delta, however, they are located at important locations or flow splits. Daily delta outflow will soon be estimated by UVMs. ADCPs have been used during the last few years to collect time-series of velocity profiles at several locations in Suisun Bay.

It appears that there is an adequate number of flow and water elevation monitoring sites in the riverine part of the system to sufficiently monitor flow conditions for the purpose of assessing restoration effects, however, there will probably be serious flow data deficiencies within the delta and bay depending upon the location of the restoration project. Restoration management will cooperate with the USGS in developing new methods to collect continuous flow data within the delta (refer to "Key Focused Research") without using UVMs. If this successful, these USGS efforts will provide additional flow time-series data at sites other than the present UVM sites.

KEY FOCUSED RESEARCH TOPIC AREAS:

1) Investigate the utility of obtaining flow data in the delta by deploying an ADCP on the channel bottom at the selected monitoring locations and attempt to relate the velocity profile data provided by the ADCP to tidal flow using a relation developed from flow measurements made with the portable ADCP flow measuring system. The time and cost of installing a UVM flow monitoring site is quite high. In order to install a UVM site, construction permits must be obtained from numerous agencies and transducer mounting piles must be purchased and driven into the channel bottom. The purchase and driving of piles is costly and requires substantial regulatory documentation.

RESTORATION MONITORING PROGRAM SUB-PROGRAM DESCRIPTION

SUB-PROGRAM: System-Wide Basic Water Quality Monitoring

SUB-PROGRAM PURPOSE: To routinely monitor the basic water quality variables (listed below) that define the fundamental condition of aquatic habitat in the Bay-Delta system.

SUB-PROGRAM ELEMENT DESCRIPTIONS (parameters):

These water quality variables are essential for interpreting biological sampling data, and are therefore an important component of the comprehensive monitoring effort. They are:

- Water Temperature - Regulates chemical and biological processes and defines habitat suitability for many species, particularly in mainstem rivers and tributaries.

- Salinity - Affects the distribution of many plant and animal species and life stages in the system. Also, an indicator of important physical processes, such as estuarine water circulation and mixing. Defines the relative proportion of freshwater and seawater at different locations in the estuary and salt loads from upstream sources. In low salinity portions of the system, specific conduction is a more appropriate measure.

- Turbidity (Light Penetration) - Affects primary production in the estuary and defines the position of the biologically important entrapment zone. Change in turbidity is a possible juvenile salmon migration cue and controller of predation in system rivers.

- Dissolved Oxygen - Indicator of net metabolism in the system. Both low and supersaturation levels can limit species abundance, distribution, and migrations in the mainstem rivers and tributaries.

- Chlorophyll concentration - An index of phytoplankton abundance, the microscopic algae that are the traditional box of the food web in the estuary.

- pH - A quantitative expression for acidity or

alkalinity of the area sampled.

- Organic Carbon - Provides information on sources and fluxes of the primary support of the estuarine food chain. Inputs from the rivers to the Delta and within the Delta and bays would be measured for this variable.

SUB-PROGRAM ELEMENT DESCRIPTIONS (COMPONENT BY AREA):

1) **Mainstem River and Tributary Basic Water Quality Monitoring**: The comprehensive monitoring program will include a routine, systematic program of basic water quality monitoring in mainstem rivers, tributaries, and terminal reservoirs. Although existing basic water quality sampling efforts are conducted for specific programs, they are collectively insufficient for supporting the adaptive management approach to ecosystem restoration. Reasons for this include:

- A cohesive and comprehensive program incorporating strategically located monitoring sites and providing adequate geographical and temporal coverage does not exist throughout the mainstem river and tributary streams.

- On the San Joaquin River system, programs have not been developed to provide data to make coordinated operational decisions regarding the attainment of water quality objectives.

- A quality controlled system of data handling, storage, retrieval and analysis for a comprehensive water quality program does not exist.

- Some localized existing basic water quality sampling efforts are reasonably comprehensive, but are short-term efforts associated with special projects (e.g. FERC relicensing or model development).

A cooperative effort with entities conducting existing basic water quality sampling programs (USBR, DWR, USGS, fish and wildlife agencies, communities, etc.) will be needed to design a basic water quality program to support its adaptive management approach to restoration. To the maximum extent possible the design will build upon existing sampling, and integrate existing and new sampling efforts. The anticipated basic components of this program are:

- Temperature, D.O., and light penetration profiles in terminal Reservoirs in the vicinity of reservoir outlets. Basic water quality conditions in terminal reservoirs directly influence downstream conditions and in some cases can be manipulated (e.g. controlling the depth of river releases) to improve conditions downstream.

- Continuous temperature monitoring in mainstem rivers and tributaries, with stations located at points where significant temperature influences are likely (at dams, mouths of major tributaries, etc.)

- Sampling of other basic parameters (e.g. turbidity, specific-conductance, organic carbon) at all stream temperature stations (above) and additional ecologically relevant locations.

- Real-time salinity and flow data at key points along the San Joaquin River system to allow coordinated management of salt loads and flows to meet water quality standards.

- A system of data storage and retrieval for all sites will be developed. Emphasis will be placed on analysis of the data to provide ecologically relevant information to support an adaptive management approach.

2) **Estuarine Basic Water Quality Monitoring:**

The DWR and USBR and DFG, working under the auspices of the Interagency Ecological Program, conduct a water quality monitoring program covering San Pablo Bay and through the Delta. This program was recently reviewed and revised in

1995 and will continue to evolve as information needs change. The revised program has been accepted by the State Water Resources Control Board in their Water Quality Control Plan 95-6. The three major elements of this revised program are:

- A network of continuous recording, multi-parameter water quality sites at key locations including Sacramento River and San Joaquin River inflow points to the Delta, CVP and SWP export facilities, and various channel locations throughout Suisun Bay and the Delta.

- A monthly boat sampling program that runs up the estuary collecting near-surface water quality data and lower trophic data with stops at discrete sites to measure conductivity, temperature profiles and collect phytoplankton and zooplankton samples.

- Special studies that focus on specific problems.

The USGS also makes monthly water quality measurements along the central deep channel from the southern limit of South San Francisco Bay to Rio Vista on the Sacramento River. This sampling design, conducted since about 1968 provides descriptions of water quality along the longitudinal axis of the San Francisco Bay-Delta system.

These existing water quality monitoring program generally adequate today's information needs and contains enough sites to monitor trends, but is limited by funding. However, to meet the objective of determining ecological changes resulting from restoration activities, additional sites (and possibly additional parameters) should be added to supplement the existing program. For example, more sites should be added in the shallows of Grizzly and Honker Bays and downstream in San Pablo, Central and South bays, dead-end sloughs in the northern and eastern Delta, and the southern Delta. In addition, a comprehensive program for data analysis and evaluation should be developed and water quality and fish sampling programs need to be better coordinated so that it is easier to perform integrated analysis of the two types of data.

3) **Integrated Analysis of Basic Water Quality Conditions**: Basic water quality sampling in the system is, and will probably continue to be, obtained and reported from a variety of individual programs, each with their own objectives and information needs. The comprehensive, integrated assessment of this information will be promoted by establishing and supporting a team of experts whose objective is to produce and distribute integrated analysis and reports (maps, contour plots, and time series plots) of the variables listed above on an annual basis and to make sure there is an analysis plan for the data. An integrated-analysis approach will also be served by a single entity which maintains all relevant basic water quality data in a computer file server and including the data, as appropriate, in geographic information system.

KEY FOCUSED RESEARCH AREAS:

1) Analytical and field reconnaissance efforts to design a comprehensive basic water quality monitoring program for the system, built-on and integrated with existing monitoring efforts.

2) Development of a plan for storage, retrieval and analysis of water quality data.

3) Development of a computer model or models to predict water quality conditions in unmonitored areas and evaluate restoration scenarios.

RESTORATION MONITORING PROGRAM SUB-PROGRAM DESCRIPTION

SUB-PROGRAM: System-Wide Aquatic

Contaminants Monitoring

SUB-PROGRAM PURPOSE: To monitor levels of contaminants potentially harmful to aquatic life, system-wide, in water, sediments, and biota for documenting trends in contamination levels, bioaccumulation, and identifying potential biological effects; and to identify time periods and locations where specific contamination reduction efforts should be focused.

SUB-PROGRAM ELEMENT DESCRIPTIONS:

1) **Bay-Delta System Water and Sediment Contaminants Monitoring:** The Bay-Delta system does not currently have a comprehensive, routine aquatic contaminants (herbicides, pesticides, metals, etc.) monitoring program to help identify areas or time periods where contaminants are an ecological concern and provide trend information on contaminant levels. A core program modeled after, and building upon, the Comprehensive Conservation and Management Plan's (SF Estuary) Regional Monitoring Program, should be established for the entire system (terminal reservoirs to the Golden Gate) to provide this information. Emphasis should be given to monitoring those contaminants most likely to cause an adverse biological effect. Collaboration with existing monitoring programs (e.g., SF Estuary RMP, USGS' NAWQUA, USGS' SF Bay Program, Sacramento Coordinated Monitoring Program, DPR's programs, and CVRWQCB Bay Protection and Toxic Clean-up Program) could be considered as an implementation strategy.

2) **Toxicity Monitoring:** Water and sediment toxicity testing should be integrated into the chemical and biological monitoring programs. Toxicity surveys can provide a direct link from contaminant levels and adverse biological effects, and help insure that aquatic organisms are protected from toxic materials. If toxicity is observed, Toxicity Identification Evaluations (TIEs) and other techniques can help determine what chemicals are the cause, so contaminant reduction efforts can directed effectively. Long-term toxicity monitoring can provide a direct measure of potential biological benefits of contaminant reduction programs.

   Toxicity monitoring has the potential to be logistically difficult and expensive. For this reason, responsible agencies with current programs in place and experts should cooperate to design and help implement a toxicity monitoring program that is both practical and useful.

3) **Bioaccumulation Monitoring:** The SFEI is establishing a program to investigate and monitor contaminants (PCB's, dioxin, pesticides, mercury, etc.) in fish and shellfish tissue from San Francisco Bay through Suisun Bay, primarily to protect human health and track tissue contaminant levels through time. The scope of this new program should be expanded into the upper estuary, Delta, and rivers and adapted to address potential adverse effects to fish and aquatic invertebrate populations and be coordinated with the State's Mussel watch program.

4) **Fish Condition Monitoring:** If fully implemented, the overall monitoring program (including existing programs) will include routine collection of juvenile and adult fishes from throughout the Bay-Delta system. A systematic examination of fish collected during these efforts can provide a rapid measure of fish health that can be monitored to identify contaminant problem areas and monitor trends in fish health.

   Full implementation of these long-term monitoring elements should be preceded, or accompanied by focused studies as listed below. These studies should be closely coordinated to maximize their use to assess possible effects (e.g., growth, mortality, reproduction) on fish populations. The long-term monitoring programs and the focused studies will be needed to reliably link

variations in fish populations and ecosystem processes with contaminant levels, or to fully understand the dynamics (sources, fates, etc.) of system contaminants.

KEY FOCUSED-RESEARCH TOPIC AREAS:

1) Investigations of contaminant effects on fish and invertebrate populations and ecosystem processes such as recommended by IEP's Contaminant Effects Team and other established technical groups. Emphasis should be on the integration of contaminant effect investigations with the aquatic biological monitoring program.

2) Pilot-level water and sediment contaminants studies and comprehensive literature reviews are required to determine appropriate sampling locations, frequency, and contaminant constituents for long-term monitoring. An adaptive sampling design should be considered to address spatial and temporal distribution of different contaminants and fish populations, varying habitat types, and the hydrodynamics characteristics of the sampling sites.

3) Development and implementation of biomarkers (e.g., hormonal disruption, histopathology, DNA damage) for assessing sublethal contaminant effects on fish.

4) Development of a multi variate fish condition index that is biologically meaningful and easily obtained during routine fish sampling. Possible variables include lesions, tumors, condition factor, and simple blood tests. A larval fish condition index would be especially useful in assessing population level effects.

RESTORATION MONITORING PROGRAM SUB-PROGRAM DESCRIPTION

SUB-PROGRAM: Estuary River Wetland and Riparian Habitat Monitoring Sub-program

SUB-PROGRAM PURPOSE: To monitor the ecological components of mainstem and tributary areas to evaluate the condition of wetland and riparian habitat.

SUB-PROGRAM ELEMENT DESCRIPTIONS:

Currently, there is no overall program in the Central Valley that monitors ongoing changes to habitat types or availability. The existing efforts do not collectively comprise a program that is sufficiently comprehensive to support an adaptive management approach to wetland and riparian habitat restoration.

In order to develop a program to monitor the system's wetland and riparian habitat conditions three important, related questions should be answered:

1) Are individual habitat restoration actions successful?

   The results of individual efforts to restore habitats, such as tidal marsh lands and shaded riverine aquatic habitat, are difficult to predict. Although individual habitat restoration projects will be carefully planned and engineered, it will still be necessary to carefully monitor short and long term results to identify and guide any necessary follow-up activity to assure that the habitat values envisioned for a project are achieved.

2) Is there net improvement in the system's habitat conditions?

   Habitat improvement-related implementation objectives can either be enhanced or offset by system changes that are unrelated to specific restoration efforts. In order to know that net overall improvement in desired habitat objectives is being achieved, habitat conditions throughout system must be regularly monitored and evaluated.

3) What are the values of restored habitat and how are those values changing over time?

Habitat improvement efforts must be evaluated in two general ways. The most basic way is to simply consider the areal extent of restoration (e.g. the number of acres of riparian forest). As important, is the quality of the habitat and ecosystem value it is providing. Connectivity, vegetation productivity and density, rate of succession, and wildlife use are just a few examples of habitat values that will need to be considered when evaluating the success of its restoration efforts and overall system habitat conditions in the future.

The program will likely include the following general components:

- Regular (every 3 to 5 years) large-scale aerial or satellite photo surveys along all major system rivers and the estuary to measure the system-wide extent (and to some extent, other attributes) of targeted habitat types and river bed morphology.

- Regular (seasonal and annual) and flood-event driven more fine scale aerial photo surveys of restoration project sites and representative reference sites.

- Regular (every 3 to 5 year) system-wide boat and ground-based estuarine bathymetric surveys to support hydrodynamics monitoring efforts and provide information on estuarine depth-distribution characteristics.

- Regular ground surveys of vegetation characteristics and wildlife (including special status and exotic species) in habitat restoration project areas, and in randomly (stratified) selected sites throughout the system.

- Inclusion of all wetland riparian habitat and habitat use monitoring data in a comprehensive Geographic Information System.

The fish and wildlife agencies, public works agencies (e.g. U.S. Army Corps of Engineers), conservation groups (e.g. Ducks Unlimited, nature conservancy, etc.), and others as appropriate will work to design and implement a comprehensive program of habitat monitoring for the estuary and its tributaries.

MONITORING PROGRAM SUB-PROGRAM DESCRIPTION

SUB-PROGRAM: Estuary Primary Productivity and Nutrient Monitoring

SUB-PROGRAM PURPOSE: To monitor key nutrient and primary production variables in the Bay-Delta estuary.

SUB-PROGRAM ELEMENT DESCRIPTIONS: Nutrient concentrations and other factors affecting system productivity levels are fundamental variables affecting the condition of the estuary's biotic community, and must be integrated into the analyses of fish and zooplankton responses to restoration efforts. The key nutrient and primary production-related variables are:

- chlorophyl concentration
- chlorophyl species composition
- light penetration
- solar insolation
- dissolved nitrogen
- particulate, dissolved, and total organic carbon
- water temperature

To a large extent this productivity and nutrient information is now gathered by existing programs (listed below). These existing programs should cooperate to enhance them as necessary to meet the various program objectives and incorporate their information into the overall ecosystem monitoring program.

1) **USGS Water Quality Surveys:** USGS

(Menlo Park) conducts routine monthly water quality sampling, including the variables listed above, (see "System-wide Basic Water Quality Monitoring" sub-program description) at __ channel sites from South Bay to Rio Vista. Through interprogram cooperation, the surveys will be expanded to include appropriate shoal stations.

2) **DWR/USBR/DFG Water Quality Compliance Monitoring**: The Department of Water Resources and U.S. Bureau of Reclamation, working under the auspices of the Interagency Ecological Program, conduct a water quality monitoring program through Suisun Bay and the Delta, including most of the variables listed above. This program was recently reviewed and revised in 1995 and is described in the "System-wide Basic Water Quality Monitoring" subprogram description.

   Information from these surveys will be incorporated into the overall monitoring program.

KEY FOCUSED RESEARCH AREAS:

1) Pilot monitoring/studies of primary production in estuary shoal areas.

2) The role of micro zooplankton in estuary productivity.

3) Estimation of, and factors affecting, total system productivity (up through the zooplankton trophic level).

4) Differences in energy/nutrient sources between geographical areas of the estuary.

5) Occurrence and role of introduced phytoplankton species in the Estuary.

MONITORING PROGRAM SUB-PROGRAM DESCRIPTION

SUB-PROGRAM: Mainstem River and Tributary Aquatic Biological Community Sub-Program

SUB-PROGRAM PURPOSE: To monitor the ecological components of mainstem and tributary areas to evaluate the condition of wetland and riparian habitat.

SUB-PROGRAM ELEMENT DESCRIPTIONS: The assessment and adaptive management of restoration efforts must be supported by more consistent and broad monitoring of the entire community for two reasons. First, habitat restoration efforts may affect the abundance and distribution of species which prey upon, are eaten by, or compete with higher profile species such as chinook salmon. A full understanding of the response or lack of response of these higher profile species, therefore requires information about changes in the abundance and distribution of associated species. Secondly, restoration objectives are intended to promote general ecosystem health. Improving and monitoring the general condition the aquatic community, including resident native species, is consistent with that approach.

Existing aquatic biological monitoring in Central Valley mainstem rivers and tributaries is heavily focused on a few anadromous fish species, particularly chinook salmon, steelhead, striped bass, and white sturgeon. Limited amounts of broader aquatic ecological information is available from incidental catches during species-specific sampling and from special investigations by agencies and universities.

To meet the Restoration Plans, an adequate program would consists of routine aquatic biological community monitoring in Central Valley mainstem rivers and tributaries below terminal reservoirs. This monitoring will likely include routine seasonal sampling for fish and benthic macro invertebrates at representative stream sites throughout the system. Predatory fish monitoring at key times at sites where these predators are likely to concentrate (i.e. barriers, diversion dams, fish ladders etc.) may also be needed.

KEY FOCUSED RESEARCH AREAS

1 Studies evaluating predator/prey relationships along key migration routes.

2 Food availability studies along alternative migration routes

3 Determine factors affecting path of migration utilized by outmigrants.

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