Arch. Hydrobiol. 132: 297-307.
Müller-Navarra, D.C. 1995. Biochemical versus mineral limitation in Daphnia. Limnology and Oceanography 40: 1209-1214.
Müller-Navarra, D.C. and W. Lampert 1996. Seasonal changes in seston food quality for Daphnia galeata. Journal of Plankton Research 18: 1137-1157.
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I-000334

Appendix

- List of References cited in the proposal

- TABLE 1. Sampling Sites for Assessment of the Quantity, Quality, and Sources of Food for Secondary Producers in the Delta

- TABLE 2. Target Conditions of Variable External (River Input) and Internal (Primary Production) Sources and Losses of Organic Matter to the Delta

- Letter of support from the Manager, Branch of Environmental Monitoring and Analysis, California Department of Water Resources

- Itemized Budgets by Institution

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I-000337

TABLE 1. Sampling Sites for Assessment of the Quantity, Quality, and Sources of Food for Secondary Producers in the Delta

Site	Location (IEP station)	Habitat Type	Presumed Sources of Organic Matter	Target Conditions	Other Programs
①	Grizzly Bay (D7)	shoal and tidal mudflat	benthic microalgae, phytoplankton, marsh and riverine inputs	range of flows; high and low microalgal biomass	IEP, USGS
②	X2 (D4, D10, D8, or D6)	estuarine turbidity maximum	inputs from shoals, marshes, rivers	range of flows and geographic locations	IEP, USGS, HG
③	Montezuma Slough	tidal marsh	marsh vegetation, river inputs, phytoplankton	range of flows and seasonal growth cycles of marsh vegetation	IEP, HG
④	Sacramento River at Rio Vista (D24)	tidal river channel; inputs from the Sacramento River	terrigenous, riverine algae and vascular plants, treated sewage	range of flows and seasonal growth cycles of phytoplankton	IEP, USGS, HG
⑤	Yolo Bypass	seasonal agricultural wetland	terrigenous, agricultural, riverine algae and vascular plants	sampling when the bypass is flooded (high flow)	IEP, HG
⑥	Central Delta, Middle River (D28A)	tidal freshwater channel	phytoplankton, river inputs, vascular plants	range of flow conditions (including reversals) and seasonal cycles of phytoplankton	IEP, HB
⑦	Central Delta, Old River	tidal freshwater channel	phytoplankton, river inputs, vascular plants	range of flow conditions (including reversals) and seasonal cycles of phytoplankton	IEP, HB, HG
⑧	Intake to Clifton Ct. Forebay (C9)	South Delta, site of export losses	phytoplankton, river inputs, vascular plants	annual cycles of pumping and phytoplankton growth	IEP
⑨	Paradise Cut	shallow freshwater habitat, long residence time	phytoplankton, agricultural	seasonal growth cycles of phytoplankton	HB
⑩	San Joaquin River Vernalis (C10)	tidal river channel; inputs from the San Joaquin River	terrigenous, riverine algae and vascular plants	range of flows and seasonal growth cycles of phytoplankton	IEP

IEP = Interagency Ecological Program (including D1485 compliance monitoring); USGS = U.S. Geological Survey, Menlo Park or Sacramento; HB = USGS special study of herbicide concentrations/effects supported by the IEP Contaminants Work Team; HG = proposed USGS assessment of mercury contamination and cycling (proposal to CALFED)

TABLE 2. Target Conditions of Variable External (River Input) and Internal (Primary Production) Sources and Losses of Organic Matter to the Delta

Condition	Target Months	Inflow	Exports	Outflow	Yolo Bypass	Primary Production
small inputs, losses, and primary production (baseline)	Oct-Nov	low	low	low	dry	low
pulse inputs of river flow (response to first flush)	Dec-Feb	high	low	high	dry	low
large flood (external sources dominant)	Dec-Feb	very high	low	very high	flooded	low
declining inputs, small losses, increasing primary production during spring blooms (internal sources becoming dominant)	Apr-May	moderate	low	moderate	dry	high
small inputs, large exports, high primary production of mid-summer (internal sources dominant, but increasing losses to export)	June-July	low	high	low	dry	high
small inputs, large exports, high primary production of late-summer (internal sources dominant, but maximum losses to export)	Aug-Sept	low	high	low	dry	high

STATE OF CALIFORNIA—THE RESOURCES AGENCY PETE WILSON, Governor

DEPARTMENT OF WATER RESOURCES
ENVIRONMENTAL SERVICES OFFICE
3251 S STREET
SACRAMENTO CA 95816-7017

July 17, 1997

Dr. Jim Cloern
U.S. Geological Service, MS496
345 Middlefield Road
Menlo Park, California 94025

Dear Dr. Cloern:

Measurement of Primary Productivity in the Delta

I have reviewed your proposed scope of work regarding the identification of important sources of food that fuel secondary production in the Delta. Our office recognizes the need for measurements of primary productivity in the Delta and agrees that a relatively simple model for estimating primary productivity from routine IEP measurements of chlorophyll and turbidity would be valuable. We are therefore willing to participate in your study. Specifically, we will work with you to provide space on the San Carlos during selected dates of D-1485 monitoring in the Delta during 1998 and 1999.

Please call me at (916) 227-7548 if you have any questions.

Sincerely,

Stephen P. Hayes
for L.W.

Leo Winternitz, Branch Manager
Environmental Monitoring and
Analysis Branch

Itemized Budgets by Institution

USGS Contribution

USGS, Tasks 1A, 1C, 2A, 2B, 4B, 5	1998	1999	2000	TOTAL
Salary+Benefits:				
J. Cloern (2mo/yr)	$19,958	$20,557	$21,174	$61,689
B. Cole (2mo/yr)	$13,622	$14,031	$14,452	$42,105
J. Edmunds (2mo/yr)	$7,548	$7,774	$8,007	$23,329
Hydrologic Technician (6mo/yr)	$21,912	$22,570	$23,247	$67,729
Laboratory technician (6mo/yr)	$21,912	$22,570	$23,247	$67,729
TOTAL Salary+Benefits	$84,952	$87,502	$90,127	$262,581
Supplies	$7,000	$8,000	$9,000	$24,000
Ship Operations (75% of $6K/day), prorated from annual cost	$67,500	$90,000	$45,000	$202,500
TOTAL Direct Costs	$159,452	$185,502	$144,127	$489,081
Indirect Costs (52.7%)	$84,031	$97,760	$75,955	$257,746
TOTAL REQUEST	$243,483	$283,262	$220,082	$746,827

Request to CALFED

USGS, Tasks 1A, 1C, 2A, 2B, 4B, 5	1998	1999	2000	TOTAL
Salary+Benefits:				
J. Cloern (2mo/yr)	NC	NC	NC	NC
B. Cole (2mo/yr)	NC	NC	NC	NC
J. Edmunds (2mo/yr)	NC	NC	NC	NC
Postdoctoral Associate (12mo/yr)	$63,552	$65,458	$67,422	$196,432
TOTAL Salary+Benefits	$63,552	$65,458	$67,422	$196,432
Supplies	$7,000	$8,000	$9,000	$24,000
Travel	$5,000	$6,000	$7,000	$18,000
Ship Operations (25% of $6K/day)	$22,500	$30,000	$15,000	$67,500
Publication Costs			$2,000	$2,000
TOTAL Direct Costs	$98,052	$109,458	$100,422	$307,932
Indirect Costs (52.7%)	$51,673	$57,684	$52,922	$162,280
TOTAL REQUEST	$149,725	$167,142	$153,344	$470,212

Virginia Inst. Marine Sci., Task 1B, 2A, 5	1998	1999	2000	TOTAL
Salary+Benefits:				
E. Canuel (1 mo/yr)	$4,633	$4,865	$5,108	$14,606
Lab Specialist (6 mo/yr)	$13,000	$13,650	$14,333	$40,983
Grad. Res. Asst. (6 or 12 mo/yr)	$7,000	$14,700	$15,435	$37,135
Fringe	$4,761	$4,999	$5,249	$15,009
TOTAL Salary+Benefits	$29,394	$38,214	$40,125	$107,733
Supplies	$6,000	$6,000	$3,500	$15,500
Travel	$3,000	$4,000	$3,700	$10,700
Publication Costs			$1,000	$1,000
Tuition	$2,500	$5,000	$5,000	$12,500
Other (equip. maint.; shipping; subcontract isotopes)	$11,800	$11,800	$800	$24,400
TOTAL Direct Costs	$42,694	$55,014	$54,125	$151,833
Indirect Costs (40%)	$17,078	$22,006	$21,650	$60,733
TOTAL REQUEST	$69,772	$87,020	$75,775	$232,566

Stanford University, Tasks 4B, 5	1998	1999	2000	TOTAL
Salary+Benefits:				
S. Monismith (1 mo/yr)	$8,437	$8,690	$8,951	$26,078
J. Koseff (0.5 mo/yr)	$5,243	$5,400	$5,562	$16,205
Graduate student (50%RA years 1 and 2)	$19,302	$19,881		$39,183
Postdoctoral Assoc. (18 months)	$41,200	$21,218		$62,418
Fringe benefits	$13,994	$9,004	$3,701	$26,699
Total salaries	$88,176	$64,193	$18,214	$170,583
Tuition (IST year, TGR years 2 and 3)	$7,759	$3,460	$0	$11,219
Travel	$2,000	$2,000	$2,000	$6,000
Publication Costs		$2,500	$2,500	$5,000
Computer Maintenance	$3,000	$3,000	$3,000	$9,000
TOTAL Direct Costs	$100,935	$75,153	$25,714	$201,802
Indirect Costs (58.41%)	$54,424	$41,876	$15,019	$111,319
TOTAL REQUEST	$155,359	$117,029	$40,733	$313,121

UC Davis, Tasks 1D, 2A, 3, 4A, 5	1998	1999	2000	TOTAL
Salary+Benefits:				
A. Jassby(5mo/yr)	$25,125	$26,381	$27,700	$79,206
M. Brett (1 mo/yr)	$5,631	$5,913	$6,208	$17,752
D. Muller-Navarra (6 mo/yr)	$19,264	$20,227	$21,239	$60,730
Technician (6 mo/yr)	$13,986	$14,686	$15,420	$44,091
Total Salary	$64,006	$67,207	$70,567	$201,779
fringe (19%)	$12,161	$12,769	$13,408	$38,338
TOTAL Salary+Benefits	$76,167	$79,976	$83,974	$240,117
Supplies	$12,000	$9,000	$7,000	$28,000
Travel	$5,500	$5,500	$5,500	$16,500
Publication Costs			$2,500	$2,500
Equipment (freezer, freeze drier, pumps, PC)	$25,000			$25,000
TOTAL Direct Costs	$118,667	$94,476	$98,974	$312,117
Indirect Costs (25.5%, except equipment)	$23,885	$24,091	$24,601	$72,577
TOTAL REQUEST	$142,552	$118,567	$123,575	$384,694

Item 8

NONDISCRIMINATION COMPLIANCE STATEMENT

COMPANY NAME

United States Geological Survey

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

CERTIFICATION

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

James E. Cloern

OFFICIAL'S NAME

22 July 1997

DATE EXECUTED

EXECUTED IN THE COUNTY OF San Mateo

PROSPECTIVE CONTRACTOR'S SIGNATURE

Physical Scientist

PROSPECTIVE CONTRACTOR'S TITLE

United States Geological Survey

PROSPECTIVE CONTRACTOR'S LEGAL BUSINESS NAME