

## I. EXECUTIVE SUMMARY

DWR WAREHOUSE

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### a. Project Title and Applicants

Exposure of Green Sturgeon and Migratory Ducks to a Complex Mixture of Contaminants Through a Diet of Nonindigenous Clams

Dr. Kathryn M. Kuivila, Dr. Samuel N. Luoma, Janet K. Thompson, Dr. A. Keith Miles, Dr. John Y. Takekawa, and Jon R. Burau, U.S. Geological Survey

### b. Project Description and Primary Biological/Ecological Objectives

Green sturgeon and migratory ducks are two species of concern in San Francisco Bay Estuary. This study proposes to investigate the exposure of green sturgeon and diving ducks to contaminants in nonindigenous clams, and the resulting nutritive importance and energetic value of the clams as food for sturgeons and ducks. The pervasively dominant bivalves in the Delta and Suisun Bay are two nonindigenous clams, *Potamocorbula amurensis* and *Corbicula fluminea*. These clams are exposed to and bioaccumulate a complex mixture of organics and trace metals. In turn, these clams are probably eaten by green sturgeon and migratory ducks. Little is known about the actual concentrations of contaminants, especially pesticides, in these clams in the estuary.

Water quality and monitoring are of importance for CALFED. This proposed study will also evaluate the use of *Potamocorbula* and *Corbicula* as biosentinels for monitoring water quality in the estuary and subsequent effects up the food web. The variety and complexity of the pesticide and trace metal inputs to the estuary makes discrete sampling for widespread water quality evaluation logistically insurmountable. The use of biosentinels as integrative samplers of select compounds of interest simplifies the task of monitoring water quality and is a relatively direct assessment of complexities like bioavailability.

### c. Approach/Tasks/Schedule

The approach of this proposed study is to measure the concentrations of organics and trace metals in the tissues of *Potamocorbula* and *Corbicula* in the Delta and Suisun Bay over a two-year period to understand the seasonal and spatial variations. Aerial and benthic surveys, and feeding experiments will be used to evaluate the dietary importance and nutritive value of *Potamocorbula* and *Corbicula* to diving ducks and sturgeon. In addition, this multi-discipline study will use these two clams to demonstrate the use of biosentinel species as a monitoring tool for the complex mixture of contaminants present in the estuary.

The tasks include : 1) sampling clams and analyzing for organics, trace metals, condition, population growth dynamics, and reproductive state; 2) determining the dietary importance and nutritive value of these clams to migratory ducks and sturgeon; 3) creating a conceptual model of hydrodynamics in Suisun Bay as a framework for interpreting contaminant concentrations. The first two years will

include temporal and synoptic benthic sampling for contaminants, aerial and benthic surveys, feeding experiments with diving ducks, and deployment of instrumentation for the hydrodynamic study. The third year will also include modelling the bioaccumulation of contaminants in the ducks and sturgeon, creating the hydrodynamic model of Suisun Bay, and completing a writeup of the results.

**d. Justification for Project and Funding by CALFED**

This proposed study will provide information to help CALFED address their objectives of providing good water quality and improving the quality of aquatic habitats for species of concern. This study addresses the potential exposure of green sturgeon and diving ducks to a complex mixture of contaminants through a diet of nonindigenous clams. This information can be used by resource managers and CALFED to pinpoint contaminants of concern. This proposal also evaluates the use of biosentinel species as a tool to monitor water quality in the estuary.

**e. Budget Costs and Third Party Impacts**

CALFED Funding Request is for \$ 1,272,000 (54% of total cost) over a 3-year period and a partnership with the USGS is for \$ 1,086,000 (46% of total cost) over the 3-year period. The total cost is \$ 2,358,000 over the 3-year period.

**f. Applicant Qualifications**

The six applicants are all well-known experts within their individual fields, with a collective experience in studying contaminants, benthos, and waterfowl that is unique, yet they work well as a team in interdisciplinary studies such as this one. All of the applicants have been actively working in San Francisco Bay for more than seven years, some for decades, with extensive interactions with resource managers and regulators in the Bay Area and have all contributed substantially to the current understanding of the sources, transport, and potential effects of contaminants on aquatic life in the San Francisco Bay Estuary.

**g. Monitoring and Data Evaluation**

Data collected by this project can be used to evaluate water quality in the Delta and Suisun Bay.

**h. Local Support/Coordination with other Programs/Compatibility with CALFED objectives**

The project will coordinate with on-going projects funded by the Interagency Ecological Program, the Regional Monitoring Program, Central Valley and San Francisco Regional Water Quality Control Boards, U.S. Fish and Wildlife Service, California Department of Water Resources, local hunting clubs, and with proposals to CALFED, especially the proposed assessment of selenium contamination by Luoma et al.

## II. TITLE PAGE

**a) Title of Project:**

**Exposure of Green Sturgeon and Migratory Ducks to a Complex Mixture of Contaminants Through a Diet of Nonindigenous Clams**

**b) Principle investigators: (\* principle contact person)**

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**c) Type of Organization: Federal agency**

**d) Tax identification number: 53-0196958**

**e) Technical and financial contact person: Same as above**

**f) Participants/Collaborators in Implementation : No others**

**g) RFP project group type: Other services**

### III. PROJECT DESCRIPTION

#### a. Project Description and Approach

##### 1) Introduction

The pervasively dominant bivalves in the Delta and Suisun Bay are two nonindigenous clams, *Corbicula fluminea* and *Potamocorbula amurensis*. These clams are subjected to a complex mixture of contaminants, including organics and trace metals, which varies seasonally (Luoma and others, 1990; Brown and Luoma, 1995). Although individual contaminants have been studied, little is known about the simultaneous bioaccumulation of the complex mixture of contaminants in these clams, and the resulting exposure of two species of concern, green sturgeon and migratory ducks, which eat the clams. Published studies (Luoma and others, 1990; Brown and Luoma, 1995) have measured the bioaccumulation of trace metals in *Corbicula* and more recently *Potamocorbula* in Suisun Bay. Very little data is available on the concentrations of organics, especially pesticides, in *Corbicula* and *Potamocorbula* in the estuary. Pereira and others (1996) measured PAHs and pesticides, primarily organochlorines, in *Corbicula* in the San Joaquin River in 1992.

The relationship of nonindigenous invertebrates to migratory waterbirds or fishes in the San Francisco Bay Delta has not been assessed. Populations of *Potamocorbula* have grown exponentially in the estuarine waters of San Francisco Bay (Nichols and others, 1990). Similarly, the invasive freshwater clam, *Corbicula*, is now common in the fresher waters of the Delta. Researchers have suggested that the clam *Macoma* which has been an important dietary component for wintering diving ducks inhabiting San Francisco Bay, is being displaced by *Potamocorbula*, and that *Potamocorbula* may be affecting change in the Bay's ecosystems (Nichols and others, 1990; Alpine and Cloern, 1992; Kimmerer and others, 1994). Yet, little is known about the importance or potential detriment of *Potamocorbula* or *Corbicula* as a food for ducks or fishes. Other studies have shown higher concentrations of elemental contaminants in *Potamocorbula* than *Macoma* (Brown and Luoma, 1995). *Potamocorbula* and *Corbicula* may not yield proportionately the same caloric value as *Macoma*. If so, diving ducks and green sturgeon may be consuming greater volumes of these nonindigenous clams, and consequently being exposed to higher intakes of contaminants. Moreover, the energetic costs to these species of concern could be compromised by lower caloric value and greater contaminant burdens of *Potamocorbula* and *Corbicula*.

In the Central Valley, hundreds of pesticides are applied annually, in quantities of up to 6.6 million pounds for a single compound (California Department of Pesticide Regulation, 1994). The magnitude of the pesticide applications and the variability of input to the estuary result in a highly-complex pattern of pesticide concentrations over space and time. The USGS and other agencies have had some success in studying the input and transport of pesticides applied at very specific times of the year to specific crops, such as dormant spray pesticides applied to orchards in the winter (Kuivila and Foe, 1995) and pesticides applied to rice fields in the spring (Domagalski and Kuivila, 1991; Crepeau and others, 1996). However, there remain many pesticides applied in significant amounts

which are not so easily studied. In turn, the potential effects of these pesticides cannot be determined if the concentrations and exposure time are unknown. The use of biosentinel organisms for monitoring is a tool for looking at bioavailable concentrations of the complete mixture of bioaccumulative contaminants, integrated over time.

## 2) Project Objectives

The first major objective of this focused research is to determine the potential exposure of green sturgeon and migratory diving ducks to organics and trace metals through a diet of nonindigenous clams (*Potamocorbula* and *Corbicula*). The spatial and temporal variability of concentrations of organics and trace metals in the tissues of *Potamocorbula* and *Corbicula* will be determined in the Delta and Suisun Bay. The study will identify seasons and/or hydrologic conditions when predators are most and least exposed, via their food, to the complex suite of contaminants that enter the Bay-Delta, with the goal of aiding development of restoration strategies that minimize the predators' exposure to such contaminants. In addition, both the importance of these nonindigenous clams as a dietary component and their nutritive value to the energetic requirement of diving ducks and sturgeon will be determined.

The second major objective is to demonstrate the utility of using *Potamocorbula* and *Corbicula* as biosentinel species to monitor the estuary for a complex mixture of contaminants, including both organics and trace metals.

Questions we seek to answer include :

- What organics, especially pesticides, and trace metals are bioaccumulating in the clams and what is the temporal and spatial variability of these contaminant concentrations?
- Using diving ducks as a surrogate species for both migratory waterbirds and green sturgeon, what is the importance of these nonindigenous clams in the diet and how does the contaminant body burden of the clams affect their nutritive value to the energetic requirements of species of concern?
- What do the seasonal and spatial patterns of contaminant concentrations within the framework of the conceptual hydrodynamic model tell us about sources and pathways of the contaminants?

## 3) Approach

The overall approach of this proposed study is to measure the concentrations of organics and trace metals in the tissues of *Potamocorbula* and *Corbicula* in the Delta and Suisun Bay over a two-year period to understand the seasonal and spatial variations. Aerial and benthic surveys, and feeding experiments will be used to evaluate the dietary importance and nutritive value of *Potamocorbula*

and *Corbicula* to diving ducks. In addition, this study will use these two clams to demonstrate the use of biosentinel species as a monitoring tool for the complex mixture of contaminants present in the estuary.

#### *Contaminant studies*

Benthic sampling will include both temporal sampling (monthly sampling at 4 sites) and synoptic sampling. The temporal sampling will include a site at the mouth of the Sacramento River, a site at the mouth of the San Joaquin River, and two sites in Suisun Bay. Three synoptic samplings will be done at a series of ten sites in the Delta and Suisun Bay during periods of interest, such as high flow and low flow conditions.

Both organics (Kuivila) and trace metals (Luoma) will be analyzed in the tissues of *Potamocorbula* and *Corbicula*. Sampling and analytical techniques are well established for trace elements. For the organic analysis, a method will be developed to look for the wide variety of pesticides used in the Central Valley, in addition to typically-analyzed compounds such as PCBs, PAHs, and organochlorine pesticides. Conventional methods for analysis of pesticides on sediments and tissue focus on compounds more likely to be found (i.e. hydrophobic or lipophilic compounds), taking advantage of simpler sample cleanup procedures. Recent studies in the estuary (Domagalski and Kuivila, 1993; Pereira and others, 1996; Bergamaschi and others, 1997) have found elevated concentrations of some pesticides associated with sediments despite physical-chemical properties which would suggest little, if any, association with sediments.

Benthic samples will also be collected to monitor growth, condition, reproduction, and recruitment (Thompson) in *Potamocorbula* and *Corbicula*. Condition and reproductive activity are necessary in interpreting contaminant concentration in tissue, because seasonal cycles in weight loss and gain will bias these results. In addition, the reproductive cycle needs to be considered when interpreting lipophilic contaminant concentrations in tissues because reproductive tissue can have a higher percentage of lipids than the somatic tissue, so seasonal growth and release of reproductive products can change these concentrations very rapidly. Population estimates at these stations, in conjunction with population data from ongoing USGS and DWR benthic studies, will be used to estimate contaminant loads that are available to higher trophic levels in this part of the bay and delta.

To help characterize the food that is being assimilated by clams at each location, clam tissue will be analyzed for the two stable isotopes of carbon ( $^{13}\text{C}$  and  $^{12}\text{C}$ ) and nitrogen ( $^{15}\text{N}$  and  $^{14}\text{N}$ ) and for two classes of lipid compounds (sterols and fatty acids) (Canuel). Because the origin of organic matter is reflected in the isotopic ratios of carbon and nitrogen and in the lipid components, we will be able to determine the origin of assimilated carbon in the tissue (Canuel and others, 1995). This will help in interpreting the origin of the contaminants in the clam tissue as most are thought to be assimilated through the clams ingestion of the food.

Ancillary hydrodynamic data and suspended sediment concentrations will be collected in the Delta and Suisun Bay during the period of the benthic sampling. A conceptual model of hydrodynamics

and sediment transport (Burau and Schoellhamer) will be developed for Suisun Bay to provide a framework for interpreting temporal and spatial variations in contaminant concentrations in the clams. The trace metals (and possibly some pesticides) will provide additional information about the inputs, for example Cu, Cd, and Zn could signal mine drainage input whereas Ni & Vd are a signal of recent terrigenous input (Brown and Luoma, in preparation).

#### *Migratory diving duck and green sturgeon studies*

Aerial surveys will be conducted to establish specific, geographic areas of habitat use by large populations of diving ducks. Observers will record waterfowl species and numbers on audio tapes synchronized by time with Global Positioning System (GPS) coordinates from a laptop computer connected to the aircraft GPS. Data sets will be transcribed, compiled, and projected in geographic information system (GIS) maps. Benthic surveys will then be conducted in areas identified as diving duck habitats. Diving transects will be conducted to determine evidence of foraging by diving ducks. Vacuum sampling will be conducted to determine population estimates of clams in area of observed foraging and in areas with no evidence of foraging. In cooperation with local hunting, gut samples from harvested diving ducks will be collected to assess intake of nonindigenous clams.

*Potamocorbula* and *Corbicula* obtained from benthic surveys will be processed to determine caloric value. Each sample will comprise about 5 - 7 gms of soft-tissue. Samples will be dried and analyzed with bomb calorimetry to determine energy content per ash-free dry weight. Caloric value will be correlated with contaminant burdens determined in studies by Kuivila and Luoma. Energetic experiments will involve maintaining 5 - 10 different ducks on an ad libitum diet of duck conditioner and then feeding with either *Potamocorbula* or *Macoma* following a 12-hour fasting period. Three repeated measures trial will be conducted on each duck on a metabolism cage for each prey item, for a total of 30 - 60 trials. Fecal matter will be collected during the trials and 24 h after the last feeding. The excreta will be freeze dried analyzed for energy content.

An existing diving duck foraging model of cadmium uptake (Lovvorn and Gillingham 1996) will be modified to examine the mechanisms of bioaccumulation in both diving ducks and sturgeon. The model will be adapted for available prey, their distribution and abundance in Suisun Bay, foraging efficiency rates of diving ducks and sturgeon, and contaminants of interest. Captive trials of birds in pens with known densities of prey and videotape records of birds in field situations will be used to estimate foraging efficiency. Available literature on foraging behavior and energetics of sturgeon will be used in the model for green sturgeon.

#### **b) Location and/or geographic boundaries of project**

Study area encompasses the Delta and Suisun Bay as bounded by Freeport on the Sacramento River, Vernalis on the San Joaquin River, and seaward to and including Carquinez Strait. Study sites are located in the counties of Contra Costa, Sacramento, San Joaquin, and Solano.

### **c) Expected Benefits**

This proposed study will provide information to help CALFED address their objectives of providing good water quality and improving the quality of aquatic habitats for species of concern. Green sturgeon and migratory diving ducks are two species of concern identified by CALFED. This study addresses the potential exposure of green sturgeon and diving ducks to a complex mixture of contaminants through their diet of nonindigenous clams in different seasons and different hydrologic regimes. This information can be used by resource managers and CALFED to determine the appropriate course of action to decrease stressors on these species.

This proposal also evaluates the use of biosentinel species as a tool to monitor water quality in the estuary. Spatial and temporal variations in contaminant concentrations will help identify sources of contaminants. As an indirect benefit, this study may identify changes in water quality as various ecosystem restoration projects are implemented in the Delta.

### **d) Background and Biological/Technical Justification**

There is very little information available on the contaminant exposures of these two species of concern. The information provided by this study is the first step in evaluating the potential effects of contaminants on green sturgeon and migratory diving ducks. The nonindigenous clams, and thus their predators, are exposed to a complex mixture of organics and trace metals in the estuary but the actual magnitude and timing of the exposure is unknown.

Another possible approach would be modelling of contaminant concentrations. Most of the data available on pesticides in the estuary are concentrations of pesticides in water. The dissolved concentrations do not fit the pattern one would predict based on amount and timing of use and measured degradation rates often vary from literature values. The level of complexity increases greatly in trying to model the concentrations associated with sediments or bioaccumulated in clams. Published measurements of pesticides associated with suspended sediments often indicate that the pesticides are not in equilibrium between the water and sediments (Domagalski and Kuivila, 1993; Pereira and others, 1996; Bergamaschi and others, 1997).

This study will also demonstrate the utility of using *Potamocorbula* and *Corbicula* as "integrative samplers" to monitor the estuary for some bioavailable contaminants. The costs and logistics to analyze water and sediment-associated contaminants in the estuary are staggering. This biosentinel approach is not the answer for monitoring all contaminants but gives an integrated view to help pinpoint compounds, geographical areas, or times of year to do further studies. Previous studies have shown that *Potamocorbula* is responsive to changes in exposure to specific trace metals under varying salinity conditions in Suisun Bay (Brown and Luoma, 1995).

The proposed study is a new project, designed initially for three years, but will hopefully "pour the foundation" for a long-term monitoring effort. This proposal builds on information and knowledge

from past studies and a network of benthic sampling sites in Suisun Bay. The USGS Toxics program supports a baseline of metal biomonitoring stations in Suisun Bay; a proposal to CALFED by Luoma et al would expand the analytes in this baseline to selenium. The present study would expand the study to more realistic coverage of the complex hydrodynamic regime in the Bay-Delta, and thus allow coordination with physical models of the system. It will provide the first systematic biomonitoring data for shallow water habitat in the Delta; it will provide the first data on simultaneous exposure to a mixture of contaminants; it will simultaneously study contaminant bioaccumulation and biological factors that influence bioaccumulation; and for the first time it will coordinate data on contaminants in prey tissues with exposures to predators.

#### **e) Proposed Scope of Work**

The overlapping phases of this proposed project include aerial and benthic surveys, benthic sampling and analysis, diet and energetics experiments, hydrodynamic and bioaccumulation modeling, and final analysis and write-up. The sampling and surveys will begin within 30 days of the USGS receiving a signed funding agreement. Project results will be provided in the form of 1) quarterly progress reports, 2) consultations with CALFED staff and investigators, 3) presentations at meetings and conferences, 4) a final data report with an executive summary, and 5) a fact sheet interpreting the study results for resource managers.

#### **f) Monitoring and Data Evaluation**

Data collected by this project can be used to evaluate water quality in the Delta and Suisun Bay. The use of clams as biosentinels for monitoring in an integrative manner is much more cost-efficient than trying to sample often enough in time and space throughout the estuary. We envision this study as the beginning of a long-term monitoring effort of the complex mixture of contaminants in the estuary. The sampling in this study will be closely coordinated with proposed studies directed at mercury cycling (Marvin-DiPasquale et al to CALFED) and selenium effects (Luoma et al, to CALFED), expanding the mixture of contaminants USGS is proposing to assess in the Bay-Delta. The hydrodynamic and biological aspects of the present proposal will facilitate interpretation of the the Se and Hg studies. It will be highly beneficial to the CALFED goal of coordinated study and monitoring of the Bay-Delta to partner in study of all these contaminants simultaneously; these studies together can provide an unprecedented, coordinated view of the complex contaminant issues in the Bay-Delta. These coordinated studies will also continue and expand the multi-discipline cooperation and collaboration that characterize USGS studies. Project data and all written reports must be reviewed and approved by USGS technical specialists.

#### **g) Implementability**

The proposed work is implementable and technically feasible. No special permits are involved.

## IV. COSTS AND SCHEDULE

### a) Budget Costs

CALFED funding is being requested because this project will provide information to help CALFED address their objectives of providing good water quality and improving the quality of aquatic habitats for species of concern (green sturgeon and migratory ducks). The CALFED funding request is for \$ 1,272,000 (54% of total cost) over a 3-year period in partnership with the USGS for \$ 1,086,000 (46%) over the 3-year period. The total cost of the projects are \$ 2,358,000 over the 3-year period. Cost breakdown by task and category is shown in Table 1.

Table 1 - Budget for Project

Task	Labor hours	Salary and Benefits	Overhead	Service Contract	Material & Acq. Contract	Misc. & Other	Total Cost
Kuivila	9,186	\$216,160	\$135,000	0	0	\$ 98,840	\$ 450,000
Luoma	6,264	\$ 84,000	\$ 62,100	0	0	\$ 33,900	\$ 180,000
Thompson (Canuel)	6,264	\$102,500	\$ 81,000	0	0	\$ 63,500	\$ 247,000
Miles & Takekawa	3,527	\$ 74,000	\$ 22,200	0	0	\$ 88,800	\$ 185,000
Burau	624	\$ 14,500	\$ 71,500	0	0	\$124,000	\$ 210,000
<b>CALFED Total</b>	<b>25,865</b>	<b>\$491,160</b>	<b>\$371,800</b>	<b>0</b>	<b>0</b>	<b>\$409,040</b>	<b>\$1,272,000</b>
<b>USGS partnership</b>	<b>6,892</b>	<b>\$207,400</b>	<b>\$374,700</b>	<b>0</b>	<b>0</b>	<b>\$503,900</b>	<b>\$1,086,000</b>

**CALFED FUNDING REQUESTED**

**= \$ 1.272 million over a 3-year period**

**USGS Partnership**  
**TOTAL PROJECT**

**= \$ 1.086 million over a 3-year period**  
**= \$ 2.358 million over a 3-year period**

## **b) Schedule Milestones**

Aerial and benthic surveys, benthic sampling, and method development for organics analysis will commence within 30 days of the USGS receiving a signed funding agreement. Sampling and analysis of the four temporal sites and deployment of hydrodynamic instrumentation will begin within 6 months. Synoptic benthic sampling and feeding and energetics experiments will commence in the second year. The third year will include finishing up the temporal benthic sampling for contaminants, modelling the bioaccumulation of contaminants in the ducks, creating the conceptual model of Suisun Bay hydrodynamics, and completing a writeup of the results.

## **c) Third Party Impacts**

We know of no third party impacts of the proposed project.

## V. Applicant Qualifications

The principle investigators for this project are Dr. Kathryn M. Kuivila, Dr. Samuel N. Luoma, Janet K. Thompson, Dr. A. Keith Miles, Dr. John Y. Takekawa, and John R. Burau of the U.S. Geological Survey. We are not aware of any potential conflicts of interest.

Dr. Kathryn M. Kuivila will be in charge of overall project coordination and will be responsible for the organic analysis of the clam tissues and interpretation of that data. Dr. Kuivila received her Ph.D. in Chemical Oceanography from the University of Washington. She is currently employed as a research hydrologist by the Water Resources Division of the U.S. Geological Survey in the California District Office in Sacramento, California. Her primary focus of research is on the transport, degradation, and fate of organic contaminants, particularly pesticides, in the San Francisco Bay Estuary. She has been studying pesticides in San Francisco Bay since 1990. Dr. Kuivila has been collaborating with the Central Valley Regional Water Quality Control Board, California State Water Quality Control Board, Interagency Ecological Program, U.S. EPA, and California Department of Fish and Game.

Dr. Samuel N. Luoma will be responsible for the trace metal analysis of the clam tissue and interpretation of that data. Dr. Luoma received his Ph.D. from the University of Hawaii in Marine Biology. He is currently employed as a senior research hydrologist by the Water Resources Division of the U.S. Geological Survey in the National Research Program in Menlo Park, California. His primary focus of research is on trace metal biogeochemistry, bioavailability and biomonitoring. Dr. Luoma has an international reputation in the scientific community and is routinely a member of committees to influence environmental regulations and policy decisions on the federal, state, and local levels. He has been working in San Francisco Bay since the late 1970's and is well respected by the state and local resource managers in the area.

Janet K. Thompson will be in charge of the benthic sampling and responsible for the growth, condition, reproduction, and recruitment measurements on the clams. Ms. Thompson received her Masters in Marine Biology from California State University at San Francisco and is currently a Ph.D. candidate in Civil Engineering at Stanford University. She is currently employed as a biologist by the Water Resources Division of the U.S. Geological Survey in the National Research Program in Menlo Park, California. Her area of expertise is estuarine benthic ecology with special emphasis on transport mechanisms between benthic and pelagic systems. Ms. Thompson is recognized in the scientific community for her expertise in benthic ecology and has participated in a number of local meetings and workshops involving local policy. She has been working in San Francisco Bay since the early 1970's.

Dr. A. Keith Miles will be responsible for benthic surveys and energetics studies. Dr. Miles received his Ph.D. from Oregon State University in Wildlife Ecology. He is currently employed as a research biologist by the Biological Resources Division of the U.S. Geological Survey. His primary focus of research is on the effects of contaminants on estuarine and marine habitats, particularly prey organisms of waterfowl and marine mammals under trust to the United States Government. Dr.

Miles' emphasis is to determine consequences of accumulation of contaminants in prey, and discriminate effects caused by contaminants from naturally occurring changes in prey populations. Since 1987, he has conducted studies on the effects of contaminants on the structure or dynamics of invertebrate or vegetative assemblages, and the potential for accumulation of these contaminants among prey guilds and their migratory bird or marine mammal predators. His studies have been conducted at Chesapeake Bay, and currently at San Francisco Bay and the Arctic environment. He has worked in cooperation with the U.S. Fish & Wildlife Service, U.S. Navy, and the California Department of Parks and Recreation. He is primary author on 6 scientific journal articles on environmental contaminants, and primary author or co-author on 9 other related articles published or pending publication.

Dr. John Y. Takekawa will be responsible for aerial surveys and foraging modelling. Dr. Takekawa received his Ph.D. from Iowa State University in Animal Ecology. He is currently employed as a research wildlife biologist by the Biological Resources Division of the U.S. Geological Survey at the San Francisco Bay Estuary Field Station in Vallejo. His primary expertise is as a waterfowl specialist and the use of telemetry to study habitat use. Dr. Takekawa has been working in the San Francisco Bay area for the past ten years. His research has included collaborative studies with U.S. Fish & Wildlife Service and California Dept. of Fish & Game.

Jon R. Burau will be responsible for collecting data and developing the conceptual hydrodynamic model of Suisun Bay. Mr. Burau received his Masters degree in Civil Engineering from Stanford University and is currently a doctoral candidate at Stanford. He has been studying the hydrodynamics of San Francisco Bay since 1984. From 1984 to 1989, he constructed and applied computer models of the San Francisco Bay system under the direction of Dr. Ralph T. Cheng in cooperation with the California Department of Water Resources, U.S. Bureau of Reclamation, and the California State Water Resources Control Board. Since 1993, he has been studying salinity intrusion in Suisun Bay through the analysis of data collected from state of the art oceanographic equipment. Jon was a co-principal investigator, along with Drs. Wim Kimmerer and Bill Bennett, in the IEP sponsored Entrapment Zone studies. Many publications and technical presentations have resulted from this work.

#### Table 2 - References

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## **VI. Compliance with standard terms and conditions**

A nondiscrimination compliance statement is included with this proposal. Public entity standard clauses will be submitted before or at signing of the final contract. Federal law prohibits Federal agencies from agreeing to the indemnify, hold harmless clause (Attachment D, item 9). The USGS is only able to sign with the following statement :

The USGS agrees to cooperate to the extent allowed by federal law, in submittal of all claims for alleged loss, injuries, or damage to persons or property arising from the acts of USGS employees, agents, subcontractors, or assigns, acting within the scope of their employment in connection with the performance of this agreement, pursuant to the Federal Tort Claims Act (28 U.S.C. &2671, et seq.).

NONDISCRIMINATION COMPLIANCE STATEMENT

U.S. Geological Survey

COUNTY NAME

The company named above (hereinafter referred to as "prospective contractor") hereby certifies, unless specifically exempted, compliance with Government Code Section 12990 (a-1) and California Code of Regulations, Title 2, Division 4, Chapter 5 in matters relating to reporting requirements and the development, implementation and maintenance of a Nondiscrimination Program. Prospective contractor agrees not to unlawfully discriminate, harass or allow harassment against any employee or applicant for employment because of sex, race, color, ancestry, religion, creed, national origin, disability (including HIV and AIDS), medical condition (cancer), age, marital status, denial of family and medical care leave and denial of pregnancy disability leave.

CERTIFICATION

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

OFFICIAL'S NAME

Michael V. Shillers

DATE EXECUTED

July 25, 1997

EXECUTED IN THE COUNTY OF

Secramento, California

PROSPECTIVE CONTRACTOR'S SIGNATURE

*[Signature]*

PROSPECTIVE CONTRACTOR'S TITLE

Project Chief

PROSPECTIVE CONTRACTOR'S LEGAL BUSINESS NAME

U.S. Geological Survey