Lower Columbia River Estuary Plan

Volume 2

Aquatic Ecosystem Monitoring Strategy for the Lower Columbia River

Information Management Strategy

Lower Columbia River Estuary Program
Comprehensive Conservation and Management Plan

Aquatic Ecosystem Monitoring Strategy
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Lower Columbia River Aquatic Ecosystem Monitoring Strategy

I. Introduction

The mission of the Lower Columbia River Estuary Program (Estuary Program) is "to preserve and enhance the water quality of the estuary to support its biological and human communities." The Comprehensive Conservation Management Plan (Volume I) provides the framework for accomplishing this mission. The Management Plan recognizes that a key component in determining whether this mission is being met is environmental monitoring. Comprehensive environmental monitoring is critical to further our understanding of the river, track trends in the health of the river and its resources, pinpoint problem areas, assure compliance with water quality standards, and assess the effectiveness of management actions over time.

The Aquatic Ecosystem Monitoring Strategy (*Monitoring Strategy*) details how this effort will be accomplished. Building on existing monitoring programs, the strategy provides a structure for coordinated monitoring of the lower Columbia River. It represents a very important step in establishing a cooperative, long-term approach to understanding the complex ecosystem of the Columbia River. Comprehensive monitoring at this scale has not been attempted on the lower Columbia. It is an ambitious undertaking and will require an unprecedented level of cooperation, coordination, and commitment among all the involved parties. The Estuary Program will play a critical role in making it happen by supporting the continuation and enhancement of existing monitoring programs, initiating new monitoring efforts, and providing the structure to ensure an ongoing, comprehensive approach to ecosystem monitoring.

II. Background

The lower Columbia River and estuary have suffered significant degradation over the years. Hydropower development, irrigated agriculture, logging, mining, stream channelization, industrial discharges, stormwater runoff, and urbanization are all recognized factors contributing to the degradation of the river. In 1989, the Governors of Oregon and Washington established the Bi-State Water Quality Program to assess the health of the lower river and estuary. The study evaluated the water quality to determine if beneficial uses were being met. The project produced a report in 1995 titled "The Health of the River" that identified a variety of water quality and land use problems which have resulted in impaired wildlife and ecosystems. The conclusions of that report supported a nomination to the National Estuary Program.

The Lower Columbia River Estuary Program became part of the National Estuary Program (NEP) in 1995, and a three year conference agreement was signed between EPA and the two Governors in 1996. The conference agreement called for development of a comprehensive management plan for the lower river.

Water quality monitoring to track trends and evaluate the effectiveness of various activities was recognized as a key element of the plan. Under the lead of the US Geological Survey in coordination with the Estuary Program, a multi-agency subcommittee completed a draft report titled

"Interagency Long-Term Monitoring Plan to Assess Water Quality, Sediment Quality, Aquatic Health, and Biological Integrity in the Lower Columbia River." That plan, referred to from now on as the "monitoring plan", was accepted by the Estuary Program Management Committee and forms the basis of this strategy.

The monitoring plan provides a detailed assessment of the monitoring needs of the lower river based on the priority issues identified by the Estuary Program Management Committee, the technical expertise of subcommittee members, knowledge of existing programs and the availability of existing information. The subcommittee identified four general monitoring areas: water column, toxics in sediments, toxics in tissues, and habitat and biological integrity. It then developed recommendations for the specific monitoring actions and special studies needed to provide critical information and support the monitoring objectives. The monitoring plan offers the recommendations and a relative priority for each.

The monitoring plan provides the technical information to support the *Monitoring Strategy*. It takes the recommendations of that group and outlines an approach to implementation. The collaborative development of the monitoring plan represents an important precedent in developing an integrated, comprehensive monitoring program for the lower river. It shows a clear commitment on the part of all key partners to the concept of studying the ecosystem as a whole rather than as a number of independent parts as has been done in the past.

III. Purpose

The *Monitoring Strategy* establishes a process for implementing the monitoring plan for the lower Columbia River. Over time, monitoring will provide the data necessary to routinely evaluate the environmental health of the river. To meet this goal, the process must ensure that the following objectives, identified in the long term monitoring plan, are successfully accomplished. These objectives will evolve as more data becomes available and our understanding of the ecosystem improves.

The objectives are to:

- incorporate and augment existing monitoring and assessment programs;
- develop specific approaches for addressing specific monitoring questions;
- develop hypotheses that can be tested as part of the monitoring strategy;
- select monitoring variables as appropriate for sampling locations, sampling frequency, media, chemical and biological parameters, and quality control;
- provide for coordinated data management and assessment;
- assure the gathering of comparable, high quality baseline data and issue-specific data by all participating programs;
- provide for the processing and analysis of data to address immediate information needs and determine seasonal, annual and long term trends; and
- provide for periodic assessment of all data and re-evaluation of the *Monitoring Strategy*.

IV. Scope

The *Monitoring Strategy* focuses on the Estuary Program study area which includes the tidal portions of the Columbia River, its tributaries downstream from Bonneville Dam, and the tidal portion of the Willamette River and its tributaries downstream of Willamette Falls. The study area is large and complex and is influenced by a multitude of factors outside its bounds, including upper basin activities such as water impoundments, irrigation withdrawals and returns, farming and forestry activities, and many more. Thus, although most actual data collection will occur downstream of Bonneville Dam, these upstream influences will have to be considered.

Although the *Monitoring Strategy* is meant to be comprehensive and all inclusive, the complexity, the costs, and the resources needed to effect an exhaustive monitoring program of the lower river extend beyond the short term. As resources become available and as our knowledge base increases, however, it is envisioned that the scope and coverage of the program will expand, as will our ability to understand the ecosystem and its overall health. It is expected that this document will be periodically updated to reflect new knowledge, changing priorities, and emerging issues.

V. Approach

The *Monitoring Strategy* takes the recommendations from the monitoring plan and establishes a step by step, phased approach to implementing those recommendations. Sections VI and VII provide the context for the *Monitoring Strategy*, Section VIII describes the monitoring components; Section IX discusses the phased approach; Section X describes the implementation strategy for each of the monitoring components; Section XI discusses costs; and the conclusions are contained in Section XII.

The overall approach is based on key decision factors. Those factors (discussed in more detail in Section IX B) include funding, priority ranking, availability of existing programs and resources, critical information needs, and the existence of established protocols and procedures for measuring desired parameters. Section IX C describes the phased approach, initially establishing a coordination structure and developing agency cooperative agreements. As the program gets underway, other proposed actions will commence based on available resources. Over time, as sustained funding is secured, the entire program will be implemented.

There are numerous decisions regarding actual monitoring that will not be made in this document. Such aspects as appropriate quality assurance and quality control procedures, and actual sample design and procedures will have to be developed through agreements with the participating partners in the monitoring program.

This strategy does identify:

- what decisions need to be made;
- a process for coming to agreement;
- a proposed structure and oversight role to ensure that implementation moves forward in a consistent and organized manner; and
- recommendations for how, when, and at what scale monitoring activities should occur.

VI. Relationship to the Management Plan

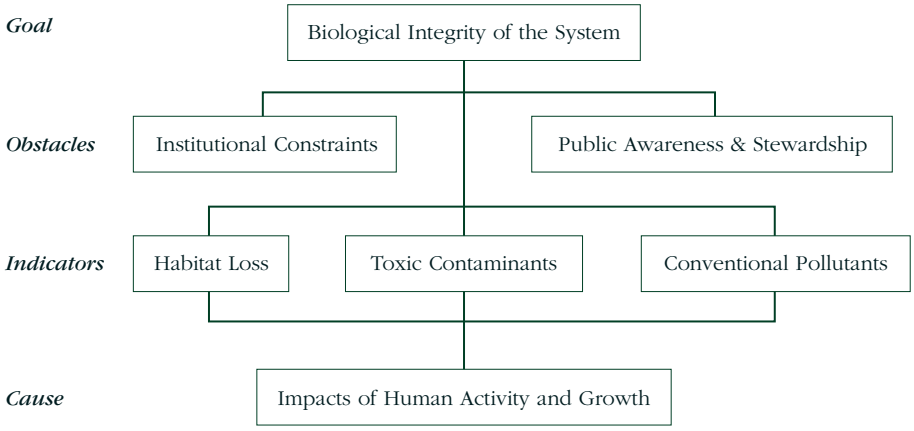
The *Monitoring Strategy* is one aspect of the implementation phase of the Management Plan. It is key to determining whether the goals of the Estuary Program are being met.

The Management Plan identifies seven priority issues related to the health of the Lower Columbia River. The issues are:

- biological integrity;
- impacts of human activities and growth;
- habitat loss and modification;
- conventional pollutants;
- toxic contaminants;
- institutional constraints; and
- public awareness and stewardship.

The issues are clearly interrelated. At the core is the Estuary Program's fundamental goal to achieve a high level of biological integrity. Biological integrity has been degraded by human activity and growth over the last hundred years. The degradation is evidenced by habitat loss and modification, the presence of toxic contaminants in fish tissue and sediments, and problems with conventional pollutants (such as elevated temperature, increased dissolved gases, bacteria, and sediment). Institutional constraints posed by multiple jurisdictions and lack of public awareness and stewardship make protection of the river challenging. The following flow chart (Figure 1) depicts that relationship.

Figure 1
Interrelationship of Priority Issues

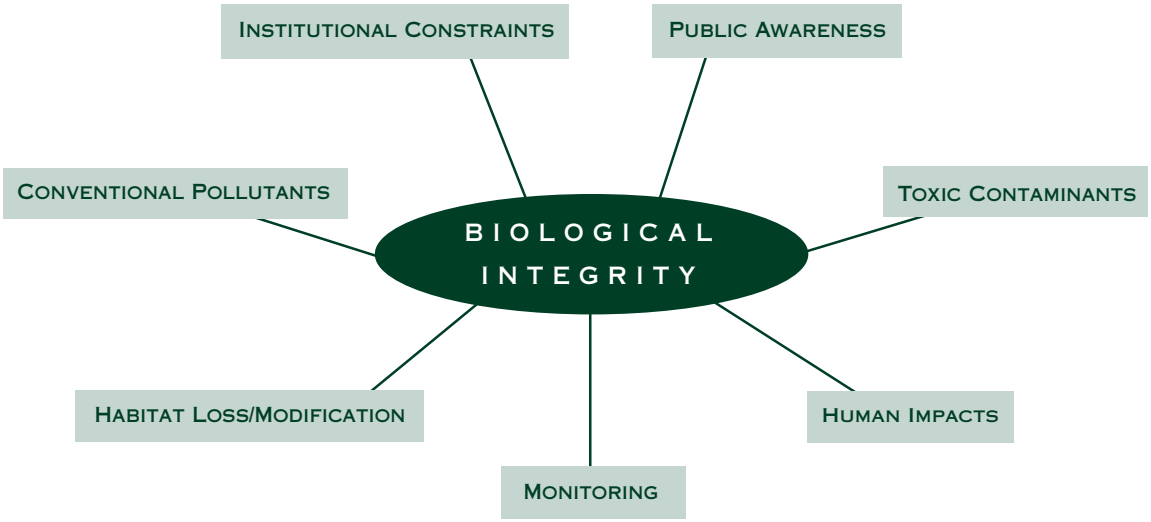


The Management Plan describes 43 specific actions to address the problems associated with the seven priority issues. The implementation of all the actions should result in the improvement of the biological integrity of the lower river. The 43 actions are grouped into three broad categories.

- **Habitat and Land Use:** Loss of habitat and wetlands was identified in the Estuary Program planning process as the number one risk to public health, ecological health, and quality of life in the lower river and estuary. The Estuary Program will primarily encourage and assist other entities in implementing these actions, although it will directly implement some aspects of the actions.
- **Education and Management:** Several actions call for increased education and improved consistency and coordination among government agencies with responsibility for the lower river and estuary. The Estuary Program will take the lead in implementing these actions.
- **Conventional and Toxic Pollutants:.** These actions involve the regulatory authority of a variety of local, state, and federal agencies. In some cases, the actions reinforce existing activities, and in other cases call for increased regulatory activity. The Estuary Program's primary role will be to monitor the progress of the responsible entities to ensure that the actions are implemented and the goals are met. This involves watching, encouraging, assisting where possible, and motivating where needed. In a few cases, the Estuary Program may initiate minor aspects of these actions, such as conducting additional studies.

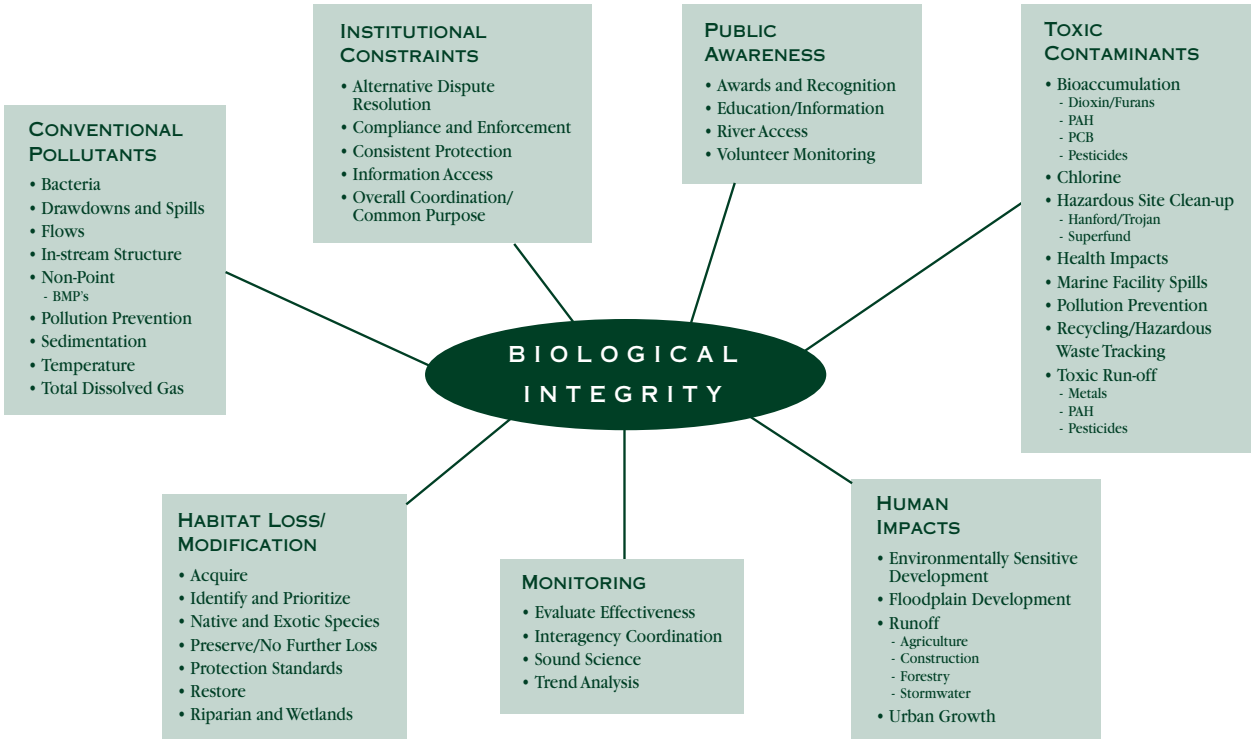
The *Monitoring Strategy* plays a critical assessment role in many of these actions as well as an important role in promoting government consistency and coordination. In 31 of the 43 actions, there is a clear relationship between monitoring and the implementation, evaluation, or tracking of a specific action. The following series of diagrams attempts to depict these relationships. Figure 2 (page 6) shows the components of the Estuary Plan directed at improving biological integrity with monitoring depicted as one arm of the system. Figure 3 (page 7) shows the relationship of the 43 actions to the components of the Estuary Plan. Figure 4 (page 11) shows the basic elements of the *Monitoring Strategy.*

Figure 2
Basic Components of the Management Plan



Using these simplified depictions, the interrelationship between the Estuary Plan and *Monitoring Strategy* is very clear. One cannot operate successfully without the other. As the various actions are implemented and pieces of information gathered and evaluated, a more complete understanding of the ecosystem emerges and a healthier river system results. Just as the Management Plan cannot be implemented without unprecedented cooperation and commitment, so it is with the *Monitoring Strategy*.

Figure 3
Management Plan Actions



VII. Relationship to Other Monitoring Programs

The *Monitoring Strategy* does not propose establishing a new monitoring entity for the lower Columbia River. Rather, it proposes a comprehensive, coordinated framework that builds on existing monitoring programs and ongoing studies. Many of the existing programs are administered by organizations that were involved in development of both the Management Plan and the *Monitoring Strategy*. With the support of the Estuary Program, existing agency programs would continue and, where appropriate and feasible, these efforts would be augmented by Estuary Program initiatives which would advance our understanding of the lower river ecosystem. Where new efforts are called for, the Estuary Program will contract for their implementation.

The Estuary Program is a coordinating body with no legislative authority to direct the actions and programs of the agencies involved in monitoring. Those programs exist for a variety of reasons that may or may not coincide with Estuary Program goals and objectives. However, to the extent that common purposes can be identified, the *Monitoring Strategy* will use those commonalties to develop a more coordinated monitoring system. Such a coordinated system does not exist at present but most participants in the project agree that it is needed. Clearly it will involve a commitment and agreement by all the partners to the processes for the sharing of information and resources, collecting and analyzing data, and quality control.

The following discussion briefly examines existing monitoring programs that may either meet some aspect of the Estuary Program needs or could meet program needs with the commitment of additional resources and the development of appropriate agreements. Table 6 (see Appendix) provides more detail on these programs. Chart 1 found in the Appendix shows existing and proposed sample sites.

A. State Agency Programs

1. Oregon Department of Environmental Quality

The Oregon Department of Environmental Quality (DEQ) has an extensive statewide network of water quality ambient monitoring sites. In addition to one site on the mainstem Columbia River near the mouth of the Willamette, DEQ maintains sites on many of the lower Columbia River tributaries. These are monitored on a monthly basis or on rotation (see Table 6 and Chart 1). DEQ supports additional monitoring which will help support agency programs. However, the current program is fiscally limited as it tries to meet the requirements of assessing Total Maximum Daily Load (TMDL) requirements compliance statewide, and the additional monitoring commitments of the Oregon Plan for Salmon and Steelhead.

2. Washington Department of Ecology

The Washington Department of Ecology (Ecology) currently has ambient monitoring sites on the major tributaries on the Washington side of the lower Columbia and the upper Columbia. There are no sites on the main stem (see Table 6 and Chart 1). Like DEQ, Ecology is required to meet TMDL requirements statewide and address declining salmon and steelhead populations. Ecology supports monitoring efforts on the lower Columbia River which help meet agency needs regarding these two issues.

3. Other State Agency Programs

Because of the Endangered Species Act listing of the Lower Columbia River Steelhead, the Departments of Fish and Wildlife in Washington and Oregon are either implementing or planning to implement extensive habitat enhancement and restoration efforts in the study area. These activities are limited to the tributaries of the lower river but may ultimately provide long term water quality benefits to the estuary and the lower river. The habitat protection, enhancement, and restoration efforts of these agencies have monitoring components to assess habitat condition and success of implementation.

B. Federal Programs

1. US Geological Survey (USGS)

USGS is primarily a data gathering and research organization. It provides cost sharing so it can cooperate with local agencies to undertake monitoring needs beyond the compliance bounds of the state agencies and can thus implement special studies and research projects given sufficient support. The USGS, through its National Stream Quality Accounting Network (NASQAN) program, currently maintains four ambient water quality sampling sites on the Columbia River, one on the Snake, and one on the Willamette. These sites have provided most of the data for long-term trend analysis for the lower river and now provide a backbone to the Estuary Program Monitoring Strategy (see Table 6 and Chart 1). Currently there are discussions within USGS to discontinue these sites in favor of other program objectives that would focus on primary productivity in the Columbia River. This is also an important objective for the program and meets other monitoring needs. Unfortunately, without the existing USGS sites, the only ambient site remaining on the lower river would be operated by DEQ.

The Estuary Program has a cooperative agreement with USGS to conduct a Semi-Permeable Membrane Device (SPMD or Lipid Bag) monitoring survey for the entire Columbia River to trace the level of lipid-soluble organics in the water column throughout the system. This new sampling technique holds considerable promise for future application on the river.

The USGS Biological Resources Division is also conducting a long-term monitoring study throughout the Columbia Basin including several sites in the study area for the occurrence and distribution of contaminants in biota tissues (see Table 6). This will provide information critical to our understanding of toxics in animal tissue.

2. US Environmental Protection Agency (EPA)

The EPA is currently conducting a temperature study of the Columbia River above Bonneville Dam. Using historic temperature data, EPA is developing a model for predicting water temperature and will attempt to answer questions regarding what causes elevated mainstem water temperatures and what management actions might be taken to reduce them. No actual field work is being done. The results, however, may help address current temperature problems in the lower river.

In 1997 EPA also undertook a one-time survey of contaminants in fish flesh in the river system above Bonneville, looking specifically at the exposure of Native Americans to toxic contaminants through fish consumption. The results have not been released, but this information may help direct fish tissue sampling efforts in the lower river.

3. US Army Corp of Engineers (USACE)

The USACE conducts routine monitoring for temperature and total dissolved gas at 11 sites in the lower river. This effort provides long-term information on two parameters that are of particular concern because of non-compliance with water quality standards and the probable negative impacts on migrating salmonids.

The USACE, because of its responsibilities for channel maintenance dredging and the proposed channel deepening project, also conducts sediment sampling for toxic contaminants. This information provides background data on toxic contaminants in the sediments of the navigation channel.

C. Other Monitoring Efforts

1. Portland Harbor Contaminated Sediments

A recent joint DEQ/EPA survey of sediments in the Willamette River in the Portland Harbor area identified areas of extensive toxic contamination. It is possible that this contamination provides the source of sediment contamination found in the lower Columbia.

2. Research

The Columbia River Inter Tribal Fish Commission, the National Marine Fisheries Service, the University of Washington, Oregon State University, Portland State University, and perhaps others have research projects in the lower river. These projects are specific to certain research needs and they add valuable pieces of about the lower river.

3. Oregon Graduate Institute

The Oregon Graduate Institute has an ongoing project in the Columbia River estuary with continuous monitoring stations for temperature, salinity, and conductivity. This system, known by the acronym CORIE, provides instantaneous water quality data for these constituents.

4. Permitted Dischargers

All municipal and industrial facilities with permitted discharges are required to do routine monitoring of their outfalls. The extent of the monitoring required and the constituents monitored vary on a case-by-case basis.

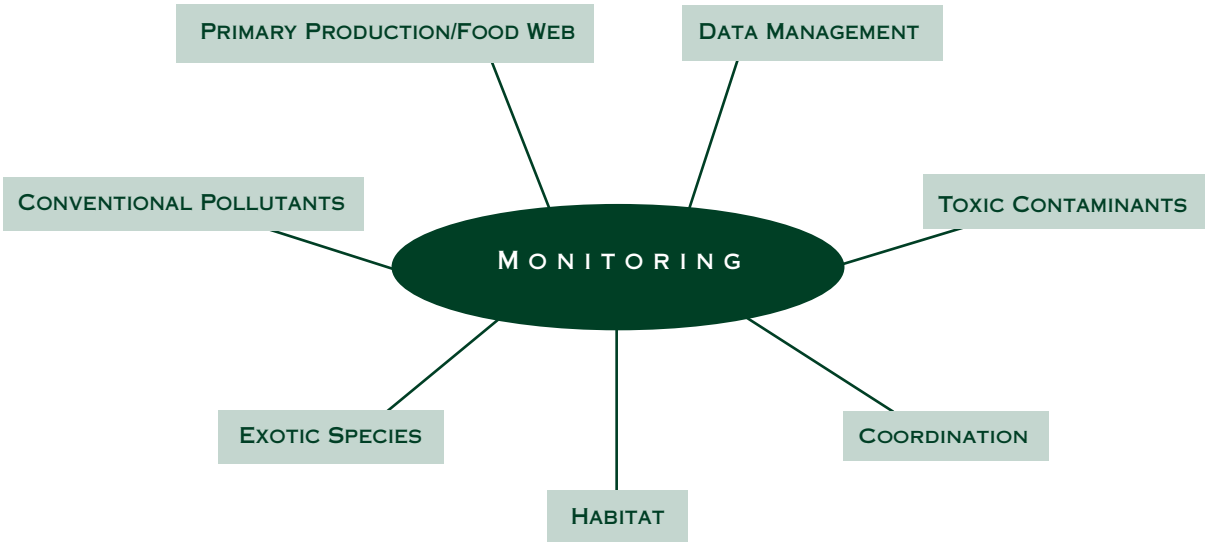
VIII. Components of the Monitoring Strategy

The basic components of the *Monitoring Strategy* include coordinating and overseeing the program; developing a data management system; monitoring for and assessing the impacts of conventional pollutants and toxic contaminants; measuring and assessing habitat health; measuring primary productivity; developing an understanding of food web relationships; and evaluating the impacts of exotic species (see Figure 4). The following pages describe the components in some detail. Figure 5 provides a visual representation of the overall monitoring strategy.

A. Coordination and Oversight

Coordination, collaboration, and cooperation are the key elements of the *Monitoring Strategy*. The monitoring plan identified a series of work elements related to coordination including organizing and overseeing the efforts of multiple agencies and multiple projects; administering multiple contracts; tracking large amounts of data; evaluating and storing data; and communicating findings to the public, decision makers, and participants. Managing the development of interagency agreements on items such as Quality Assurance/Quality Control (QA/QC) procedures, sampling protocols, data evaluation and storage, data assessment, and, ultimately, program evaluation are all significant undertakings that will require considerable time, energy, and resources (see Figure 5). It is anticipated that the Estuary Program will provide the mechanisms to ensure that the *Monitoring Strategy* is implemented and sustained.

Figure 4
Basic Components of the Monitoring Strategy



B. Managing Data and Information

It is essential to effectively manage the large volume of existing information as well as the new information that will be developed. This is a large and complicated task. Information now exists in a multitude of formats located in a variety of places. No real effort has been made to organize this information and make it available. Currently, those organizations collecting information on the lower river do so to meet their own missions. They have different procedures and protocols for data collection, analysis and storage. There is no coordination of data management among agencies.

The Estuary Program issued a report titled "Information Management Strategy" in August 1998. (The complete report is Part 2 of Volume 2). This strategy envisions providing a home for all types of information related to the lower river. Managing the monitoring data is the key component (see Figure 5).

The goals of the Information Management Strategy are to:

- improve the transfer and exchange of information among potential users;
- improve accessibility of data to the public and develop tools to present the results in meaningful ways; and
- track the implementation of Management Plan actions.

The data would include:

- water quality monitoring data (chemical, biological, physical);
- habitat data and information (extent, type, condition);
- fish and wildlife data and information (species, condition, including exotic species);
- pollutant loading data (point and non-point source information);
- quality assurance data for each data type;
- metadata; and
- other data such as hydrologic data, geographic data, and historic data.

C. Quality Assurance Program

Quality assurance (QA) programs are critical to the success of monitoring. Good quality control (QC) data, and assessments of those data, can allow the comparison over time of data among agencies. Poor or non-existent quality control data can prevent such comparisons. As part of the implementation of the monitoring strategy, detailed QA[1] plans and performance criteria will need to be developed and put into practice as appropriate for each component of the plan.

There are three facets of quality assurance.

1. Quality Assurance elements are procedures that are used to control the unmeasurable components of a monitoring program such as sampling the wrong site or area; sampling at the wrong time; using the wrong equipment or materials; applying an inappropriate method or sequence of procedures for sample processing or sample analysis; switching samples; or incorrectly identifying samples.
2. Quality Control data are those data generated to estimate the magnitude of bias and variability in processes used to obtain environmental data. These processes include sample collection, field processing, shipping, storage, and laboratory analysis.
3. Quality Assessment is the overall process of assessing the quality of the environmental data by reviewing the application of the QA elements and the analysis of the QC data.

D. Performance Criteria

One objective of any monitoring plan is to establish performance criteria. For the *Monitoring Strategy* this will be accomplished in two ways.

1. All final sampling plans will specify those criteria that are quantifiable in advance. (Examples include frequency of sampling, geographic space between samples, number of samples used to make up a composite, hydrologic conditions to be sampled, and detection levels of analytical methods.)
2. All final sampling plans will include sufficient quality control data to estimate the magnitude of bias and variability that is associated with environmental sampling.

Specifying criteria is relatively easy to accomplish. Including sufficient quality control data may be more difficult because the variability and bias for many of the plans' components are unknown. This makes it difficult to establish performance criteria in advance of data analysis for all topics. It does not, however, prevent collecting sufficient QC data to estimate the bias and variability associated with each planned constituent. As the magnitudes of bias and variability become more quantified, then more specific performance criteria can be established.

E. Monitoring for Conventional Pollutants

Conventional pollutants are those constituents or characteristics of the water that occur naturally but as a result of human activity or, in some cases, as the result of natural events, have been altered in such a way as to have become problems for either the survival of aquatic organisms or a threat to human health. Conventional pollutants include bacteria, temperature, total dissolved gas, pH, dissolved oxygen, nutrients, total organic carbon, and sedimentation. Not included in this grouping are trace elements. Although they may occur naturally, in excess amounts they become toxic and are therefore included in the toxic contamination discussion. The following discussion provides a brief background on why the various conventional pollutants are of concern.[2]

1. **Bacteria** - Fecal coliform bacteria, an indicator of contamination by human or animal wastes, have, on occasion, been found at levels high enough to suggest a possible health risk for those having contact with the water.
2. **Temperature** - Late summer and early fall water temperatures in the lower river routinely exceed the water quality standard of 20 degrees C (68°F). The temperatures are sufficiently high to present a serious risk to native cold water species such as salmonids, particularly the juvenile downstream migrants.

3. **Total Dissolved Gas (TDG)** - During high flow periods in late spring and early summer, spillage over the dams causes excessive entrainment of dissolved gases, particularly nitrogen. The resulting supersaturation is significant enough to threaten the survival of juvenile salmonids and has caused large numbers of mortalities.
4. **Sedimentation** - Sediments can carry contaminants downstream and may be one of the mechanisms contributing to high toxic levels in some lower river sediments. Excessive levels of suspended sediments are not usually a problem in the lower river.
5. **Nutrients** - Nutrient concentrations in the lower river are at high enough levels to potentially cause nuisance algal blooms. This has typically not been a problem, but a better understanding of the river nutrient cycle, primary productivity, and food webs would enhance our understanding of the ecosystem and allow a determination of the adequacy of existing food webs to support native species.
6. **pH and Dissolved Oxygen** - On occasion there have been exceedances of water quality standards for both of these parameters. There seems to be little cause for concern, but they are easily tracked as part of an ambient program and should be assessed regularly to identify any significant changes. They also affect and are affected by primary productivity.

The conventional pollutant monitoring objectives (see Figure 5) are as follows:

Temperature

- Determine spatial, daily, and seasonal variability and long term trends.
- Determine if water temperatures exceed state standards.
- Determine effect of current management practices.
- Determine effect of proposed management alternatives.

Total Dissolved Gas

- Determine spatial and seasonal variability of TDG in Columbia and lower Snake rivers.
- Determine annually if TDG values exceed state standards.
- Determine effects of current management activities.
- Determine effects of proposed management alternatives.

Bacteria

- Determine the spatial and short-term variability of indicator bacteria concentrations associated with areas of water contact activities.
- Identify sources of contamination that can be minimized.
- Provide better quantification to the random reporting of rashes and itching associated with water contact recreation.

Nutrients, Dissolved Oxygen, pH, Major Ions, Suspended Solids, Total Organic Carbon, Chlorophyll

- Determine spatial and seasonal variability and long term trends.
- Develop baseline data for determining primary productivity.

F. Monitoring for Toxic Contaminants

Toxic contaminants tend to be human in origin with the exception of some naturally occurring trace metals. Regardless of the origin, however, they are toxic to aquatic life or humans if one is exposed to sufficient quantities or concentrations. The toxic contaminants of concern specifically identified in the Management Plan include dioxins/furans, PCBs, DDT and its metabolites, DDE and DDD, and Polycyclic Aromatic Hydrocarbons (PAHs). Several other pesticides and some trace metals are also of possible concern. In addition, recent monitoring of the sediments in the lower Willamette River in the Portland Harbor area indicate serious toxic contamination. The impacts of these findings remain unknown but will need to be addressed as more information becomes available. The following discussion provides a brief background on issues of concern related to toxics.

1. **Pesticides** - Concentrations of DDT and its metabolites DDE and DDD have been found in fish tissues in sufficient quantities to warrant concern for those who consume large amounts of fish. It is also suspected that these are passed up the food chain causing shell thinning in bald eagle eggs and possibly affecting the reproductive capability of other top predators such as otters and mink. A variety of other pesticides have been detected at low levels. The Bi-State Study identified aldrin, dieldrin, parathion, and chlordane as pesticides of possible concern.
2. **PCBs** - Concentrations of PCBs in fish tissue have been found in high enough levels to adversely affect wildlife and humans consuming the fish. There is concern that PCBs could be affecting the reproductive success of lower river eagles and otters.
3. **Dioxins/Furans** - Concentrations of dioxins and furans in sediments and fish tissue may be another contributing factor in the poor reproductive success of eagles, mink and otter. They may also pose a cancer threat to humans who consume large quantities of fish.
4. **Metals** - There are elevated levels of cadmium and chromium in the kidneys of otters, elevated levels of lead, mercury and cadmium in bald eagle eggs, elevated levels of mercury and arsenic in some fish tissues, and elevated levels of arsenic, cadmium, and copper in some backwater sediments.
5. **Radionuclides** - Radionuclides have been monitored in the lower river from 1961 to 1993. During this time no standards have been exceeded. There remains a concern, however, because of the storage of radioactive wastes and their possible movement in the groundwater.

For the purposes of monitoring, the toxic contaminants can be divided into three subgroups based on the type of medium: water column, sediments, and tissues. Each medium has a set of monitoring objectives (see Figure 5).

Water Column[3] **-** Contaminants in the water column can be separated broadly into organic compounds and trace elements. Organic compounds can be further divided into hydrophobic (low water solubility) and hydrophilic (water-soluble). Hydrophobic compounds include many pesticides, such as DDT and its metabolites, and PCBs. The Bi-State Study detected few of these constituents in the water column and recommended that further monitoring of this class of contaminants be conducted using tissues and sediments. Hydrophilic compounds include soluble pesticides and some industrial organics such as petroleum products. The Bi-State Study and others have observed detections for approximately 20 compounds of this class in the lower river.

Trace elements include metals such as arsenic, cadmium, chromium, copper, iron, lead, manganese, and zinc. The Bi-State Study and others found generally low trace element concentrations in filtered water, with the exception of iron and arsenic. Suspended trace elements also appear to be in low concentrations.

The toxic contaminant monitoring objectives for the water column are:

- Describe the spatial and temporal characteristics of contaminant concentrations in the water column, including both dissolved and particulate phases.
- Describe factors that are associated with transport of contaminants into, within, and from the study area. These include regional sources areas, hydrologic conditions, and potential management activities such as dredging and reservoir drawdown.

Sediments - A variety of contaminant problems may often be associated with sediments, both in the streambed and in the water column. In the lower Columbia River Basin, previously documented contaminants included a suite of organic compounds and trace elements. Notable among these have been several trace metals (cadmium, copper, and zinc), dioxins, furans, pesticides, and chlorinated organic compounds (including dieldrin, lindane, chlordane, PCBs, and DDT and its metabolites), and various industrial organic compounds such as PAHs and other semivolatile compounds. Many of the contaminants found in the lower river may have been transported from various point and non-point sources upstream of Bonneville Dam and from the Willamette River and other tributaries.

The toxic contaminant monitoring objectives for sediments are:

- Characterize the concentrations and characteristics of streambed sediment and associated contaminants within the study area. Contaminant characteristics include:
  - spatial distributions of sediments and contaminants;
  - correlations between grain size and/or organic content with contaminant concentrations; and
  - changes in contaminant concentrations over time, both seasonally (for suspended sediment) and annually (for both suspended and streambed sediments).
- Characterize the fate and transport of sediments (including associated contaminants) to, within, and from the study area.
- Characterize the impacts of selected upstream reservoirs on the transport of sediment and associated contaminants to the study area.

Tissues - From both an ecological and a human health perspective, contaminants in animal tissues in the lower Columbia River system are important. Previous studies, including the Bi-State Study, identified trace elements, dioxins and furans, chlorinated organic compounds such as PCB congeners, and DDT and PAHs in tissue from otters and bald eagles. In some cases, reported contaminant concentrations in the lower river have exceeded reference levels, causing concern for the health of a given species or for the humans consuming them. Bioaccumulation of contaminants in tissues is a particular concern.

The monitoring objectives for toxic contaminants in tissues are:

- Characterize the concentrations, distribution, and variability of contaminants in selected species of aquatic biota and wildlife with the food chain.
- Characterize the impacts of contaminants, using biological endpoints, in aquatic biota and wildlife in the study area.
- Characterize the relationships between biological endpoints and contaminant concentrations in aquatic biota and contaminant concentrations in sediment and water.
- Characterize human health risks from exposure to toxic chemicals in fish and shellfish in the lower Columbia River Basin.

Radionuclides

The toxic contaminant monitoring objectives for radionuclides are:

- Determine long term trends of radionuclide concentrations in water and sediments in the lower river.
- Determine exceedances of water and sediment standards by radionuclides in the lower river.

G. Habitat Monitoring

The Columbia River has lost a significant amount of habitat over the last century. The loss of natural habitat is closely related to the increase in urban and agricultural land and to activities that have altered river flow such as dams, diking, and irrigation withdrawals. Characterizing stream habitat is an important component of many water quality assessment programs, yet few detailed protocols exist for large rivers.

Habitat monitoring and assessment help identify the natural and anthropogenic factors that affect water quality and aquatic biological communities. Habitat assessments also are done to understand the physical, chemical, and biological consequences of altering stream conditions, or large changes in land use. Effective habitat monitoring consists of measuring physical and biological characteristics on several different scales. Habitat monitoring includes, but is not limited to, assessment of instream physical conditions, riparian areas, floodplains, wetlands, and land use activities.

The monitoring plan identifies six attributes of habitat for monitoring in the lower Columbia River. These are: channel configuration; vegetative state; bottom composition; floodplain and estuarine function, including wetlands and riparian zones; disturbed areas; and bathymetry. These attributes are not necessarily independent but are categories of assessment that may be studied in common manners and/or at common scales (see Figure 5).

The habitat monitoring objectives are:

- Determine the current status of each of six habitat attributes and relate them to baseline data to assess whether there have been significant changes in the type of habitat in the lower Columbia River.
- Determine the quality and function of these habitat components. Are there areas or processes that are dysfunctional and that may need special attention or restoration?

H. Exotic Species Monitoring

Although it is recognized that there are numerous aquatic non-indigenous species in the lower Columbia River, the exact number is unknown. One national data base identifies 120 aquatic non-indigenous species in Oregon. The accuracy of this information is suspect, but the possibility of a very significant problem for native species is quite real. Organisms such as the European Green Crab, Chinese Mitten Crab, Purple Loosestrife, Spartina, and others represent potentially serious threats to the ecological balance of the lower river.

Since species can just as easily reach the lower river from upstream as from the ocean, the whole river system needs to be monitored for introduced species. Unfortunately, that scope of monitoring is well beyond the range of the *Monitoring Strategy*. As a result, it is particularly important that the program maintain close communication and coordination with those groups who are addressing non-indigenous species issues throughout the entire system. Currently these include the US Coast Guard, Washington Department of Fish and Wildlife, and a regional effort administered by the Pacific States Marine Fisheries Commission.

The objectives for monitoring non-indigenous species in the lower river are:

- determine the populations of individual non-indigenous species and their distributions.
- determine and monitor mechanisms of introduction (e.g., ballast water discharge, recreational boats, etc.).

I. Monitoring for Nutrients, Primary Production and Food Webs

The Columbia River is home to a complex array of native species, including invertebrates, fish, raptors and seabirds, and mammals. Under historical conditions, many complex food web pathways supported these species. One important source of organic matter to these food webs is energy input through microalgal (phytoplankton) production. This provides a food source for invertebrate grazing, with subsequent consumption of the invertebrates by fish.

There is some scientific evidence that the estuary has shifted to a phytoplankton-derived food web in contrast to a historic, pre-development food web based more on wetland and intertidal production. The estuarine turbidity maximum (ETM), a zone of high productivity associated with resuspension of sediments near the interface of tidal saline and fresh water inputs, appears to have an overemphasis on phytoplankton production compared to historic conditions. The ETM in the Columbia River Estuary is considered to be one of the most important processes supporting food webs in the estuary, and its alteration could have important consequences for animals that depend on it. Other food webs supporting invertebrates originate from organic material, such as leaf litter, woody debris, and other detritus, as well as benthic macroalgae.

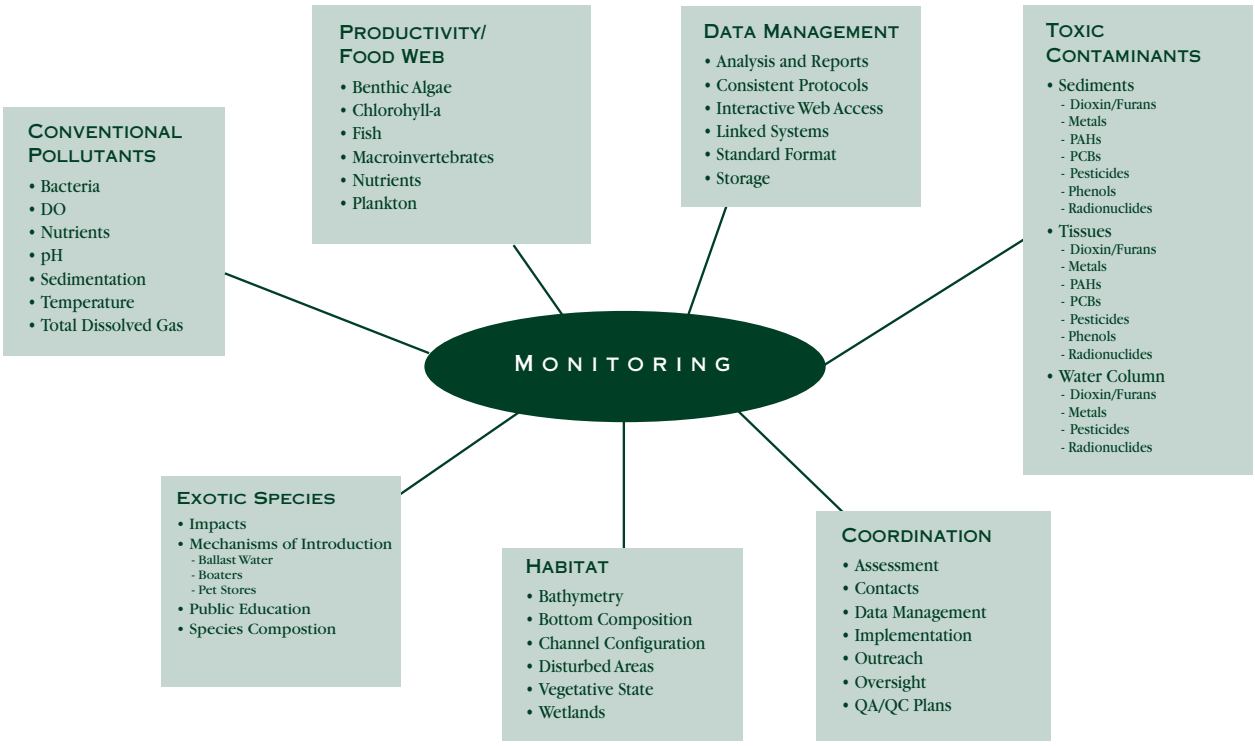
Algal and macroinvertebrate species data can be used to assess water quality, because both groups of organisms are sensitive to water quality conditions. Alterations in physical or chemical conditions have important implications on community structure, structural changes in aquatic food webs, and the survival and reproductive success of native species. However, although some data have been collected on algal populations, macroinvertebrates, and fish in the lower Columbia River, the systematic and comprehensive use of these data has been difficult because of the complete lack of a long-term sampling series. It has been further hampered by inconsistent basin-wide representation, sampling methodologies, and levels of taxonomic identification among studies. These studies are made more difficult in large rivers such as the Willamette and the Columbia because most established protocols for collection of invertebrates are designed for smaller rivers where the entire cross-sections can easily be assessed. There have been few, if any, attempts to describe the connections between physical and chemical conditions, primary production, and community structure of algae, macroinvertebrates, and fish populations.

The monitoring objectives for nutrients, primary productivity, and food webs are:

- Develop baseline information for indicator parameters reflecting food web structure, including suspended particulate matter, nutrients, dissolved oxygen and pH, primary productivity, and macroinvertebrates.
- Assess the temporal changes in water quality constituents associated with primary production, including dissolved oxygen, pH, nutrients, total suspended solids, biochemical oxygen demand, chlorophyll-a, and total organic carbon. Include diurnal, seasonal, and annual changes, determine the main factors controlling their variability, and determine whether these parameters meet water quality standards.
- Assess the overall biological integrity of the lower Columbia River by relating indicators of food web structure and production to higher trophic levels.
- Assess the long-term, cumulative impact of changes in hydrosystem operations and basin-wide watershed restoration activities on habitat and water quality improvement.

The diagram below provides a visual representation of the various components of the monitoring strategy and their relationships.

Figure 5
Monitoring Strategy Details



IX. Proposed Implementation Process

The following discussion provides the rationale and approach for the actual implementation of the *Monitoring Strategy*. It identifies decision factors that need to be considered and proposes a phased implementation process for each of the *Monitoring Strategy* components.

A. Prioritization of Monitoring Plan Recommendations

The recommendations in the monitoring plan were developed from an analysis of issues identified by the Bi-State Water Quality Report, the seven priority issues of the Management Committee, and from the Environmental Indicators papers. All recommendations are essential to achieving a comprehensive, sustained monitoring effort that will ultimately provide an ongoing analysis of river health.

To help further refine the recommendations in the monitoring plan and identify their priority for implementation, the recommendations were prioritized by the experts based on the degree to which each:

- adds information to highly valued topics;
- fills data gaps;
- is mandated or is already being done;
- fulfills management needs;
- is cost effective; and
- whether other actions depend on its implementation.

B. Other Decision Factors

1. Estuary program Objectives

First and foremost, the *Monitoring Strategy* must meet and be consistent with the objectives of the Estuary Program. Thus, all monitoring actions need to have a clear relationship to the seven priority issues and, more specifically, to those 31 actions that have monitoring implications. Monitoring actions which most clearly and directly address management concerns and needs would logically rise to the top of the implementation strategy.

2. Need for Information

The Bi-State Water Quality Study and the Estuary Program Management Plan identified a number of areas where information was lacking or needed further development. Monitoring actions that address these information gaps are essential.

3. Funding

Funding is one of the primary keys to successful implementation of the *Monitoring Strategy*. Decisions regarding which actions to implement will be highly dependent on the amount of money available, the sources of that funding, and the priority placed on the element under consideration. The *Monitoring Strategy* reflects this reality with its proposed phased implementation.

The Estuary Program anticipates funding from EPA for plan implementation, including monitoring. The Program has also requested funding from the States of Oregon and Washington for the 1999 biennium to assist with implementing both the Management Plan and the *Monitoring Strategy*. However, the funds anticipated from EPA and the states will not cover full implementation. They would support two thirds of a full-time employee in the first year which would ensure that, at a minimum, initial coordination efforts focused at setting up the monitoring structure and developing interagency agreements, could begin. Clearly, however, State and federal NEP funds will need to be augmented by other funds before any significant monitoring can be undertaken.

4. Cost

The costs of specific plan elements is also a factor in deciding what should be implemented and when. Prioritizing an action solely on cost would be inappropriate; the return on the investment should be paramount. If a key element must be completed before other work can be done and that item is expensive, its cost should not preclude it from having a high priority for implementation. Similarly, if the cost of an action is high, but the environmental improvement to be gained is high, cost should not preclude implementation. Likewise, if the cost of an action is high, but the cost of delaying the action is high in terms of ecological or public health, the action should not be precluded because of cost.

5. Existing Versus New Initiatives

There are existing monitoring activities on the river. Coordinating with and supporting these activities, if they meet program objectives, will be important to maximize the use of our monitoring dollars. By coordinating with existing programs we achieve not only cost savings, but we open up avenues of communication and data sharing. New initiatives will require time to develop and implement, and new funding to support them. Where such initiatives are necessary to provide missing data or basic data to support other needs, they must be prioritized accordingly.

6. Timing

The timing of the various monitoring components is also an important decision factor. Because certain programs already exist, some data collection can occur immediately. However, as noted earlier, some elements of the *Monitoring Strategy* are dependent on the implementation of others. Clearly, the timing of implementation will have to reflect both realities.

7. Benefits

The benefits derived from the implementation of a particular action will also carry weight in the decision process. Monitoring elements that need to be accorded special consideration include those most directly related to priority issues or management needs, those that are cornerstones of a number of other monitoring elements, and those that may be directly related to an important political objective, such as saving salmon. Both the short and long term benefit of implementing the action should be considered. Again, the cost of not acting must also be considered.

8. Agency Missions

Because the strategy will actually rely on agencies such as DEQ, Washington Department of Ecology, and USGS undertaking monitoring activities, the missions of those agencies will be a factor in decisions regarding implementation. As noted in an earlier section, agencies will likely be most supportive of monitoring actions that dovetail with their respective program needs.

9. Other Factors

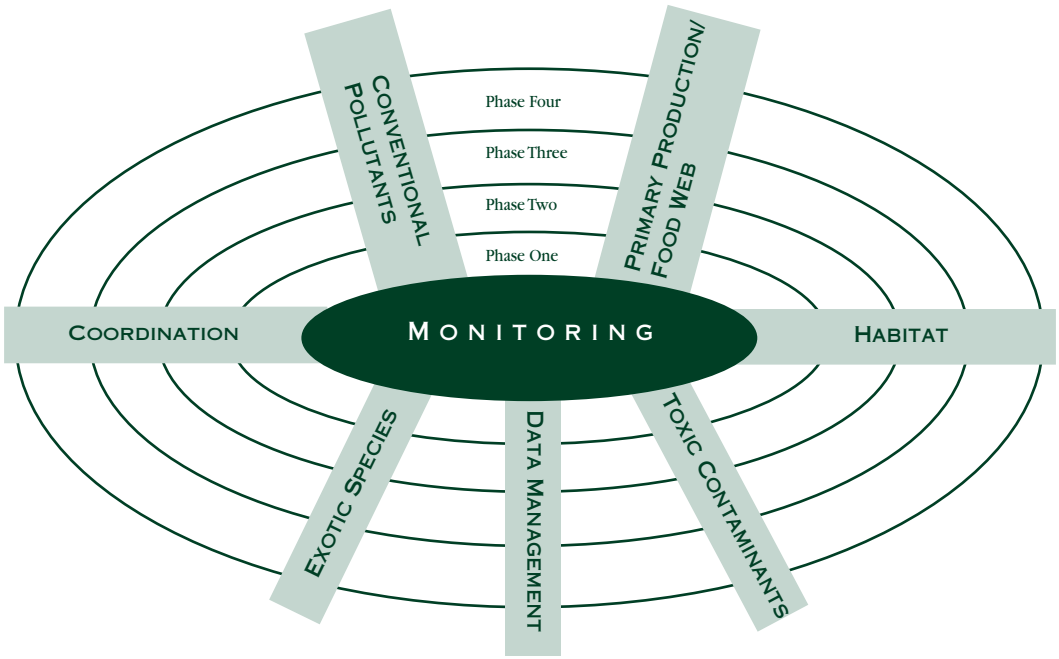
Other factors that may affect the decision process include the needs and concerns of Estuary Program stakeholders. As information becomes available, needs may change or evolve.

C. Phases of Implementation

The Estuary Program will almost assuredly not have sufficient resources to implement the entire set of recommendations at once. It is in fact likely that there will be very limited resources available during the first year of implementation. Recognizing that fact, and recognizing that a number of decision factors must continue to be assessed as the strategy progresses, it seems that the best, most logical approach is to implement the program in phases.

The discussion that follows identifies four broad implementation phases. They are not meant to be absolute; they need to be highly flexible based on resources, timing, management needs, information needs, and other presently unforeseen circumstances. Figure 6 depicts how the phases relate to the various components of the monitoring strategy.

Figure 6
Phases of Implementation



Description of Phases

1. **Phase One** would begin once the Management Plan is approved and the program implementation budget is available (on or shortly after July 1, 1999). Phase One would entail setting up the monitoring coordination structure and developing cooperative agreements between the monitoring partners. The coordination of existing ambient monitoring activities that can be linked to the Estuary Program would begin. Once the oversight structure is in place, Phase One could begin to address some of the first priority activities recommended in the monitoring if more resources are available. Decisions regarding the order in which the priority activities would be undertaken will be based on an evaluation of the decision factors described above.
2. **Phase Two** can be initiated as the funding base expands. Phase Two would include some high priority special studies, those elements of the monitoring recommendations that need more development (i.e., historic data analysis, determination of protocols or methods) and those needing information resulting from Phase One analysis. Assuming that sufficient resources are available, all first priority recommendations that are economically feasible should be implemented during Phase Two. Some of those ranked second priority may also be implemented.
3. **Phase Three** would include those elements that had not been previously funded, those ranked third priority, and those that are dependent on the development of information from Phase Two monitoring efforts. Phase Three would also include special studies and any other remaining elements. The development of new or more complete information under Phases One and Two will likely lead to a need for new studies or revisions to the existing recommendations. These needs could alter the priorities for Phase Three.
4. **Phase Four** would occur when the assessment of the original plan is completed in year five of the project. At this point, it is hoped that sufficient data will have been collected to allow for meaningful trend analysis and provide answers to some of the original management questions. It is assumed that a new set of recommendations would be developed during the assessment and that Phase Four would address those recommendations.

The phases and monitoring activities associated with each phase are detailed in Section X and in Table 7 in the Appendix.

D. Responsibilities for Implementation

A number of parties will implement aspects of the *Monitoring Strategy*. As described earlier, several agencies currently monitor at a number of sites. It is anticipated that existing ambient monitoring will continue. When the *Monitoring Strategy* calls for collecting additional data at existing agency monitoring sites, it may be feasible for that agency to extend its sampling to include the additional data needs. When the strategy calls for new efforts, those efforts could be completed by an existing agency or contracted out. In either case, new efforts will require new funds.

Some of the factors to consider in assigning responsibility for implementation include:

- Capability - does the agency or organization have expertise and knowledge to undertake the task?
- Capacity - does the agency or organization have the lab capacity and field staffing necessary to accomplish the task?
- History - has the agency or organization been involved in monitoring the Columbia River previously?
- Commitment - can the agency or organization commit to a long term program?
- Existing efforts - does the agency or organization have on-going programs that can be built upon?
- In-kind resources - can the agency or organization bring additional resources to the project such as matching funds or in-kind services?
- Mission - is the project consistent with the agency or organization's main mission?

The Estuary Program will take the lead in overseeing the implementation of the *Monitoring Strategy*. This will include convening and coordinating appropriate parties to seek the commitment and support to ensure that the strategy is implemented.

X. Implementation Recommendations

The section that follows recommends an approach for implementating each of the *Monitoring Strategy* components based on the four phases described in Section IX.

A. Monitoring Oversight

1. **Phase One—**establish a coordinated structure since there is currently no overall coordination of monitoring efforts on the lower Columbia River. This first step would include:
   - setting up the coordination structure and organizing a monitoring committee comprised of appropriate scientists and stakeholders;
   - working with the implementing committee of the Estuary Program and the monitoring committee to identify and allocate monitoring resources appropriately;
   - reaching agreement with existing ambient monitoring programs to coordinate their efforts with the Estuary Program, to share data, and to develop comparable procedures for sampling, quality assurance, data storage and assessment;
   - developing and overseeing any contracts for expanded monitoring work and special projects; and
   - beginning discussions with partners regarding expansion of existing programs.

2. **Phase Two—**expand monitoring activities and increased coordination and oversight Activities would include:
   - continuing oversight;
   - expanding special projects and overseeing implementation of Phase Two monitoring components;
   - beginning the assessment and evaluation of data; and
   - ensuring information is made available to the public and decision makers.
3. **Phase Three—**continue oversight and implementation of the recommendations for Phase Three monitoring components. Begin the process of re-evaluating the monitoring plan and developing a 5-year monitoring assessment report.
4. **Phase Four—**continue monitoring program oversight, implementation of any remaining recommendations from the original monitoring plan, and implementation of the recommendations from the 5-year monitoring assessment report.

B. Data Management

1. **Phase One**—Data Storage. Focus on locating all existing data, improving access to the existing data, and heightening public awareness of the information available.
2. **Phase Two—**Data Organization. Focus on creating uniform procedures for establishing protocols and procedures for collecting, analyzing and recording data that ensure consistency with data management standards; developing strategies for linking monitoring agency databases; storing all data on STORET X; and tracking the development of other relevant data.
3. **Phase Three—**Data Management (short-term). Over a period of up to three years, implement a short-term approach to managing data. It would include using the Estuary Program homepage to link a networked system of databases, and working with DEQ, Ecology and EPA to analyze data and develop reports.
4. **Phase Four—**Data Management (long-term). With the completion of the 5-year monitoring assessment report, seek resources for implementing the data recommendations from that report and for developing a totally interactive data management system for the lower Columbia River basin.

By design, this approach coincides with the phases of the Monitoring Strategy. However, data management needs may move at a different schedule than monitoring. Early monitoring needs will include gaining access to historic data and data storage capabilities, as well as achieving agreements on comparable protocols, procedures, data entry, and storage. Data assessment, trend analysis, and report needs will not occur for at least the first two to three years of data gathering. Clearly, if more funds are available, it would be desirable to establish a comprehensive data management system as soon as possible. Likewise, if the ability to analyze historic data is established early in the process, it would facilitate the development of monitoring strategies.

C. Conventional Pollutants

The recommendations for monitoring conventional pollutants based on the objectives described in Section IX are:

Temperature

1. Continue current ambient monitoring.
2. Conduct synoptic study of temperature in August at mouths of tributaries, causal sources, and within lower Snake and Columbia main stem.
3. Monitor temperatures in tributaries to complement existing ambient programs.

4. Fund an extension of USEPA temperature model to include the river below Bonneville Dam.
5. Continue the Estuary Program's participation in USEPA temperature modeling effort and the states' TMDL processes.

Total Dissolved Gas

1. USACE to continue current, continuous TDG monitoring operations for next 5 years.
2. USACE to adopt QA/QC plan for TDG program.
3. USACE to assess annually the number of days a site exceeds standards, noting whether the dam was voluntarily or involuntarily spilling water.
4. The Estuary Program to participate as reviewer and decision process for TMDL.

Bacteria

1. Continue current ambient monitoring, ensuring inclusion of indicator bacteria.
2. Develop comparable standards for Oregon and Washington.
3. Conduct bacterial survey at selected beaches (special study).
4. Conduct survey of water contact recreationalists to determine relationship between bacteria levels and incidences of rash, disease, etc.

Nutrients, Dissolved Oxygen, pH, Major Ions, Suspended Solids, Total Organic Carbon, Chlorophyll

1. Continue current ambient monitoring activities.
2. Add additional monitoring sites to provide better coverage of the ecosystem.

Decision Tables 1-5: Following each set of monitoring component recommendations is a decision table which takes each of the monitoring recommendations and broadly assesses the current status of the measure, what other pieces of information are needed to accomplish the task, what it will accomplish, its priority ranking, and what Management Plan actions are addressed. Darkened spaces indicate a positive response. Numbers refer to recommendations listed on the previous pages. As an example, in Table 1, "Temp 1" is the first recommendation for temperature and is found on the previous page. "Bact 4" is the fourth bacteria recommendation found above.

Table 1
Conventional Pollutants Decision Matrix

Monitoring Recommendation	Existing Program	Funding Needed	Historic Data Analysis Needed	Needs Protocols or Methods Developed	Needs Standards Adopted	Indicates Environmental Impacts	Measures Health Impacts	Measures Trends	Increases Understanding	Measures Compliance	Priority Ranking	CCMP Actions Addressed
Temp 1	■					■		■	■	■	1	2, 4, 10, 22, 32
Temp 2		■				■		■	■	■	2	10
Temp 3		■				■		■	■	■	3	2, 4, 10, 32
Temp 4		■				■		■	■		3	10, 32
Temp 5	■								■		3	32
TDG 1	■					■		■	■	■	2	32
TDG 2		■						■	■	■	3	32
TDG 3						■		■	■	■	3	32
TDG 4	■								■			32
Bact 1	■				■		■	■	■	■	3	8, 9, 16, 33, 34
Bact 2	■		■	■	■					■	3	22
Bact 3		■				■	■		■	■	3	22, 33
Bact 4		■				■	■		■	■	3	22, 33
Conv 1	■					■		■	■	■	none	30, 34
Conv 2		■				■		■	■	■	none	30, 34

The following is a proposed phased approach for conventional pollutants:

1. Phase One

a) Monitoring Partners: Ecology, DEQ, USGS, USACE, OGI.

- Continue existing ambient monitoring for temperature.

b) USACE:

- Continue existing monitoring for TDG.

c) Monitoring Partners: Ecology, DEQ, USGS.

- Continue existing ambient monitoring for temperature, bacteria, nutrients, DO, pH, SS, TOC, major ions, and C.

d) Estuary Program:

- Establish coordination structure, maintaining liaison with and supporting efforts of monitoring partners.
- Develop cooperative agreements to share data and develop comparable procedures for sampling, quality assurance, data storage, and assessment.

- Track development of TMDLs for temperature and TDG.
- Explore increasing the number of state ambient sites on the main stem of the lower river.
- Develop agreements and implement expanded ambient system with DEQ and Ecology.
- Begin discussions with Ecology and DEQ on a consistent standard for bacteria.

Recommendations Addressed: Temp 1,5 TDG 1,4 Bact 1,2 Conv 1

2. Phase Two

a) Monitoring Partners: Ecology, DEQ, USGS, OGI and USACE.
- Continue existing ambient monitoring for temperature and TDG.

b) Monitoring Partners: Ecology, DEQ, USGS.
- Begin expanded ambient monitoring for temperature, bacteria, nutrients, DO, pH, SS, TOC, major ions, and TOC.

c) Estuary Program:
- Maintain liaison with and support efforts of monitoring partners.
- Provide overall coordination of interagency ambient monitoring and data assessment.
- Contract to conduct synoptic study of August temperatures in mouths of tributaries.
- Reach agreement with monitoring partners to expand ambient temperature monitoring to include mouths of tributaries as necessary to further define TMDL issues.
- Help coordinate bi-state implementation of TMDLs for temperature and TDG.
- Facilitate adoption of Ecology and DEQ agreement on consistent standard for bacteria.
- Work with USACE to adopt QA/QC for TDG.

Recommendations Addressed: Phase One ongoing Temp 2,3 Conv 2 TDG 2

3. Phase Three

a) Monitoring Partners: Ecology, DEQ, USGS, OGI and USACE.
- Continue existing ambient monitoring for temperature and TDG.

b) Monitoring Partners: Ecology, DEQ, USGS.
- Continue expanded ambient monitoring for temperature, bacteria, nutrients, DO, pH, SS, TOC, major ions, and TOC.

c) Estuary Program:
- Maintain liaison with and support efforts of monitoring partners.
- Provide overall coordination of interagency ambient monitoring and assessment of data.
- Continue implementing TMDL management actions for temperature and TDG.
- Contract to conduct bacterial survey at selected beaches.
- Fund an extension of EPA temperature model below Bonneville Dam.
- Contract to conduct survey of water contact recreationalists for water contact diseases.
- Conduct major evaluation of data, develop status report and recommendations for next phases of the monitoring program.
- Work with USACE to assess exceedances of TDG standards.

Recommendations Addressed: Phases One, Two ongoing Bact 3,4 Temp 5 TDG 3

4. Phase Four

a) Estuary Program and Monitoring Partners:

- Evaluate the results of 5-year monitoring assessment report and implement permanent program for monitoring conventional pollutants.

b) Monitoring Partners:

- Continue existing ambient monitoring programs and modify as appropriate to meet new Estuary Program directions.

Recommendations Addressed: Phases One, Two, and Three ongoing

D. Toxic Contaminants

The recommendations for monitoring toxic contaminants in the water column, sediments, and tissues are:

Water Column

1. Use state and NASQAN ambient monitoring programs and their sites as the basis for developing monitoring program for contaminants in water. Augment state ambient programs to include monitoring for toxics at existing stations at mouths of key tributaries.
2. Estuary Program work with USGS in the redesign of NASQAN program in the Columbia River Basin.
3. Evaluate existing data to describe current conditions and guide development of sampling strategy for suspended and filtered water trace elements, hydrophillic pesticides, and hydrophobic compounds in water.
4. Consider periodic sample collection with 5-year intervals if ongoing programs are not augmented for toxics in water.

Sediments

1. Develop a baseline by sampling a few locations for a wide variety of constituents. Over time, scale back the number of constituents sampled and increase the number of locations and/or frequency. Fourteen sites are identified for initial sampling, and the following factors are noted for sampling design (see Chart 1, Appendix C, Map 1):
   - coordinate with tissue contaminant and habitat surveys wherever possible;
   - sample during low flow;
   - include boundaries of study area;
   - do not target specific point sources;
   - include both sides of river;
   - sample with variable frequency at different sites depending on contaminant levels;
   - target both backwater and main stem sites; and
   - focus on fine grained sediments.
2. Establish discharge measuring stations in tidally-affected portions of lower Willamette, and support the existing station in the lower Columbia to help determine fate and transport of contaminants.
3. Conduct reconnaissance sampling for toxic contaminants in water and suspended sediment in the lower Columbia River to define the optimum sample volumes and to develop sampling and analytical methods (special study).

4. Develop and implement a sampling program for contaminants in suspended sediment, based upon results of reconnaissance studies and analysis of existing data, which will also allow calculation of loads at the boundaries of the study area and the mouths of key tributaries. Coordinate this program with existing ambient monitoring programs whenever possible and augment those programs to include toxic contaminants as necessary (special study).
5. Evaluate the influence of identified "hot spots," contaminant spills, and dredging on contaminant transport (special study).
6. At selected sites, establish and maintain continuous measurement of turbidity as a surrogate for suspended sediment.
7. Estuary Program to promote a process providing guidance on management of contaminated materials in non-dredged sediments.
8. Conduct coring studies as an attempt to identify trends in contaminant concentrations in sediments (special study).
9. Conduct a study of sediment cores to determine the effect of extreme hydrologic events on the redistribution of sediment contaminants, especially into the estuary (special study).
10. Characterize contaminants in bed sediments within reservoir pools to evaluate the potential effect of sediment and contaminant mobilization due to dam draw down or removal (special study).

Tissues

1. Implement a phased approach by starting with amphipod/bivalve sampling in conjunction with streambed sediment sampling (recommendation Sed 1).
2. Develop stratified random network design for sampling fish populations. As they become available, use new data as well as data from ongoing USGS and EPA studies to modify network design.
   - Establish sampling strata that reflect differences in physical or biological characteristics and are organized into segments as defined by the Bi-State Study.
   - Sample constituents that are generally of the same groups as those included in the sediment studies, but allow modification for specific compounds.
3. Chose a final target species for monitoring.
   - Include fish species for sampling that represent a variety of niches and food webs in the river and estuary. Include both anadromous as well as resident fish.
   - Select species that are located throughout the specified reach, are important food sources for animals or humans or important indicator species, and have healthy sustaining populations that will not be impacted by sampling or overlapping food chain members.
4. Conduct statistical analysis of existing and new data to modify network (special study).
5. Examine human health risks from consumption of contaminated organisms.
6. Document fish and other species' life history/migratory patterns (special study).
7. Evaluate the impact of native verses hatchery fish on tissue contaminant data, including effects of barging, location of rearing, and contamination of hatchery fish by contaminants in food, especially PCBs (special study).

Radionuclides

1. Current monitoring by Washington Department of Health is adequate. No new sampling is recommended.
2. Include radionuclide data collected by the WDH during periodic *Monitoring Strategy* assessment to determine need to add the future monitoring.

Table 2
Toxic Contaminants Decision Matrix

Monitoring Recommendation	Existing Program	Funding Needed	Historic Data Analysis Needed	Needs Protocols or Methods Developed	Needs Standards Adopted	Indicates Environmental Impacts	Measures Health Impacts	Measures Trends	Increases Understanding	Measures Compliance	Priority Ranking	CCMP Actions Addressed
WC 1	■	■	■			■	■	■	■	■	2	8, 9, 16, 17, 29, 30
WC 2	■	■				■	■	■	■	■	2	30
WC 3	■	■	■			■	■	■	■	■	3	8, 9, 26, 30, 35
WC 4		■				■	■	■	■	■	3	8, 9, 12, 22, 25, 30, 35
Sed 1		■	■			■		■	■	■	1	8, 12, 34, 35
Sed 2		■				■		■	■		1	10
Sed 3		■		■		■	■	■	■		1	2, 10, 32
Sed 4		■	■	■		■	■	■	■		1	29, 30, 34, 35
Sed 5		■	■			■	■	■	■	■	1	8, 12, 30, 35
Sed 6		■				■		■	■	■	2	29, 32
Sed 7		■	■		■					■	2	2, 32
Sed 8		■	■	■		■		■	■		3	23, 29, 35
Sed 9		■	■	■		■		■	■		3	29, 39
Sed 10		■	■	■		■	■	■	■		3	39
Tis 1		■	■	■		■	■	■	■	■	1	29
Tis 2		■	■	■		■	■	■	■	■	1	12, 29, 34
Tis 3		■				■	■	■	■	■	2	29, 34
Tis 4		■	■			■	■	■	■		1	12, 29, 30
Tis 5		■	■			■	■		■	■	2	29
Tis 6	■	■	■						■		3	
Tis 7	■	■	■			■	■	■	■	■	3	
Rad 1	■						■	■	■	■	3	43
Rad 2		■					■	■	■	■	3	43

The following is a proposed phased approach for toxic contaminants.

1. Phase One

a) Estuary Program:

- Establish monitoring coordination structure and maintain liaison with monitoring partners.
- Develop cooperative agreements with monitoring partners to share data and to develop comparable procedures for sampling, quality assurance, data storage, and assessment.
- Begin discussions with ambient monitoring partners to include monitoring for toxics at existing stations in study area.
- Work with USGS to redesign NASQAN program to include toxic constituents or to develop separate monitoring program.
- Work with monitoring advisory committee to finalize baseline sampling network for toxics in sediments.
- Work with monitoring advisory committee to develop stratified random network design for monitoring toxics in fish tissue and choose final target species for monitoring.
- Participate in discussions on establishing discharge monitoring stations on lower Willamette River and lower Columbia River.

b) Monitoring Partners: DEQ, Ecology, USGS.

- Participate in discussions to develop cooperative agreements for sampling toxics.

Recommendations Addressed: WC 1,2 Sed 1,2 Tis 1,2

2. Phase Two

a) Estuary Program:

- Maintain monitoring coordination structure and liaison with monitoring partners.
- Implement baseline sampling for sediment toxics through contract or agreement with monitoring partners.
- Implement sampling for toxics in fish tissue through contract or agreement with monitoring partners.
- Contract for special study to analyze existing data, develop sampling design, and conduct reconnaissance sampling for toxics in water and suspended sediment in lower river to define optimum sample volumes and to develop sampling and analytical methods.
- Contract for special study to evaluate the influence of identified “hot spots,” contaminant spills, and dredging on contaminant transport.
- Reach agreement with USGS and other partners regarding discharge monitoring stations on lower Willamette and Columbia to help determine fate and transport of contaminants.
- Coordinate with Washington Department of Health on radionuclide monitoring.

b) Monitoring Partners: DEQ, Ecology, USGS.

- Begin sampling for toxics as part of regular ambient monitoring.

Recommendations Addressed: Phase One ongoing WC 3 Sed 3,5 Tis 3 RAD 1

3. Phase Three

a) Estuary Program:

- Maintain monitoring coordination structure and liaison with monitoring partners.
- With monitoring partners, evaluate results of baseline sampling program for sediment toxics and modify/cut back monitoring accordingly to include key constituents and sample sites enabling evaluation over time.
- With monitoring partners, evaluate results of the fish tissue study and existing data. Conduct statistical analysis to determine direction for continued long-term fishtissue monitoring.
- Based on the results of the reconnaissance sampling for toxics in water and suspended sediments and an analysis of existing data, develop an agreement with monitoring partners DEQ, Ecology, USGS to implement long-term sampling program to track trends.
- Through agreement with monitoring partners, establish and maintain continuous measurement of turbidity at selected sites.
- Contract for a special study of human health risks associated with the consumption of contaminated organisms and correlate it to fish and other species' life history/migratory patterns.
- With monitoring partners, stakeholders and other interested parties, develop a process to provide guidance on management of contaminated materials in non-dredged sediments.

b) Monitoring Partners: DEQ, Ecology, USGS.

- Continue ambient sampling for toxics and implement new studies based on agreements with Estuary Program.

Recommendations Addressed: Phases One and Two ongoing Tis 4,5 Sed 4,6,7

4. Phase Four

a) Estuary Program:

- Maintain monitoring coordination structure and liaison with monitoring partners.
- Contract for special study to attempt to identify trends in contaminants in sediments through core sampling and analysis.
- Contract for special study of sediment cores to determine the effect of extreme hydrologic events on the redistribution of sediment contaminants.
- Contract for special study to evaluate the impact of sampling native versus hatchery fish on tissue contaminant data.
- Contract for study to characterize contaminants in bed sediments within reservoir pools.
- Assess radionuclide monitoring to determine if more effort is needed.

b) Estuary Program and Monitoring Partners:

- Evaluate the results of the 5-year reassessment report.
- Adjust existing toxic monitoring programs, and develop and implement new toxic monitoring strategies.

Recommendations Addressed: Phases One, Two, Three ongoing Sed 8,9,10 Tis 6 Rad 2

E. Habitat

The recommendations for aquatic habitat monitoring are:

1. Conduct remote sensing, at high resolution (1 meter scale), to characterize habitat conditions and use the information to evaluate indicator sites and subsequent sampling schemes.
2. Complete a metadata survey to allow assessment of existing data from which to establish a baseline and establish current status and trends (special study).
3. Analyze existing data to reconstruct historical landscape patterns (special study).
4. Based on survey of existing data, develop and implement a sampling scheme that addresses sites, frequency, and approach. One set of sites should be located by stratified random sampling and one set should be added in a deterministic manner based on need.
5. Conduct aerial photography or high-resolution video multiple-spectral scanning. Consider repeating annually.
6. Conduct system wide bathymetry survey (special study).
7. Convene a habitat-and biological-monitoring workshop to solicit input on:
   - the habitat monitoring plan, including consideration of habitat component categories;
   - indicator sites, site selection, and methods of control of non-indigenous species;
   - large river habitat and Index of Biotic Integrity (IBI) monitoring protocols;
   - the use of the Hydrogeomorphic (HGM) approach for wetland assessment; and
   - Identification of additional key data gaps.

Table 3
Aquatic Habitat Monitoring Decision Matrix

The following is a proposed phased approach for monitoring aquatic habitat.

Monitoring Recommendation	Existing Program	Funding Needed	Historic Data Analysis Needed	Needs Protocols or Methods Developed	Needs Standards Adopted	Indicates Environmental Impacts	Measures Health Impacts	Measures Trends	Increases Understanding	Measures Compliance	Priority Ranking	CCMP Actions Addressed
Hab 1		■		■		■			■		1	1, 2, 3, 4, 5, 7, 9, 31, 32
Hab 2		■	■			■		■	■		1	1, 3, 9, 31
Hab 3		■	■			■		■	■		1	1
Hab 4		■		■		■		■	■		1	1
Hab 5		■		■		■			■		1	2, 3, 4, 5, 7, 9, 12, 31, 32
Hab 6		■	■	■		■			■		1	12
Hab 7		■		■		■		■	■		1	1, 2, 6

1. Phase One

a) Estuary Program:

- Establish monitoring coordination structure and maintain liaison with monitoring partners.
- Develop cooperative agreements with monitoring partners (including US Fish and Wildlife, Oregon and Washington Fish and Wildlife Departments, and others) to share data on habitat and to develop comparable procedures for sampling, quality assurance, data storage and assessment.
- Contract for a special study to survey existing habitat metadata and, as resources allow, analyze the data to establish a baseline and determine current status and trends.
- Conduct a workshop to identify ways to measure the biological integrity of lower Columbia River (workshop to be held in May 1999).

b) Monitoring Partners:

- Participate in workshop and the development of habitat assessment techniques.

Recommendations Addressed: Hab 2,3,7

2. Phase Two

a) Estuary Program:

- Maintain monitoring coordination structure and liaison with monitoring partners.
- Complete analysis of habitat metadata and begin development of aquatic habitat sampling scheme with monitoring partners and monitoring committee.
- Depending on results of May 1999 workshop, conduct a second habitat monitoring workshop as necessary to further refine sampling scheme and monitoring techniques.
- Contract to conduct remote sensing to characterize habitat conditions and to assist in developing sampling schemes.
- Contract for aerial photography or high-resolution video multiple-spectral scanning to better characterize habitat in study area (special study).
- Through contract or interagency agreement, begin implementation of aquatic habitat monitoring scheme using both stratified random sampling and deterministic approaches.

b) Monitoring Partners:

- Participate in development of habitat monitoring scheme.
- Participate in developing interagency agreements to implement habitat monitoring.

Recommendations Addressed: Phase One ongoing Hab 1,4,5

3. Phase Three

a) Estuary Program:

- Maintain monitoring coordination structure and liaison with monitoring partners.
- Provide overall coordination of interagency habitat monitoring and assessment of data.
- Contract for system wide bathymetry if not completed during Phase Two (special study).
- Contract for an analysis of habitat metadata to reconstruct historical landscape patterns and contrast them with existing conditions.
- Use data that has been gathered to begin overall assessment of habitat monitoring scheme for inclusion in 5-year reassessment report.

b) Monitoring Partners:

- Continue habitat monitoring and assessment.

Recommendations Addressed: Phases One and Two ongoing Hab 3,6

4. Phase Four

a) Estuary Program:

- Maintain monitoring coordination structure and liaison with monitoring partners.
- Provide overall coordination of interagency habitat monitoring and assessment of data.

b) Estuary Program and Monitoring Partners:

- Evaluate the results of the 5-year reassessment report.
- Adjust existing habitat monitoring program, and develop and implement new habitat monitoring strategies.

Recommendations Addressed: Phases One, Two and Three ongoing

F. Exotic Species

The recommendations for monitoring exotic species are:

1. Monitor mechanisms of introduction.
2. Sample at least once every 5 years. For those organisms that are not currently being adequately sampled, sample more frequently. For introduced benthic macroinvertebrates, sample at same time as sampling for contaminants in sediments. The following organism groups should be sampled:
   - Plants including terrestrial, wetland, and aquatic macrophytes
   - Zooplankton
   - Benthic macroinvertebrates
   - Amphibians
   - Fish
   - Reptiles
3. Create and promote an education program directed at recreational boaters, aquarium trade retailers and their customers, schools, and the public.
4. Evaluate the impacts of introduced species, such as the Asiatic clam and shad, to determine whether they compete with species such as salmon (special study).
5. Conduct a thorough review of existing efforts to sample non-indigenous organisms (special study).
6. In conjunction with the US Coast Guard, conduct an investigation of ballast water (special study).
7. In conjunction with the Oregon and Washington Fish and Wildlife Departments, investigate the introduction of non-indigenous species by recreational boaters (special study).
8. Examine the potential impacts of organisms that may just be reaching the estuary, such as green crabs, mitten crabs, and zebra mussels (special study).

Table 4
Exotic Species Monitoring Decision Matrix

Monitoring Recommendation	Existing Program	Funding Needed	Historic Data Analysis Needed	Needs Protocols or Methods Developed	Needs Standards Adopted	Indicates Environmental Impacts	Measures Health Impacts	Measures Trends	Increases Understanding	Measures Compliance	Priority Ranking	CCMP Actions Addressed
Ex 1			■	■		■		■	■		**2**	**1, 11**
Ex 2		■	■	■		■		■	■		**2**	**2, 4, 5, 11**
Ex 3	■	■							■		**2**	**11, 15, 18**
Ex 4		■	■	■		■		■	■		**2**	**11**
Ex 5	■	■	■						■		**3**	**11**
Ex 6		■		■	■	■		■	■	■	**3**	**11**
Ex 7		■				■		■	■	■	**3**	**11, 18**
Ex 8		■		■		■		■	■		**3**	**11**

The following is a proposed phased approach for monitoring exotic species.

1. Phase One

a) Estuary Program:

- Establish monitoring coordination structure and maintain liaison with monitoring partners.
- Develop cooperative agreements with monitoring partners (including Oregon and Washington Fish and Wildlife Departments, US Fish and Wildlife Service, US Coast Guard, and National Marine Fisheries Service) to share data on non-indigenous species and to develop comparable procedures for sampling, quality assurance, data storage, and assessment.
- As resources permit, evaluate results of US Coast Guard study and other information to begin developing strategy for exotic species monitoring.

b) Monitoring Partners:

- Assist in assessing existing information and developing monitoring strategy.

Recommendations Addressed: Ex 5

2. Phase Two

a) Estuary Program:

- Maintain monitoring coordination structure and liaison with monitoring partners.
- If not completed under Phase One, complete thorough review of existing efforts to sample non-indigenous species and finalize monitoring strategy.
- Through contract or interagency agreement, implement a sampling program directed at those species not currently being sampled through other programs.
- Contract to evaluate the impacts of introduced species to determine whether they compete with species such as salmon.

- Work with Fish and Wildlife agencies and the US Coast Guard to develop strategy for monitoring mechanisms of introduction.
- Work with Sea Grant, Oregon Marine Board, Fish and Wildlife agencies to create and promote an education program directed at recreational boaters, aquarium-trade retailers and their customers, schools, and the public.

b) Monitoring Partners:

- Assist in the monitoring and assessment of the impacts of non-indigenous species in the lower river.

Recommendations Addressed: Phase One ongoing Ex 1,2,3,4

3. Phase Three

a) Estuary Program:

- Maintain monitoring coordination structure and liaison with monitoring partners.
- Through agreement with monitoring partners or through contract, implement a strategy to monitor the mechanisms of introduction including ballast water, recreational boating, and other possible mechanisms.
- Use the information developed through the sampling program and special studies in Phase Two to develop agreements with monitoring partners to implement an ongoing program to assess the impacts of introduced species, including the impacts of those organisms that may just be reaching the estuary.
- Continue and expand educational efforts with all partner agencies.

b) Monitoring Partners:

- Continue and expand efforts to assess and address impacts of non-indigenous species in the lower Columbia River and the Columbia River basin.

Recommendations Addressed: Phases One and Two ongoing Ex 6,7,8

4. Phase Four

a) Estuary Program:

- Maintain monitoring coordination structure and liaison with monitoring partners.

b) Estuary Program and Monitoring Partners:

- Evaluate the results of the 5-year reassessment report.
- Adjust existing non-indigenous species monitoring efforts based on the findings of the report and develop and implement new strategies as needed.

Recommendations Addressed: Phases One, Two, and Three ongoing

G. Nutrients, Primary Production, and Food Webs

The recommendations for monitoring primary production and food webs are:

1. Develop a large Columbia River Index of Biotic Integrity (IBI) for macroinvertebrates as indicators of food web relationships.
   - Follow standard criteria and protocols for shallow and backwater habitats and other habitat types as necessary.
   - Developed and stratify IBI by habitat type.
   - For long-term monitoring, use the shallow and backwater sites used to develop IBI.

2. Conduct targeted studies of suspended particulate matter, nutrients, and primary production, both benthic and planktonic. Include interactions with macroinvertebrates and high trophic levels. Emphasize food web parameter assessments for tributaries and shallow and backwater habitats as highest priority over mainstem sites. Data collection may include:
   - remote sensing and continuous monitoring for chlorophyll, augmented with frequent profile sampling (consider continuous monitoring for nutrients, especially ammonia and nitrate, as technology improves);
   - analysis of primary production rates using C14 consumption or DO production;
   - analysis of coarse and fine grained particulate organic matter and benthic biomass;
   - analysis of algal community composition including multivariate statistical techniques to indicate water quality;
   - macroinvertebrate grazer populations in relation to primary production rates;
   - analysis of a variety of habitats including mainstem, shallow backwater areas, tidal reaches and mouths of tributaries; and
   - analysis of seasonal and daily variability.
3. Add chlorophyll-a to Ecology and NASQAN sample collection programs.
4. Complete a survey of metadata to fully assess the historical data and current sampling plans (special study).
5. Model (at large scale) primary production in above habitat areas (special study).
6. Assess food webs from benthic invertebrates through fish. Maximize amount of information and understanding of links between habitat, water quality, macroinvertebrates, and fish by doing assessments at same sites (special study).
7. Reconstruct history of water quality in the estuary and behind selected reservoirs by examination of diatoms in sediments (special study).
8. Reconstruct organic matter source of food webs by studying multiple stable isotope ratios in consumers and sediments, including cores (special study).

Table 5
Nutrients, Primary Productivity, and Food Webs
Monitoring Decision Matrix

Monitoring Recommendation	Existing Program	Funding Needed	Historic Data Analysis Needed	Needs Protocols or Methods Developed	Needs Standards Adopted	Indicates Environmental Impacts	Measures Health Impacts	Measures Trends	Increases Understanding	Measures Compliance	Priority Ranking	CCMP Actions Addressed
Prod 1		■	■	■		■		■	■		**1**	**1, 6**
Prod 2		■				■		■	■		**1**	**1, 11, 32**
Prod 3	■	■				■		■	■		**3**	
Prod 4		■	■					■	■		**3**	**10, 11**
Prod 5		■		■		■		■	■		**3**	**1, 11, 32**
Prod 6		■		■		■		■	■		**3**	**1, 11, 32**
Prod 7		■	■	■		■		■	■		**3**	
Prod 8		■	■	■		■		■	■		**3**	

The following is a proposed phased approach for monitoring nutrients, primary productivity, and food webs.

1. Phase One

a) Estuary Program:

- Establish monitoring coordination structure and maintain liaison with monitoring partners. With monitoring partners, develop cooperative agreements to include dissolved oxygen, pH, total organic carbon, nutrients, chlorophyll-a, and biological oxygen demand as part of ambient monitoring programs. Based on the results of the May 1999 workshop on biological integrity, work with monitoring partners and monitoring advisory committee to begin development of large Columbia River Index of Biotic Integrity for macroinvertebrates.

b) Monitoring Partners:

- Support development of cooperative monitoring agreements and development of IBI for macroinvertebrates.

Recommendations Addressed: Prod 1,3

2. Phase Two

a) Estuary Program:

- Provide oversight and coordination of cooperative ambient monitoring program.
- Develop agreements with monitoring partners to incorporate IBI into sediment sampling for toxics identified in toxics monitoring program.
- Contract for special study of suspended particulate matter, nutrients and primary production, including interactions with macroinvertebrates and higher trophic levels.

b) Monitoring Partners:

- Implement expanded monitoring to help assess primary productivity and food webs.

Recommendations Addressed: Phase One ongoing Prod 2

3. Phase Three

a) Estuary Program:

- Provide oversight and coordination of expanded cooperative ambient monitoring program.
- Work with monitoring partners to assess results of special study to monitor primary production and food webs to determine if this provides a reasonable assessment of biological integrity.
- Depending on results of analysis of special study in previous bullet, develop agreements to implement long term assessment of primary productivity.
- Contract to undertake the following special studies as resources allow:
  - a complete survey of metadata to assess fully the historical data and current sampling plans;
  - an assessment of food webs from benthic invertebrates through fish
  - maximize amount of information and understanding of links between habitat, water quality, macroinvertebrates, and fish by doing assessments at same sites; and
  - development of a model of primary production in above habitat areas.

b) Monitoring Partners:

- Participate in cooperative agreements for the long-term assessment of primary production.

Recommendations Addressed: Phase One and Two ongoing Prod 4,5,6

4. Phase Four

a) Estuary Program:

- Provide oversight and coordination of expanded cooperative ambient monitoring program.
- Contract for a reconstruction of the history of water quality in the estuary and behind selected reservoirs by examination of diatoms in sediments.
- Contract for a reconstruction of organic matter sources of food webs through studies of multiple stable isotope ratios in consumers and sediments, including cores.

b) Estuary Program and Monitoring Partners:

- Evaluate the results of the 5-year reassessment report.
- Adjust existing primary production and food webs monitoring efforts based on the findings of the report and develop and implement new strategies as needed.

Recommendations Addressed: Phases One, Two, and Three ongoing Prod 7,8

(Table 7 shows the entire monitoring strategy. It is included in the Appendix.)

H. Assessment

Assessing the data on a regular basis and evaluating the effectiveness of the Monitoring Plan and *Monitoring Strategy* are critical to the viability and relevance of the monitoring program. Much of the sampling scheme is premised on the fact that data gaps exist and that modifications will be needed as existing and new information is processed, as trends become apparent, or as management needs change.

The Estuary Program will work with its monitoring partners to comprehensively assess the Monitoring Plan and *Monitoring Strategy* to update our understanding of the river and to identify and implement any major changes that might be needed. That comprehensive review will occur at a minimum every five years. In addition, the monitoring plan and *Monitoring Strategy* will be assessed every two years as part of a biennial review of the Estuary Program. The 5-year comprehensive review will very likely result in a significant updating of the monitoring plan. The Estuary Program, in cooperation with its partners, will evaluate the information generated and the recommendations and provide direction for future efforts.

Some factors to consider in that review include:

- the current understanding of environmental conditions;
- any new or emerging problems for monitoring to track;
- the implementation of the existing plan and whether it is meeting goals and expectations, schedules, etc.;
- the overall working relationship between the partners;
- interpretation of the data to date to include trends, sources of pollutants;
- the success of the data management strategy;
- information dissemination to the public, decision makers, and others;
- the adequacy of funding and resources;
- design problems and successes;
- scheduling and logistics problems;
- contractual concerns;
- QC data review including a review of procedures;
- data surprises and information gaps that need to be addressed; and
- new information available.

XI. Costs

The numbers below attempt to provide some indication of how much the various elements of the *Monitoring Strategy* in each of the four phases will cost. Some of the figures are fairly accurate, but most are only gross estimates. (Note: the costs are not cumulative from phase.) A key activity under Phase One of the *Monitoring Strategy* will be to work with the members of the monitoring advisory group to develop a detailed scope of work for each monitoring element in Phase Two, identify anticipated costs, and develop a schedule for implementation based on available resources, priority needs, etc. Similarly, the staffing levels needed to implement Phase Two will have to be developed as a part of that process.

A. Phase One	Phase One Year One Costs	Ongoing Costs
Oversight & Coordination	$48,000 .67 FTE	$48,000
Data Management		
Interagency Agreements		
Establish Advisory Committee		
Followup Biological Integrity Workshop	$10,000	
Data Management Contract (enhanced access)	$20,000	$20,000
Habitat Metadata Analysis	$30,000	
TOTAL	**$108,000**	**$68,000**

B. Phase Two	Phase 2 Year One Costs	Ongoing Costs
Oversight & Coordination	$72.000 1.0 FTE	$72,000
Project Support	$45,000 1.0 FTE	$45,000
Data Management Contract	$50,000	$50,000
Add DEQ ambient site w/toxics	$7,500 @ 6 samples/yr	$7,500
Add Toxics to existing DEQ ambient sites (one Willamette, one Columbia)	$12,000/yr	$12,000
Fund USGS ambient site w/toxics (possible cost share available)	$70,000 @ 6 samples/yr	$70,000
Synoptic Temperature Study	$50,000	
Tributary Temperature Study (5 new sites + existing ambient trib sites)	$5,000	
USACE - TDG - QA/QC	$2,500	
Sample plan for toxics in sediments, tissues	$20,000	
Baseline sampling for sediment toxics (20 sites)	$64,000 @ 3,200/site	$25,000
Boat & Crew	$17,000 for 4 days	$8,500
QA review	$15,000	$5,000
Baseline for toxics in fish tissue (100 samples)	$320,000 @ $3,200/each	$64,000
Boat & Crew	$12,500 for 8 days	$6,000
QA review	$15,000	$5,000

Reconnaissance sampling for toxics in water and suspended sediments	$10,000 existing data analysis & sample design, sample costs covered above	
Develop discharge monitoring stations	$30-40,000 installation $30,000 2 sites/yr	$30,000
Develop habitat sampling scheme	$20,000	
Implement habitat sampling (10 sites)	$50,000 4 times/yr	$50,000
Conduct remote sensing	$145,000	
Conduct aerial photography or video scanning	$80,000	
Review of existing exotic species monitoring	$30,000	
Develop & implement sample program for target exotics (10 sites)	$15,000	
Determine impacts of introduced species	$100,000	
Create exotic species education program	$10,000	$10,000
Develop strategy to monitor mechanisms of introduction	existing staffing	
Develop large Columbia River IBI	$30,000	
Initial primary productivity sampling (3 sites)	$7,500 analysis	$15,000
	$5,000 field work	$10,000
TOTAL	**$1,345,000**	**$485,000**

C. Phase Three	**Phase 3 Year One Costs**	**Ongoing Costs**
Oversight & Coordination	$72,000	$72,000
Project Support	$45,000	$45,000
Data management	$50,000	$50,000
Data analysis & evaluation report	$100,000	
Ongoing DEQ ambient site w/toxics	$7,500	$7,500
Continue toxics @ existing DEQ ambient sites	$12,000/yr	$12,000
Ongoing USGS ambient site w/toxics (possible cost share available)	$70,000	$70,000
Bacterial survey @ selected beaches	$175,000	$175,000
Extend EPA temperature model below Bonneville	EPA funds	
Survey for water contact diseases	$60,000	
Evaluate sediment & tissue toxics sampling	$25,000	

Modify sediment sampling program (est 5 sites)	$8,000 @ $1,600/site	$8,000
Boat & Crew, QA review	$6,000	$6,000
Modify fish tissue sampling program (20 samples)	$32,000 @ $1,600/site	$32,000
Boat & Crew, QA review	$8,000	$8,000
Ongoing sampling for toxics in water based on Reconnaissance survey	costs covered above	
Continue habitat sampling (10 sites)	$50,000 4 times/yr	$50,000
Continue discharge monitoring stations	$30,000	$30,000
Establish continuous turbidity monitoring (3 sites)	$30,000 @ $10,000/site	$30,000
Health risk study on effects of consuming contaminated organisms	$100,000	
Develop guidance on management of contaminated materials in non-dredged sediments	coordination costs	
Conduct system wide bathymetry	$75,000	
Reconstruct historical landscape patterns	$50,000	
Monitor mechanisms of exotic species introduction	$60,000	$60,000
Implement program to assess impacts of introduced species	$100,000	$100,000
Expand educational efforts targeting exotic species	$20,000	$20,000
Analyze results of initial primary productivity work	$15,000	
Implement ongoing primary productivity assessment	$25,000	$25,000
Survey metadata related to primary productivity	$10,000	
Assess food webs from macroinvertebrates to fish	$150,000	
TOTAL	**$1,385,500**	**$800,500**

D. Phase Four	**Phase 4 Year One Costs**	**Ongoing Costs**
Oversight & Coordination	$72,000	$72,000
Project support	$45,000	$45,000
Data management	$50,000	$20,000

Develop revised monitoring strategy	existing staff & partner agencies	
Ongoing DEQ ambient site 6 samples w1/toxics	$2,500	$2,500
Continue toxics 1/yr at existing DEQ sites	$2,000	$2,000
Ongoing USGS ambient site 6 samples w1/toxics (possible cost share available)	$35,000	$35,000
Continuous turbidity monitoring	$30,000	$30,000
Ongoing discharge monitoring	$30,000	$30,000
Core analysis for trends in sediment contaminants (5 sites)	$30,000	
Core analysis for extreme hydrologic events (5 sites)	$10,000	
Evaluate contamination of native vs hatchery fish tissue	$100,000	
Characterize contaminants in bed sediments within	$40,000	
Assess existing radionuclide monitoring efforts	$5,000	
Use diatoms to reconstruct history of water quality behind selected reservoirs	$30,000	
Reconstruct organic matter sources of food webs through studies of multiple stable isotopes	$70,000	
TOTAL	**$551,500**	**$234,500**

Continuation of the following monitoring to be determined as part of revised strategy.	
Sediment sampling for toxics	$14,000
Tissue sampling for toxics	$40,000
Habitat sampling	$50,000
Exotic species sampling for impacts, extent and new introductions	$70,000
Primary productivity assessment	$25,000
TOTAL	**$199,000**

Total Program Costs

Entire package one time cost approximately:	**$3.5 million**
Ongoing portion of package approximately:	**$450,000/year**

XII. Conclusions

Comprehensive, long term environmental monitoring is critical to further our understanding of the lower Columbia River, track trends in the health of the river and its resources, pinpoint problem areas, assure compliance with water quality standards, measure biological integrity, and assess the effectiveness of management actions over time.

With the exception of one-time studies, most of the elements of the *Strategy*, once it reaches full-scale implementation, are long term features. Such things as measuring trends in water quality, assessing river health and tracking the success of management actions can only be accomplished with persistent, consistent sampling efforts over the long run. The Estuary Program and its participating partners need to seek sustained, dependable funding from a variety of sources to maintain the monitoring effort over time.

A comprehensive, coordinated *Monitoring Strategy*, built upon existing ambient monitoring programs, is the most resource efficient way to implement long term environmental monitoring on the lower river. The *Strategy* should support the continuation and enhancement of existing monitoring programs and provide the framework for a cooperative, collaborative monitoring effort by all monitoring organizations as well as an oversight mechanism to ensure effective coordination.

Because it is a two-state stakeholder process, the Estuary Program plays a critical role in ensuring the full and long-term implementation of monitoring for the lower Columbia River and estuary. The Estuary Program will take the lead by adopting this *Monitoring Strategy*.

Cooperative agreements between all involved parties will be needed to ensure commitments for:

- implementing the monitoring strategy;
- developing comparable sampling protocols and procedures;
- developing comparable quality assurance procedures;
- storing and sharing data;
- analyzing and assessing data; and
- disseminating information to the public.

The Estuary Program will take the lead in developing cooperative agreements with all organizations participating in the monitoring to ensure their commitment and participation. All those involved in implementing the Estuary Plan should commit to supporting the *Monitoring Strategy* for the long term.

Effectively managing the large volume of existing information, and that which will be developed as the *Monitoring Strategy* is implemented, is critical to the success of the program, as is making that information readily available to all interested parties. The Estuary Program will take the lead in coordinating information management.

A phased approach to implementation that supports and augments existing programs, and implements top priority monitoring recommendations as resources are available, is the most logical approach in light of limited funding and resources. A stable, long-term funding source is needed to ensure the viability of the *Monitoring Strategy*.

The *Monitoring Strategy* is meant to be here for the long run. Continued monitoring will be needed to track trends over time, and to make sure that the public and decision-makers are continually appraised of the health of the river. Constant vigilance in the form of monitoring will be needed, or gains made today will be lost to the continuing, insidious onslaught of population growth. The Willamette River is a case in point. Forty years ago, we celebrated saving it from the brink of extinction, only to face the reality that, once again, it is in need of saving. Constant surveillance and aggressive natural resource management will be needed to prevent the incremental deterioration of the lower Columbia River. Stable funding and a long-term commitment from the project participants and supporters are the only way this effort can be meaningful.

XIII. Acknowledgments

Much of the credit for this document goes to Chauncey W. Anderson who edited the monitoring plan and managed the Long-Term Monitoring Subcommittee through the lengthy and sometimes trying process of developing the monitoring plan. Credit also goes to Ian Waite and Stuart McKenzie who led the Habitat and Conventional Pollutants work groups, respectively. Finally, the project would not have been completed without the commitment of the subcommittee members themselves who found time in busy schedules to participate in this process. Members of the subcommittee included:

State and Local Agencies

Oregon Department of Environmental Quality	Gene Foster, Greg Pettit, Gil Wistar
Oregon Department of Fish and Wildlife	Dan Bottom
Oregon Department of Health	Duncan Gilroy
Lower Columbia Estuary Program	Bruce Sutherland
Washington Department of Ecology	Bill Ehinger

Colleges and Universities

Oregon Graduate Institute	Phil Barrett
Oregon State University	Patricia Benner, Marty Fitzpatrick
University of Washington	Charles “Si” Simenstad

Private Organizations

EVS Environment Consulting	Steve Ellis
Port of Portland	Kathi Futornik, Rollie Montagne
National Council of the Pulp and Paper Industry for Air and Stream Improvement	Paul Wiegand

Non-profit Organizations

Oregon Trout	Steve Hinton
Pacific Environmental Science Centre	Colin Levings

Regional Governments

Columbia River Estuary Study Taskforce	Kathy Taylor

Federal Agencies

US Geological Survey	Chauncey Anderson – Coordinator, Report editor, work group leader Ian Waite – work group leader, Stuart McKenzie – work group leader Valerie Kelly, Tim Bartish, Stan Smith, Dena Gadomski, Chuck Henny
US Fish and Wildlife	Jeremy Buck, John Marshall
National Marine Fisheries Service	Susan Hinton, George McCabe, Bruce McCain
US Environmental Protection Agency	Pat Cirone, Jack Gakstatter
US Army Corps of Engineers	Mark Siipola, Bob Willis

XIV. References

Anderson, C.W. 1998, Interagency Long-Term Monitoring Plan to Assess Water Quality, Sediment Quality, Aquatic Health, and Biological Integrity in the Lower Columbia River. Unpublished Report to the Lower Columbia River Estuary Program. 153 pp

Tetra Tech, Inc. 1996, Integrated Technical Report – Summary and Synthesis of Study Findings, 1990-1996: Redmond, Washington. Prepared for the Lower Columbia River Bi-State Water Quality Program. 109 pp

Footnotes

1 A more detailed discussion of this is located in the monitoring plan, page 39. All monitoring organizations have their own QA/QC procedures and they may not be the same. Efforts will have to be made to ensure that the procedures of the monitoring partners are comparable.

2 More detailed discussions on all the components, e.g., conventional pollutants, toxic contaminants, etc., can be found in the monitoring plan along with a complete list of references. Discussions can also be found in the Environmental Indicators papers. These are both available from the Estuary Program office.

3 A detailed technical discussion on toxic contaminants in water is contained in the monitoring plan, pages 103-111.

XV. Appendix

A. Table 6: Summary of ongoing data collection and monitoring activities in the Columbia River Basin

B. Table 7: Monitoring Implementation Strategy

C. Map 1: Existing and proposed monitoring sites

Table 6: Summary of Ongoing Data Collection & Monitoring Activities in the Columbia River Basin

Field means field parameter, or temperature, DO, pH, Specific Conductance; TSS = Total Suspended Solids (evaporated); TDS = Total Dissolved Solids; SS=Suspended Sediment; Nut. = Nutrients; Majors = major ions (cations +anions); Bac-T=Bacteria; Benth=benthic invertebrates in wadeable streams; BOD = biological oxygen demand; COD = chemical oxygen demand; CBOD = carbonaceous biological oxygen demand; TOC=Total Organic Carbon; TOX = total organic halides; TE=Trace Elements; OC=organochlorines, including DDT and PCBs; Pests=Dissolved Pesticides; PAH = polycyclic aromatic hydrocarbons; D/F= Dioxins and Furans; TBT = tert-butyl tins; Alk = alkalinity. Note: TSS, TDS, and SS are indicated separately because of methods differences.

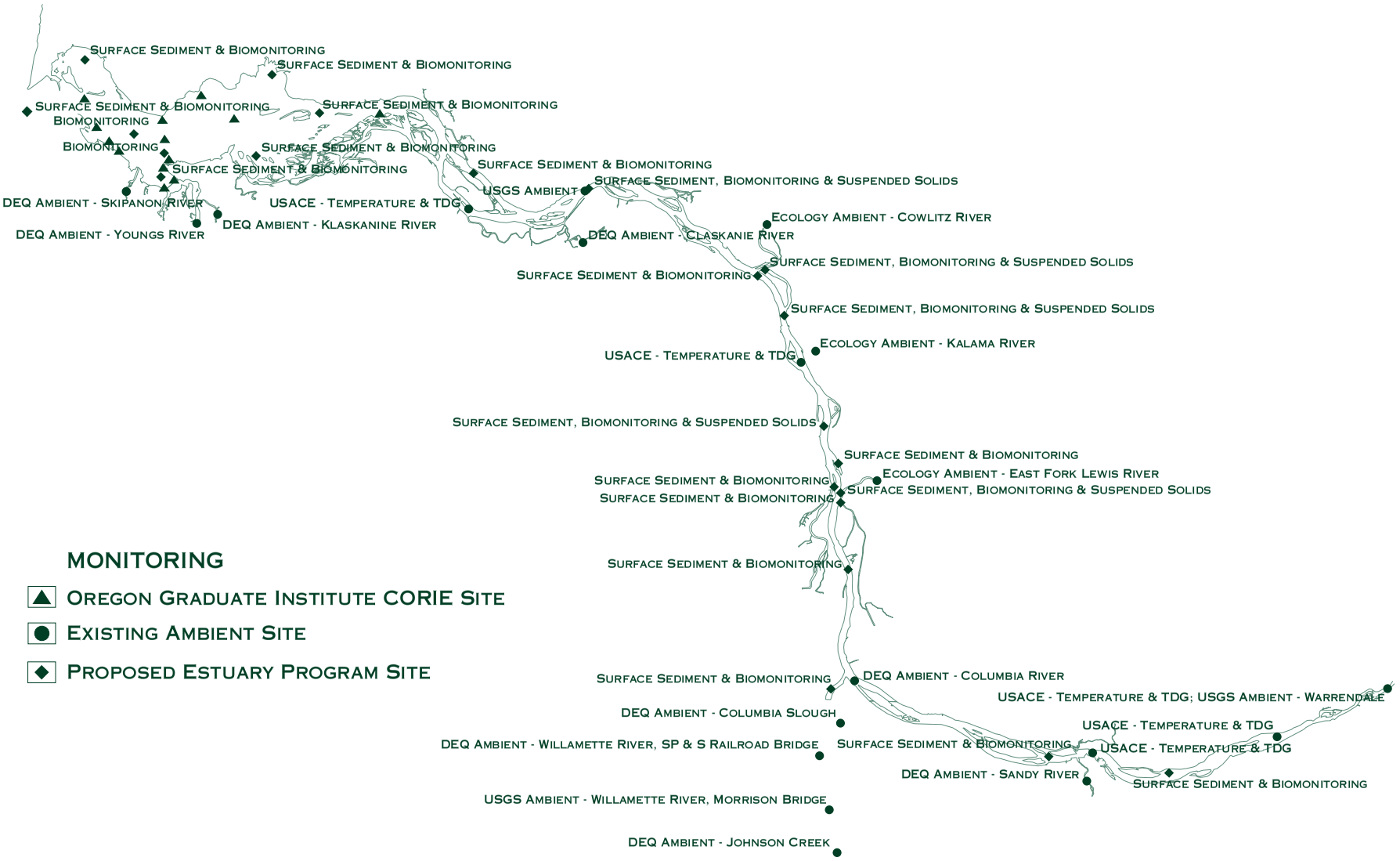
Program Name/ Description	Program Objectives	Time Frame		Spatial Coverage in Columbia Basin	Constituents	Remarks
		Period	Frequency			
Washington Department of Ecology (WDOE) - Contact: Bill Ehinger 360-407-6682						
Ambient Monitoring	Trend monitoring Standards compliance	Ongoing	Monthly	Yakima, Walla Walla, Snake, Cowlitz, E.F. Lewis, Kalama Rivers	Field, TSS, Bac-T, Benth.	Analysis of toxics performed irregularly
Oregon Department of Environmental Quality (ODEQ) - Contact: Greg Pettit 503-229-5983						
Ambient Monitoring	Trend monitoring Standards compliance	Ongoing	Monthly	Young's, Lewis & Clark, Skipanon, Klatskanine, Clatskanie, Willamette, Sandy, Columbia River @ marker 47 (RM 102.5) & other upper basin rivers.	Field, TSS, Alk, Bac-T, Majors, BOD, COD, chlorophyll, TOC, color, turbidity, TOX (Willamette Valley only)	No toxics regularly monitored See ODEQ, 1994b
National Council of the Paper Industry for Air and Stream Improvement (NCASI) - Contact: Paul Wiegand 541-752-8801						
Effluent monitoring	Compliance testing	Ongoing	Daily	All mills	TSS, BOD, CBOD, ??	No toxics
U.S. Army Corps of Engineers (USACE) - Contact: Mark Siipola 503-808-4885						
Channel Deepening	Measure contaminants in bottom sediments in navigation channel	One Time Study		• Columbia (RM 3 - 116), 89 sites • Lower Willamette, 43 sites • Navigational Channels only	• Grain size, % volatile solids at all sites. • TE, pthalates, phenols, OC, PAH, TBT4, @ select sites	• Testing new screening technique using biolumin-escense (P450 RGS) • Impact and gravity cores in Willamette
O&M (side channels)	Maintain side channels	Ongoing	Every 5 yrs	Ilwaco, Chinook, Old Cowlitz, Lower Willamette	• Grain size, %volatile solids at all sites. • TE, pthalates, phenols, OC, PAH, TBT4, @ select sites	
Total Dissolved Gas	Standards compliance	Ongoing		11 locations in Lower Columbia River	• TDG, Temperature	• With USGS
Port of Portland - Contact: Kathie Futornik 503-731-7236						
Terminal 4 Cleanup	Federal mandate to clean contaminated sediments	Proposed	One time	Near Terminal 4 in Willlamette River (~RM 6), and near Swan Island	TBT, Metals	Awaiting clarification of cleanup requirements
U.S. Geological Survey, Water Resources Division (USGS, WRD) - Contact: Valerie Kelly 503-251-3244						
NASQAN	• Long-term monitoring, basin wide • Characterize loads & concentrations in water column & suspended sediments	1995 - ?	15 x /year	4 Sites in Columbia, 1 in Snake, 1 in Willamette	• Field, Nut, SS, Pests, TE • TE in suspended sediment	• No OCs, D/F, PAH • Also, one time sampling of bed sed. @ lower sites
SPMD's	• Determine relative concentrations of hydrophobic compounds in water • Source delineation	1997	Low flow & some high flow	16 locations in Columbia & Willamette Rivers	OCs, PAHs, D/F, Semivolatiles	Data expected after Spring, 1999
U.S. Geological Survey, Biological Resources Division (USGS, BRD) - Contact: Tim Bartish 970-226-9483						
BEST	• Long term monitoring (?) • Document occurrence and distribution of contaminants in tissues in biota	1997	Planned Biannual	7 Sites in Columbia, 3 in Snake, 2 in Willamette, 1 each in Yakima, Salmon, Flathead	• 7 Biomarkers • OC, TE in whole fish	Uses NASQAN & NCBP sites
U.S. Environmental Protection Agency (USEPA) - Contact: Pat Cirone, 206-553-1597						
Contaminants in fish consumed by Native Americans	• Assess fish consumption exposure to toxics for tribes • Determine health risks to tribes	1997	One time	• Upper Columbia (above Bonneville) • 288 samples, > 90 sites	• >180 chemicals • D/F, OC, TE, PAH, PEST, Volatile & Semivolatiles	

Table 7: Monitoring Implemention Strategy

Note: Year 1 is in bold.

Phases of Implementation	Monitoring Oversight	Data Management	Conventional Pollutants
Phase One	• **set up coordination structure & monitoring committee,** • **develop interagency agreements and contracts, process to identify and allocate resources,** • begin discussions on expansion of existing programs	• **locate all existing data,** • **improve access to data,** • **heighten public awareness**	• **continue existing ambient programs for temp., TDG, bacteria, DO, pH, SS, TOC, C, nutrients,** • **track TMDLs for temp and TDS,** • explore increasing scope and number of ambient sites, • begin discussions on consistent bacteria standards
Phase Two	• continue oversight, • expand ambient programs, • expand special projects, • implement phase two components, • begin assessment of data, • ensure information reaching public, • add extra staff as needed	• agreements on consistent monitoring protocol and procedures and data management standards, • develop strategies for linking databases, • all data on STORET X, • track development of other relevant data	• expand existing ambient monitoring for other parameters and more sites, • conduct synoptic study of temp in mouths of tributaries, • further define temp TMDL, • facilitate adoption of consistent bacteria standard, • work with USACE for QA/QC for TDG
Phase Three	• continue oversight, implement phase three monitoring components • begin developing 5-year monitoring assessment report	• implement short-term approach to managing data using Estuary Program homepage to link a networked system of databases, • work with DEQ, Ecology and EPA to analyze data and develop reports	• continue expanded ambient monitoring, implement TMDL management actions for temp and TDG, • contact to conduct bacterial survey at selected beaches, • conduct survey of water contract recreationists, • conduct evaluation of data and status report
Phase Four	• continue oversight, • implement any remaining monitoring components, • seek resources for and implement recommendations from 5-year monitoring assessment report	• seek resources to implement the data recommendations from the 5-year report to possibly include totally interactive data management system	• continue existing ambient programs • implement permanent program for monitoring conventional pollutants based on recommendations of 5-year report

Toxic Contaminants	Habitat Monitoring	Exotic Species	Nutrients, Primary Productivity, Food Web
• **work w/USGS to redesign NASQAN to include toxics,** • **explore expanding existing ambient programs to include toxics,** • establish baseline sampling network for toxics in sediments, • develop random network for monitoring toxics in fish tissue, • begin discussions on discharge monitoring stations	• **conduct workshop on measuring biological integrity,** • **develop agreements to share habitat data with all parties,** • develop habitat monitoring procedures, • contract for special study to survey existing habitat metadata	• **develop agreements with all involved entities to share data and develop comparable procedures for monitoring exotic species,** • evaluate existing information on exotic species to begin developing strategy for monitoring	• **explore expanding existing ambient monitoring programs to include productivity parameters DO, pH, TOC, nutrients, chlorophyll a, and BOD**, • work with monitoring partners to begin development of index of biotic integrity for macroinvertebrates
• expand existing sites to include toxics, • implement sampling for toxics in sediment and fish tissue, • contract for special study to analyze existing data, • develop sampling design and conduct reconnaissance sampling for toxics in water and suspended sediments, • contract for special study on hot spots, • establish discharge monitoring stations, • coordinate on radionuclide monitoring	• complete analysis of metadata • begin development of habitat monitoring scheme, • conduct second habitat monitoring workshop, • contract to conduct remote sensing, • contract to begin habitat monitoring • contract for aerial photography or high-resolution video multiple-spectral scanning to characterize habitat	• complete review of existing data and finalize monitoring strategy, • implement sampling program aimed at species not currently being sampled, • contract to evaluate impacts of introduced species, • develop strategy for monitoring introduction, • create educational program	• expand existing sites to include productivity parameters, • develop agreements with monitoring partners to incorporate IBI into sediment sampling for toxics, • contract for special study of suspended particulate mater, nutrients, and primary production including interactions with macrioinvertebrates
• evaluate results and adjust sediment toxic monitoring, • evaluate fish tissue study and conduct statistical analysis to determine future direction, • evaluate results of reconnaissance sampling and implement long-term program to track trends, • establish continuous turbidity sampling at selected sites, • contract for health study of human health risks associated with consumption of contaminated organisms, • develop guidance on management of contaminated non-dredge sediments	• contract for system wide bathymetry, • contract for analysis of habitat metadata to reconstruct historical landscape patterns, • begin assessment of overall habitat monitoring scheme	• implement program to monitor mechanisms of introduction • develop agreements to implement ongoing program to assess impacts of introduced species, • continue and expand educational efforts	• assess results of special study on primary production and food webs to determine if useful way to measure biological integrity, • develop agreements to implement long-term monitoring of productivity depending on assessment, • complete survey of metadata to assess historic and current sampling plans, • conduct an assessment of food webs from benthic invertebrates through fish, • develop a model of primary production
• contract for study to identify trends in sediments through core sampling and analysis, • use cores to determine the effect of extreme hydrologic events, • contract to evaluate the impact of native versus hatchery fish on tissue contaminant data, • contract for study of bed sediments in reservoir pools, • evaluate recommenda-tions from 5-year report and adjust program	• continue coordination of interagency habitat monitoring and assessment of data, • evaluate results of 5-year report and adjust existing habitat monitoring program, • develop and implement new strategies	• evaluate results of 5-year report and adjust existing non-indigenous species monitoring efforts based on findings of the report	• contract for reconstruction of history of water quality in estuary and behind selected reservoirs using diatoms in sediments, • contract for a reconstruction of organic matter sources for food webs using multiple stable isotopes, • evaluate recommendations of 5-year report and adjust monitoring efforts



Map 1: Lower Columbia River Monitoring Sites

Lower Columbia River Estuary Plan

Volume 2

Aquatic Ecosystem Monitoring Strategy

Information Management Strategy

B Lower Columbia River Information Management Strategy

BACKGROUND

The Comprehensive Conservation and Management Plan (Management Plan) for the lower Columbia River will consist primarily of a series of actions designed to address seven priority issues related to the health of the lower river. The seven priority issues are:

- Biological integrity
- Impacts of human activities and growth
- Habitat loss and modification
- Conventional pollutants
- Toxic contaminants
- Institutional constraints
- Public awareness and stewardship

A key component of the plan is the implementation of a long-term monitoring program. This will generate a new set of data[1] to help fill in existing gaps, address continuing questions, track trends, and evaluate the effectiveness of proposed management actions. Clearly there is a need to effectively manage the large volume of existing and new information. Therefore, the goals of the Lower Columbia River Estuary Program Information Management Strategy will be to:

- improve the exchange of information among potential users;
- make the data more accessible and meaningful to the public;
- track the implementation of Management Plan actions; and
- create an institutional framework that will maintain and permit exchange of high quality data and information over the long term.

CURRENT DATA SITUATION

A myriad of federal, state and local agencies manage Columbia River resources. Over the years numerous entities, each with its own mission and purpose, have collected large amounts of data for a multitude of projects. The methods and frequency of data collection, documentation procedures, levels of accuracy, and data storage methods have varied. No single agency or body has been in a position to coordinate the collection and storage of all this water quality data. As projects were completed, funding ran out, or as priorities changed, there was no institutional structure in place to provide continuity between past and present.

Fortunately there are exceptions to this generally disorganized data management situation. For many years the US Geological Survey (USGS) and the US Army Corps of Engineers have maintained ambient monitoring sites on the lower Columbia and Willamette Rivers for selected parameters. Likewise, the Oregon Department of Environmental Quality (DEQ) has maintained an ambient monitoring site on the main stem Columbia, as well as sites on the lower Willamette

River and on some of the key tributaries (Clackamas, Johnson Creek, Columbia Slough, Clatskanie, Skipanon and Youngs Rivers). The Washington Department of Ecology (Ecology) also has ambient monitoring sites on some of the lower river tributaries (Kalama, Cowlitz, and Lewis Rivers) with rotational sites on many of the smaller tributaries. Most of this data is stored on the national data storage system known as STORET (Data Storage and Retrieval System) where it can be accessed and some analysis performed. (The Environmental Protection Agency manages STORET.[2])

Overall, however, no single agency has all the information and nor does an institutional framework exist to provide the oversight and coordination necessary to bring this information together for everyone's use.

Sources of Data and Information

The Bi-State Water Quality Program compiled a useful data bibliography. That report, "Sources of Biological, Chemical and Physical Information for the Lower Columbia River, River Mile (0 - 146), 1970-1990" by Robert McConnell, provides a fairly complete analysis of the data collected over that period of time and generally where it is located.

The McConnell document briefly describes 65 reports containing various types of biological, chemical and physical data for the lower river. An additional 55 supplemental studies are also identified but not described.[3] Based on the information in the McConnell report and existing knowledge, a list of the organizations that have been or are currently collecting data on the lower river study area has been compiled and is presented here as Appendix A. Much more effort will be needed to assess what data and reports have been developed since 1990.

Data Management Needs

The Estuary Program needs to manage existing data generated by the Bi-State Program and future data that will be generated by the proposed long-term monitoring plan. In addition, other information and data not directly related to the Estuary Program effort is also tremendously important to understanding the river ecosystem. Therefore, the Estuary Program must deal with its own information *and* address the larger data management needs of the lower river. The long-term goal is to be able to access and manage *all* the available information[4] from one location.

There are a number of specific issues related to this goal that need consideration. The Bi-State "Data Management Needs Assessment" report separated these issues into two groups. One group includes "programmatic or institutional" issues such as the scope of the data management plan. The second group includes "technical issues" that relate to system compatibility, access and other design issues.[5]

Programmatic/Institutional Issues

The ideal data management system would ensure that the appropriate data is readily accessible and easily interpreted. The institutional and programmatic requirements and constraints that make the attainment of this ideal difficult include: funding and staffing, agreements on data sharing and data standards, and timing.

Funding and Staffing

Clearly, funding the development of a data management system and providing staff to maintain the system over time is a major issue. A system which could manage all the data elements identified above would be expensive. The type of approach taken could be based on the scope and type of data considered, the degree to which it is interpreted, and accessibility. The different options will significantly affect the cost.

Similarly, the level of resources available to the organization that will ultimately implement the Management Plan will clearly affect the type of data management system selected. A related consideration is the ability to provide sufficient resources to inform and update the public and interested parties about the system.

Agreements on Data Sharing and Data Standards

Sharing electronic access to data and information is frequently talked about but often not done consistently, if at all. There are a number of legitimate reasons for this. First, organizations often feel proprietary about their data, worried that allowing direct electronic access will provide an opportunity for compromise, tampering or inappropriate use. Second, methods and protocols for collecting and analyzing the data may be different so that data from different organizations may be incompatible. Third, there are no data transmittal standards. Fourth, there is no general agreement on common data elements and names. Fifth, there are no standards for metadata. Sixth, there is no agreement on widely useful chemical, physical, and biological indicators. Finally and perhaps most importantly, agencies frequently have little incentive to go through all the effort needed to make data compatible and available.[6]

Timing

Timing is also an important issue. The Estuary Program planning phase ends in June, 1999, with the completion of the Management Plan. The implementation phase will begin at that point. To a considerable extent, the implementation of the plan is dependent upon an informed public and informed decision makers who are aware of the current situation in the river and what actions are proposed by the plan. Making people aware of the existing data and having it readily accessible will be important to the viability of the Program. To this extent, there is an immediate need to move forward on a data management plan.

At the same time, the long term monitoring plan will be implemented beginning in July, 1999. Once underway, it will take at least two years' worth of data before any serious evaluation of the river's water quality can be made. Therefore, while there must be agreements regarding how the data will be collected and where it will be stored, the actual system would not need to be in place for as much as three years.

Technical Issues

The Bi-State Report, "Data Management Needs and Assessment," identifies four technical issue categories. They include: system location, operation and maintenance, system compatibility, database design, and data accessibility.

System Location, Operation and Maintenance

A variety of options exist for system location and control. All options feature linkage via the Estuary Program home page to the site of the data, using the Internet to ensure accessibility. The system itself could be controlled by either Oregon or Washington, a federal entity, the Estuary Program and its successor (or a contractor), or a coordinated system that houses data and information at the specific organization charged with collecting it. There are advantages and disadvantages to each approach.

State Control: Both Oregon DEQ and Washington Department of Ecology have water quality data management systems and Geographic Information System (GIS) databases. The Estuary Program data could be housed at one or both of these entities as part of their existing systems. However, the political ramifications of choosing one state over the other could be interesting, and using both poses management system compatibility issues and issues associated with maintaining duplicate information. Ecology's ambient water quality monitoring data is available over the Internet. At present, DEQ's is not.

Federal Control: Environmental Protection Agency (EPA) has at least two databases that could house the Estuary Program data: the Storage and Retrieval System known as STORET which is the most universally used water quality database, and the Ocean Data Evaluation System (ODES) which is used for marine and estuarine data. Each would provide nationwide access to the data but both are difficult to use. Other federal agency databases exist for monitoring data but are less accessible. Some, like the US Geological Survey, upload to STORET from their internal database.

The Estuary Program/Management Plan Implementation Body: The advantage of controlling the data through the Estuary Program is that a system could be designed and tailored specifically to the needs of the program. Many of the institutional constraints surrounding either state or control could be eliminated. In addition, this option would allow the Estuary Program to act as a clearinghouse of information. Unfortunately, it will be expensive and long-term management could be a problem.

Coordinated System: This would be an extension of what currently exists. Data and information on the lower Columbia River would remain housed at whatever agency collected the data. The Estuary Program home page would have linkages to each of the monitoring agencies, making all the data available through those linkages. The Estuary Program or its successor would be responsible for keeping the Web site up to date. However, what would be lacking in the short -term would be any overall management of the data. The only information and data available on the Web site would be the data tables. Over time, the data management issues could be resolved through contracting for the development of software to display and interpret data for the public.

System Compatibility

There are system compatibility issues associated with any of the approaches that have the data housed in an agency's existing database. Since both DEQ and Ecology use DOS-compatible systems and store much of their ambient data on STORET, compatibility should not be a serious problem in that instance. However, this may not be true with other organizations that currently collect relevant data, although ultimately it should be possible for all the data systems to talk to each other and perhaps agree to use one system such as STORET.

Data Management Standards and Formats

If the Estuary Program elect to use an existing state or federal system to store existing and future data, it will have to comply with the data management standards and formats of that organization. Any decision about a system should be in place prior to the implementation of the long-term monitoring plan so that protocols and procedures can be set up accordingly.

Database Design

How the data will ultimately be used plays a significant role in determining what *types* of data are stored in the data management system. The following are at least a few of the possible uses:

- education
- planning and policy development
- support of management actions
- evaluation of management actions
- trend analysis
- status reports

A wide variety of data will be available for input to support these uses (see Footnote 4).

For the data to be used most effectively, however, its quality must be assured. That will require agreement regarding standard sampling and analytical protocols. If protocols are not standardized, then appropriate quality assurance/quality control (QA/QC) data will need to be collected to allow for the interpretation of data collected by different sampling techniques or analyzed by different methods.

Data Accessibility

Data accessibility is an issue of considerable importance to the parties that have databases and to the would-be users of the data. The Estuary Program is committed to making information and data about the lower Columbia River readily and easily accessible to all interested parties. This goal has to be tempered by the critical need to control the integrity of the data. Data appending and editing privileges would have to be strictly controlled before most data owners would sign onto any system. Thus, any data that is available to the general public would have to be in a "read only" format.

Information Management Criteria

Based on the prior discussions in the Data Management Needs section, the following list of criteria appear to be relevant to the evaluation of the various data management alternatives (*not* in order of priority):

- sufficient capacity to store and report environmental monitoring data including: water quality, habitat, fish and wildlife, and pollutant loading data
- sufficient capacity to store and report geographic data
- sufficient capacity to store and report hydrologic data
- reasonable cost to develop and maintain
- an easy-to-use standard interface to individual water quality databases
- common data element names and definitions
- assurance of data quality and integrity
- ability to be queried and to provide reports including such elements as trend analysis
- availability at the beginning of the long term monitoring program
- easy access to data for non-computer experts
- easy access to data for the interested public
- coordinated data sharing through linkages to other agencies
- easily updated
- continued utility independent of the Estuary Program
- flexibility to be modified as needs or resources change and technology evolves

Information Management Alternatives

A variety of alternatives exist for managing the Estuary Program data. They range from the simple to the complex, with costs and resource needs varying accordingly. For a system to meet all the criteria listed above, it will have to be fairly sophisticated. Most of the alternatives will not address all of the needs of the program, but it may possible to develop a system that can be built over time.

Alternative One

Bare Bones: The simplest and least expensive approach would be to take all the existing data and information available in electronic format and upload it to the Estuary Program Web site. This information would be in the form of data tables (preferably Access tables but this will require reformatting) and metadata text designated "read only." There would be no interpretation

of the information (see Attachment 1 for example from the Ecology Web site). Interested parties would be on their own to use the data as they see fit. As new data becomes available, it would be uploaded in the same manner. The system would essentially be a storage system. The Web site would have linkages to the DEQ, Ecology, and USGS Web sites and perhaps others but only the types of data the respective agencies put on their Web site would be available. Any specialized data queries would have to be routed through the agencies. Users would be responsible for any analysis and reports unless arrangements could be made with the host agency.

Advantages

- *Cost* - relatively inexpensive, requiring someone to administer the Web site, format the data and upload it as it is available, or create links to respective agency databases
- *Ease of access* - anyone with access to a computer and the Internet could have all the data
- *Convenience* - Since the Web site already exists, it could be used immediately and could store data until a better system becomes feasible
- *Compatibility with other systems* - not an issue since databases would not be directly linked
- *Flexibility* - could easily be upgraded to an interactive system as resources become available and new agency systems are completed or new technology becomes available

Disadvantages

- *Data management* - no ability to manipulate and interpret the data
- *Program evaluation* - without the ability to manipulate the data, it would not be possible to develop information about the health of the river and the success of program implementation
- *Interconnection with other databases* - none; strictly a data storage system
- *Storage capability* - limited; not all types of data could be stored under this arrangement

Discussion: Although the Bare Bones system would meet many of the criteria, several critical programmatic needs would not be met. It is attractive because of its flexibility in the face of rapidly changing technology. It would clearly be appropriate as an immediate interim measure until a better system can be developed. It can also be the first step toward building an interactive system that links to all the data housed at other organizations if the appropriate agreements and hardware and/or software could be developed to make it feasible.

Alternative Two

Existing State Agency Systems: The Oregon Department of Environmental Quality and the Washington Department of Ecology have existing water quality data management systems and GIS systems that could potentially house Estuary Program data.

Ecology has an in-house database (EIM) for storing all environmental data. Water quality data is entered, stored, checked for quality assurance and then annually uploaded to EPA's Storage and Retrieval System (STORET). The in-house database can do some reports and analyses but for more sophisticated functions, such as trend analysis, the data is downloaded to other programs. Ecology currently provides its ambient water quality data on its Internet home page using Access. It also provides selected water quality reports on its home page. Ecology plans to put EIM on the Web in the next biennium. In addition, Ecology has an in-house GIS data base that has the capability to store the Estuary Program geographic data.

The DEQ currently uses STORET for all of their ambient water quality monitoring data. DEQ has recently developed an in-house database known as LASAR to house all DEQ water quality data. They are hoping for more funding to continue the development of this system. Ultimately, data would be loaded directly on to LASAR and then routinely uploaded to STORET. For more complicated analyses, data will be downloaded from LASAR to other statistical programs. DEQ does not currently provide ambient water quality data on its home page but is considering doing so

late this year. Oregon has a centralized GIS data base which services many state and federal agencies. Arrangements could be made to house the Estuary Program geographic data at this facility.

Both state systems are primarily storage systems. Some reports can be generated but sophisticated analyses must be done by other programs. All existing and future the Estuary Program data could be uploaded to one or both of these systems where it could be stored and managed as time and resources allow.

Advantages

- *Availability* - presently, either system would provide the Estuary Program data storage on STORET. Arrangements would have to be made to store data on their respective in-house systems until it could be uploaded to STORET
- *Data Management* - the existing systems have the ability to do some data manipulation.
- *Public Access* - present Ecology provides data on the Internet: DEQ hopes to do so soon.
- *Costs* - moderate; no acquisition costs and limited additional staff requirements to take old data and enter it into the system (could be done on contract); however the home agency would need long-term data entry capabilities
- *Standards and Quality Assurance* - already developed and in place
- *Stability* - either system will continue to exist irrespective of the future of the Estuary Program
- *Existing Data* - at least some of the existing Estuary Program data has been entered into the STORET system
- *GIS* - each state has a GIS system that could potentially house geographic data

Disadvantages

- *Politics* - choosing which state would house the data
- *Compatibility* - minimal; issues can be resolved since both use DOS systems
- *Limited Accessibility* - no access to in-house systems for outside organizations, parties or individuals
- *Limited Resources* - the Estuary Program would have to rely on resources dedicated to other programs to input, access, and query its data unless it could contract or hire staff
- *Limited Flexibility* - not all forms of data (e.g., geographic data) or other formats could be handled by one system

Discussion: Integrating the Estuary Program's data into either the DEQ or Ecology data systems where it could be uploaded to STORET on a regular basis would meet many of the desired criteria. Ecology's data is much more available to the public, and their system appears to be more flexible than DEQ's current system, but this is changing. Both Departments are in transition with their data systems, and it is to be expected that improvements will continue to occur. Storing data with either agency will ensure that it will be available and managed for the long-term.

Alternative Three

Existing National Databases: There are a number of national databases that might function as home to the Estuary Program data. The two most feasible at present include the EPA's STORET system and Ocean Data Evaluation System (ODES).

STORET: The Storage and Retrieval System is EPA's major water quality database and the most widely used water quality database in the US. Data sets are transferred to STORET by an agency "owner" in a standard submittal format. However, STORET is old and cumbersome. A new, more complex yet flexible system has been developed and users of STORET were required to switch to the new STORET X system by the end of 1998. The new system will have the capability to

store many more types of data. It will also require much more metadata to back up the data. STORET X will be a decentralized relational database where each state will store data locally in a database provided by EPA. On a regular basis, state data will be uploaded to a national data warehouse where it will be publicly available through the Internet. The Estuary Program could opt to work directly with STORET rather than working with the state agencies as proposed in Alternative Two.

Advantages

- *Availability* - widely used national database, immediately available
- *Moderate Cost* - requires user identification code (ID) and someone who understands the system
- *Existing Use* - used by DEQ, Ecology, USGS, USACE, it has some Bi-State data already in system
- *Flexibility* - though the old system was inflexible, the new system should remedy this situation and accommodate a much larger variety of information
- *Data Management* - data can be queried and reports developed (this may change with new system, however)
- *Permanence* - could provide permanent housing for data

Disadvantages

- *Questionable Ease of Use* - remains to be seen how easy the new system will be to use; entering extensive metadata could be extremely time consuming; the use of the present system, and presumably the new system is restricted to those who understand it
- *Questionable Access* - at present, limited to those with ID and training in its use and not available to the public; the new system will allow public access through the Internet
- *Questionable Quality Assurance* - limited capability at present to store QA information, although this may change with the new system
- *Format* - most Bi-State data would need to be reformatted before it could be entered.

ODES: The Ocean Data Evaluation System is an EPA database used to store a variety of marine and estuarine data. It was designed as a data archive and data analysis system. It was originally the database of choice for the National Estuary Program.

Advantages

- *Availability* - widely used national database, immediately available
- *Moderate Cost* - does require user ID and training
- *Existing Use* - used by some of the other NEPs
- *Data Management* - data can be queried, analyzed and reports developed.
- *Capability* - can handle all of the Estuary Program's data types
- *Permanence* - could provide permanent housing for data
- *Quality Assurance* - data undergoes strict assurance, and QA information can be stored

Disadvantages

- *Ease of Use* - ODES is not easy to use and hard to learn, and its QA/QC process is very slow; ODES has been rejected by a number of NEPs for these reasons
- *Limited Access* - must have EPA user ID, not available to the public
- *Format* - Bi-State data would have to be reformatted

Discussion: The ODES system is being phased out by EPA and functionally incorporated into STORET X. Since both Washington and Oregon use STORET, as do key federal agencies, it does seem to be an attractive approach for permanent storage of data especially with the coming of the new system. Although STORET X remains untried, it should accommodate most of the Estuary Program data needs. A decision point here is whether it makes more sense to work directly with STORET or work with the states to store data on STORET.

Alternative Four

Establish a Dedicated Estuary Program Database: One way to eliminate most of the problems associated with existing systems is to design a unique system for the Estuary Program. Under this scenario, the Estuary Program would have its own server housing its Web page and all of the existing data. It could be designed to store, retrieve, and analyze data and to develop reports. It could also be designed to link to a variety of other databases with a long-term goal of providing seamless bridges to other organizations' data.

Advantages

- *Meets Criteria* - could meet most of the desired criteria for an ideal data management system
- *Flexible* - by far the most flexible in terms of access and ability to meet management needs

Disadvantages

- *Cost* - expensive to develop and would require full time dedicated staff to maintain
- *Questionable Permanence* - dependent on the survival of the Estuary Program and its successor organization
- *Technology Restraints* - technology is changing rapidly; system built today could be antiquated in a few years
- *Database Profusion* - adds yet another database to the large number of existing systems

Discussion: A dedicated Estuary Program system might be ideal for the program. It could be designed to meet our specific needs and minimize many of the problems associated with other systems. It could serve as a storehouse for all lower Columbia River data and information and would greatly assist in the use and dissemination of this information by others. Unfortunately, it may not be appropriate for more regional data management needs. In addition, high development and long-term maintenance costs probably preclude its development at the present time. This alternative should be put on hold for consideration at a future date.

Alternative Five

Contract for Data Management Services: This option is similar to Alternative Four but it would involve a contract with an organization such as a state agency, university, library, or private entity to manage the Estuary Program data.

Advantages

- *Meets Criteria* - could ensure by contract that most of the desired criteria be met
- *Database Consolidation* - could be built into an already existing system thus eliminating the issue of establishing yet another database

Disadvantages

- *Cost* - expensive to develop and maintain over the long term
- *Questionable Permanence* - dependent on the survival of the Estuary Program successor organization to continue funding the maintenance and operation of the contracted system

- *Management Constraints* - management and control could be limited by the priorities of the institution that maintains the database

Discussion: This could be an attractive option in that all the criteria could potentially be met. It would be less expensive than creating an entirely new independent system and would eliminate the database profusion issue. It would have the disadvantage of lack of control and there would be a lingering question regarding long term funding.

Discussion of Alternatives

The five alternatives, although meant to stand alone as options, can also be viewed as a logical series of steps toward the implementation of a full scale data management system. The first alternative represents an interim approach to data storage and access. Alternatives two and three represent a potential second step which would be to put all the data in STORET and work with Ecology, DEQ or EPA to generate reports and analyses. Alternatives four and five represent possible long-term solutions. Alternive four would create a dedicated lower Columbia River database, and alternative five would contract for a dedicated service. With the exception of alternative four and perhaps five, none of the options meet all management needs but each of the first three meets some of the criteria. Based on earlier discussions of timing and resources, viewing the alternatives as a series of steps or phases toward establishing a long-term institutional framework for the management of lower Columbia River information and data seems to be a viable sixth option.

CONCLUSIONS

Over the years, a large volume of data has been collected on the lower Columbia River. The data is currently distributed among a number of agencies and a variety of databases and formats. No single agency has all the information and no institutional framework exists to provide the administration and coordination necessary to bring this information together for everyone's use.

The Lower Columbia River Estuary Program has considerable data and will be generating even more as the long-term monitoring plan is implemented. This data is not currently managed and is generally inaccessible. The Estuary Program is committed to effectively managing the data so that the success of its programs can be evaluated, making information about the health of the river more accessible to all interested parties, and fulfilling its goal of enhancing government coordination.

There are changes occurring in the data management world that should ultimately make data sharing and data analysis much more feasible and accessible to organizations such as the Estuary Program. As that evolves, the Estuary Program should be in a position to take advantage of new opportunities to develop a system that meets all of its needs.

To be in such a position, the Estuary Program needs to begin a process of locating and cataloging its existing data, information and metadata. The information needs to be stored on a permanent system such as STORET and made available through links on the Internet or in hard copy. The Estuary Program also needs to be prepared for new data that will be developed through its own programs and other outside efforts. Issues such as compatibility, standards and formats, and design need to be resolved. This process should lead to a point where all the data in its raw form could be accessed in one place and in a consistent format.

As time, resources and available technology allow, all the data and information should become part of a system managed in such a way that it could be queried, analyzed and reported in various formats and venues to meet the needs of the program, other data users and the public.

The long-term monitoring plan will begin in mid-1999. It will take at least two years worth of sampling before enough data is available to do significant trend analyses. Thus, at a minimum, we are three years away from having sufficient data to effectively employ a full scale data management system.

In the meantime, based on the number of unknowns related to the viability and resources of the Estuary Program and its successor, and the number of problems associated with the various existing systems both nationally and locally, it seems that a phased approach to data management which relies on networked, distributed databases rather than a centralized data base, is the most reasonable alternative.

RECOMMENDATION

The estuary program will implement a full scale data management system for the Estuary Program and its successor organization in four phases. Phase One begins formally with the adoption of the management plan.

Phase One: Data Storage

This phase, a part of which is already underway, will focus on locating all existing data, improving access to the existing data, and heightening public awareness of the information available.

Task 1: Locate and compile all existing data and information related to the lower river.

Task 2: Place all data currently available in electronic format on the Estuary Program Web site for storage and general access.

Task 3: Develop a bibliography of all other data and information (including hard copy reports, maps, other agency databases, etc.), determine where they can be found and accessed, and provide that information on the Web site.

Task 4: Ensure all existing data that meets formatting requirements is uploaded to either DEQ's or Ecology's database so it can be stored on STORET. Determine whether geographic information can be stored on one of agency GIS databases.

Task 5: Develop and implement an ongoing process for informing the public about the data that is available.

Task 6: Develop data sharing agreements that include the sharing of GIS data layers.

Phase Two: Data Organization

This phase will focus on establishing uniform procedures. At a minimum, Task 1 would need to be completed before the implementation of the long-term monitoring plan.

Task 1: Work with monitoring organizations to establish consistent protocols and procedures for collecting, analyzing and recording data and ensuring consistency with data management standards. The protocols should identify:

- common data element names
- specific agencies with the authority to maintain individual reference tables
- minimum metadata values to facilitate sharing

Task 2: Develop strategies for linking the various monitoring agency databases into a network of Web site pages. Agreements should be reached on:

- an easy-to-use standard interface to individual water-data systems
- an easy-to-use export format for each agency data base
- procedures to ensure that all data is available on STORET X

Task 3: Track the development of other relevant data so it can be included in the system.

Phase Three: Data Management (short-term)

This phase would develop a short-term (up to three years) approach to managing the data:

Task 1: Using the Estuary Program home page, establish a networked system of distributed databases with the key data collection organizations.

Task 2: Work with Ecology, DEQ, and EPA to identify a data management program that will analyze data for trends and develop reports to meet the Estuary Program management needs.

Task 3: Upload data reports to the Web site similar to what Ecology does now.

Phase Four: Data Management (long term)

This phase would focus on seeking resources for the development of a dedicated data management system for the lower Columbia River which would allow dynamic access, reporting, and analysis of all relevant information, be accessible to all interested parties through the Internet, and provide a home for all "orphaned" information.

References

1. Geographic Parameters. January 1993. Data and Information Management Strategy, Indian River Lagoon, National Estuary Program. Prepared for: St. Johns River Water Management District. 53pp.

2. McConnell, Robert J. October 1990. Sources of Biological, Chemical, and Physical Information for the Lower Columbia River, River Mile (0-146), 1970-1990. Prepared for: the Lower Columbia River Bi-State Steering Committee. 54pp.

3. Tetra Tech. February 1993. Data Management, Needs Assessment. Prepared for: The Lower Columbia River Bi-State Water Quality Program. 25pp.

4. Tetra Tech. May 1993. Data Management, Data Management Systems Evaluation and Recommendations. Prepared for: The Lower Columbia River Bi-State Water Quality Program. 61pp.

Appendix A: Sources of Data and Information

Federal Agencies

US Geological Survey - routine long-term monitoring and special studies

US Army Corps of Engineers - routine long-term monitoring associated with dam operations and special studies related to dredging and channel maintenance

National Marine Fisheries Service - special fisheries research studies primarily in the estuary

US Fish and Wildlife Service - special wildlife research studies

US Environmental Protection Agency - pollution studies, currently modeling temperatures

Bonneville Power Administration - contracted research studies

Regional Governmental Bodies

METRO - special studies related to the lower Willamette River

Columbia River Estuary Study Task Force (CREST) - special studies related to the estuary including the Columbia River Estuary Data Development Program (CREDDP) after 1981

Northwest Power Planning Council - special studies on power generation and fisheries

Pacific Northwest River Basins Commission - special studies prior to 1981 including CREDDP, no longer in existence

State Agencies

Oregon Department of Environmental Quality - routine ambient monitoring and special studies

Oregon Department of Fish and Wildlife - studies related to fish and wildlife and habitat

Oregon Division of State Lands - information related to wetlands

Governors Watershed Enhancement Board - information related to Oregon's watershed councils

Washington Department of Ecology - routine ambient monitoring and special studies

Washington Department of Fish and Wildlife - studies related to fish and wildlife and habitat

Washington Department of Natural Resources - information related to submerged lands

Local Governments

City of Portland Bureau of Environmental Services - water quality studies

Universities

Oregon State University - specific research projects

Portland State University - specific research projects

University of Washington - specific research projects

Washington State University - specific research projects

Other Educational Institutions

Clatsop Community College - student projects

Oregon Graduate Institute - maintains continuous monitor of physical parameters at mouth

Marine and Environmental Research and Training Station - special projects

Local school districts and schools - student projects

Tribes

Columbia River Inter-Tribal Fish Commission - special contracted studies

Confederated Tribes - Umatilla, Warm Springs, Nez Perce , Yakima

Ports

The Port of Portland - special studies related to Port operations

Private Industry

Private industry, particularly the NW Pulp and Paper Association and Portland General Electric have compiled a number of reports on studies of the lower river.

Non-Profit Organizations

A number of nonprofit organizations also have collected or will be collecting data and have compiled reports. This includes a number of watershed councils on the lower river.

Footnotes

[1] Throughout this report several terms are utilized in discussing data management. These terms are assigned the following definitions:

DATA: Measured values and statistics

META DATA: Information that describes the content, quality, condition, and other characteristics of data

INFORMATION: Non-measured facts about the river and its resources

DATABASE: A set of structured computer files, designed for storing and managing data

DATA MANAGEMENT SYSTEM: the overall framework for managing data and information.

GIS: Geographic Information System

[2] The data collected under the six year Bi-State Program generally falls into the short-term project related category described in the first paragraph. Mostly it is not in STORET and most of the sites are not being monitored at the present time. The exception to this is the data which coincided with the USGS and DEQ ambient sites. This data is in STORET.

[3] Not described in the report is the data available from the 27 major NPDES discharges to the lower Columbia and its adjacent tributaries. Also not included is information from routine ambient monitoring stations that are not published. Finally the report does not include any reports completed after 1990.

[4] The categories of data and information include:

Water quality monitoring data (chemical, biological, physical)

Habitat data and information (extent, type, condition)

Fish and Wildlife data and information (species, condition - including exotic species)

Pollutant loading data (point and non-point source information)

Geographic data (resource location, source location, land uses, etc.)

Hydrologic data (flows, drawdown/spillages)

Historical information

Institutional information

[5] A series of interviews was conducted with Bi-State Program Coordinators from DEQ and Ecology to generate the issues. Although five years have passed since the report was completed, the programmatic and institutional issues remain largely the same and are still unresolved. The technical issues on the other hand have changed substantially, particularly with the widespread use of the Internet.

[6] Developing a system that could manage all the information will entail overcoming a host of technical, institutional and economic problems. An example is the Inter-Organization Resource Information Management Memorandum of Understanding (see Attachment 2).

Attachment 1

Station 27B070
Six Year Water Quality Data Summary

1997 (27B070)	Time	Flow (CFS)	Temp (C)	Conductivity (umhos/25c)	Oxygen (mg/L)	Oxygen Saturation (%)	pH
09/28/1997	1405	700	11.9	44	11.1	101.7	7.6
08/25/1997	1440		14.2	55	11.1	107.8	7.9
07/28/1997	1355		15.7	52	10.4	103.9	8.0
06/25/1997	1615		13.3	48	11.0	104.6	8.3
05/26/1997	1405		10.7	45	12.1	108.1	8.4
04/28/1997	1630		7.4	35	11.7	96.7	7.4
03/24/1997	1505		6.5	34	12.2	97.4	7.3
02/24/1997	1820		4.9	39	12.5	95.3	7.1
01/29/1997	1620		5.1	41	12.4	95.5	7.1

1996 (27B070)	Time	Flow (CFS)	Temp (C)	Conductivity (umhos/25c)	Oxygen (mg/L)	Oxygen Saturation (%)	pH
12/17/1996	1455		4.2	42	12.9	96.4	7.3
11/25/1996	1510		6.8	36	11.9	95.0	7.4
10/30/1996	1430		7.9	32	11.4	95.3	7.5
09/25/1996	1400		9.4	56	11.7	101.0	7.7
08/28/1996	1600		14.7	61	10.6	103.9	7.8
07/31/1996	1525		17.1	59	10.3	106.1	7.6
06/25/1996	1525		13.2	48	11.8	112.6	7.8
05/29/1996	1445		9.9	44	11.9	104.4	7.7
04/30/1996	1520		9.3	39	11.7	100.6	7.5
03/27/1996	1410		6.1	46	12.4	100.4	7.5
02/28/1996	1400		3.7	41	13.3	100.2	7.4
01/31/1996	1340		1.2	49	13.6	95.8	7.3

Data Qualifiers: u,j = estimated value k = actual value known to be less s = spreader x = high background count

Fecal Coliforms (colonies/ 100ml)	Suspended Solids (mg/L)	Total Persulfate Nitrogen (mg/L)	Ammonia Nitrogen (mg/L)	Total Phosphorus mg/L)	Dissolved Soluble Phosphorus (mg/L)	Turbidity (NTU)	Nitrate-Nitrite (mg/L)
18	2	0.206	0.010u	0.040	0.005u	1.8	0.1
38	2	0.094	0.010u	0.028	0.005u	0.9	
13	2	0.222	0.010u	0.026	0.005	0.7	0.2
3	4	0.163	0.016	0.018	0.005u	1.7	0.1
1	2	0.082	0.018	0.042	0.005u	1.1	0.1
8	6	0.295	0.020	0.078	0.005u	4.2	0.3
1	8	0.505	0.010u	0.041	0.005u	5.9	0.5
1	2	0.393	0.010u	0.108	0.010u	2	0.3
4	8	0.552	0.025	0.030	0.006	3.8	0.4

Fecal Coliforms (colonies/ 100ml)	Suspended Solids (mg/L)	Total Persulfate Nitrogen (mg/L)	Ammonia Nitrogen (mg/L)	Total Phosphorus (mg/L)	Dissolved Soluble Phosphorus (mg/L)	Turbidity (NTU)	Nitrate-NItrite (mg/L)
7	8	0.476	0.010u	0.040	0.006	5.3	0.5
15	19	0.584	0.010u	0.030	0.008	10	0.5
7	5	0.413	0.010u	0.013	0.005u	3.7	0.4
9	9	0.169	0.052	0.027	0.005u	7.1	0.1
12	1	0.114	0.010u	0.027	0.008	1.2	0.1
4	2	0.104	0.010u	0.018	0.005u	1.2	0.1
13	7	0.280	0.010u	0.015	0.005u	4.8	0.2
14	2	0.199	0.010u	0.010u	0.005u	2.6	0.2
1	11	0.352	0.010u	0.015	0.006	7.8	0.3
1u	3	0.233	0.010u	0.020	0.005	2.3	0.2
5	9	0.427	0.010u	0.016	0.008	7.7	0.4
1	4	0.534	0.010u	0.015	0.014	3.3	0.5

Attachment 1

Station 27B070
Six Year Water Quality Data Summary (Continued)

1995 (27B070)	Time	Flow (CFS)	Temp (C)	Conductivity (umhos/25c)	Oxygen (mg/L)	Oxygen Saturation (%)	pH
12/20/1995	1440		7.4	47	12.4	100.3	7.5
11/29/1995	1315		9.6	33	12.0	103.6	7.2
10/25/1995	1550		9.0	48	11.8	101.9	7.3
09/26/1995	1515		14.8	70	10.6	103.2	7.4
08/29/1995	1445		15.6	62	10.9	106.9	7.9
07/25/1995	1030		15.2	57	10.5	103.3	7.7
06/27/1995	1420		16.9	51	10.7	109.3	7.7
05/22/1995	1345		13.5	49	11.8	112.9	8.1
04/25/1995	1530		10.5	43	12.0	107.5	7.8
03/28/1995	1415		6.8	40	12.6	102.4	7.7
02/27/1995	1440		6.2	36	12.9	102.9	7.6
01/24/1995	1435		5.8	41	12.6	101.2	7.1
1994 (27B070)	**Time**	**Flow (CFS)**	**Temp (C)**	**Conductivity (umhos/25c)**	**Oxygen (mg/L)**	**Oxygen Saturation (%)**	**pH**
12/11/1994	1300		8.6	47	11.8	99.8	8.2
11/16/1994	1630		7.8	45	12.7	106.1	7.4
10/02/1994	1300		9.9	69	10.9	95.1	7.8

Data Qualifiers: u,j = estimated value k = actual value known to be less s = spreader x = high background count

Fecal Coliforms (colonies/ 100ml)	Suspended Solids (mg/L)	Total Persulfate Nitrogen (mg/L)	Ammonia Nitrogen (mg/L)	Total Phosphorus (mg/L)	Dissolved Soluble Phosphorus (mg/L)	Turbidity (NTU)	Nitrate-Nitrite (mg/L)
6	10	0.548	0.010u	0.010u	0.008	5	0.4
41	400	0.741	0.010u	0.077j	0.005u	180	0.5
64	3	0.199	0.010u	0.016	0.005u	1.3	0.1
82	4	0.195	0.021	0.018	0.005u	1.4	0.1
10	2	0.101	0.010u	0.010u	0.005u	0.7	
20	3	0.196	0.040	0.010u	0.010	1.1	
1	2	0.178	0.013	0.010	0.007	0.8	
4	4	0.220	0.012	0.010u	0.005u	1.9	0.1
1	4	0.242	0.014	0.017	0.007	1.9	0.2
2	3	0.309	0.010u	0.010u	0.005u	1.6	0.3
1	3	0.322	0.010u	0.019	0.009	2.7	0.3
3	3	0.386	0.010u	0.014	0.009	2.9	0.3
Fecal Coliforms (colonies/ 100ml)	Suspended Solids (mg/L)	Total Persulfate Nitrogen (mg/L)	Ammonia Nitrogen (mg/L)	Total Phosphorus (mg/L)	Dissolved Soluble Phosphorus (mg/L)	Turbidity (NTU)	Nitrate-Nitrite (mg/L)
22	3	0.125	0.010u	0.020	0.010u	1	

Attachment 1

Station 27B070
Six Year Water Quality Data Summary (Continued)

1992 (27B070)	Time	Flow (CFS)	Temp (C)	Conductivity (umhos/25c)	Oxygen (mg/L)	Oxygen Saturation (%)	pH
09/29/1992	1015		10.9	52	10.8	97.3	7.8
08/25/1992	1240		14.2	65	10.2	98.2	7.9
07/28/1992	1440		19.1	65	9.9	106.0	7.9
06/23/1992	1155		19.4	59	9.5	103.1	7.5
05/26/1992	1250		14.2	49	11.1	106.2	7.8
04/28/1992	1230		11.3	36	11.3	102.0	7.4
03/24/1992	1300		9.5	52	12.2	105.2	7.4
02/25/1992	1250		7.9	38	12.1	100.1	7.3
01/28/1992	1325		8.8	37	12.4	105.2	6.8
1991 (27B070)		**Flow (CFS)**	**Temp (C)**	**Conductivity (umhos/25c)**	**Oxygen (mg/L)**	**Oxygen Saturation (%)**	**pH**
12/17/1991			5.0	40	12.7	99.0	7.3
11/19/1991			8.4	39	11.5	97.0	7.4
10/29/1991			6.4	52	13.1	104.0	7.6

Data Qualifiers: u,j = estimated value k = actual value known to be less s = spreader x = high background count

Fecal Coliforms (colonies/ 100ml)	Suspended Solids (mg/L)	Total Persulfate Nitrogen (mg/L)	Ammonia Nitrogen (mg/L)	Total Phosphorus (mg/L)	Dissolved Soluble Phosphorus (mg/L)	Turbidity (NTU)	Nitrate-Nitrite (mg/L)
61	3		0.021	0.016	0.012	1.6	0.1
14	2		0.012	0.012	0.010k	1.6	
3	3		0.023	0.025	0.011	1.3	
14	4		0.026	0.018	0.010k	0.5	
16	3		0.010k	0.022	0.010k	0.5	0.1
24	5		0.010k	0.017	0.011	1	0.2
1	3		0.010k	0.013	0.010k	0.6	0.2
2	1k		0.010k	0.015	0.010k	2.9	0.3
21	97		0.016	0.081	0.010k	22	0.5

Fecal Coliforms (colonies/ 100ml)	Suspended Solids (mg/L)	Total Persulfate Nitrogen (mg/L)	Ammonia Nitrogen (mg/L)	Total Phosphorus (mg/L)	Dissolved Soluble Phosphorus (mg/L)	Turbidity (NTU)	Nitrate-Nitrite (mg/L)
11	4		0.011	0.016	0.010k	2	0.4
27	11		0.010k	0.020	0.010	3	0.4
21	4		0.020	0.022	0.014	1.7	0.2

ATTACHMENT 2

MEMORANDUM OF UNDERSTANDING

Inter-Organization Resource Information Management

This Memorandum of Understanding is for the purpose of promoting the sharing and coordination of resource information and to encourage cooperative resource information activities among participating organizations in support of the implementation of the President's Forest Plan.

Whereas:

- Quality data and information management are vitally important to implement regional ecosystem management.
- An integrated and coordinated effort and approach among participating organizations in managing information is logical and essential.

Therefore:

An inter-organizational approach to resource information management will be undertaken to accomplish the following:

1. Establish an inter-organizational resource information management system to support ecosystem management and consistent with the financial capability of each participating organization.
2. Respond to information management issues and actions identified by participating organizations.
3. Coordinate information management efforts and plans among participating organizations; including but not limited to the identification of key sets of data, formulation of base set of data standards, establishment of data management priorities, quality assurance and guidelines, production schedules, and data stewardship responsibilities.
4. Promote data acquisition and maintenance partnerships between organizations. Supplements to this MOU will be written as needed to document the exchange and management of data between participating organizations.
5. ~~Establish~~ Investigate the establishment of this effort as a Regional Node for the Federal Geographic Data Committee (FGDC).

It is understood and agreed that:

An inter-organization group comprised of representatives from participating organizations, called the Inter-organization Resource Information Coordinating Council (IRICC), will be established to promote the accomplishment of the above stated objectives.

Technical work groups, comprised of representatives from participating organizations, will be used to assist IRICC in completing stated goals and objectives.

Each organization will participate to accomplish above stated responsibilities.

Actions proposed by IRICC involving a change in a participating organization's process or operation will be forwarded to the Regional Ecosystem Office for review and provided to the affected organization's executive for decision.

Decisions reached by the Regional Interagency Executive Committee or any other decision body do not affect any participating organization unless their respective executive was ~~part of~~ concurred the decision ~~process.~~ Such decisions will be forwarded to the other participants for consideration.

Each participating organization will implement the agreed upon standards and direction and attempt to accomplish associated tasks (data collection, standards, etc). as soon as practical.

Representatives from each participating agency will be knowledgeable and able to fully represent their respective units; consistent with agency mission and delegations of authority.

Functionality and utility of this effort will be assessed periodically with a report of findings provided to Regional Interagency Executive Committee.

Work projects or activities which involve transfer of money, services or property will require execution of a separate agreement. Alternative agreement instruments include Challenge Cost Share Agreements, Participating Agreements, or Procurement contracts. Each project will be documented and signed by the organizational unit's responsible officer using the appropriate agreement.

New members to this MOU can be added upon approval by the Regional Interagency Executive Committee and upon signature by the authorizing executive of the new organization.

Recognized tribes are already approved to participate and each may cooperate in this effort by executing a signing addendum to this MOU.

Any party may terminate their involvement in this agreement by providing a 60 day written notice. Unless terminated by written notice, this agreement will remain in force for five years (5) after the the date of approval of the last signatory. This agreement may be renewed for subsequent years by mutual written agreement of the participants. Any participant may propose changes to this agreement. Such changes will be in the form of an amendment and will become effective upon signature by the parties shown below.

Agreed Upon:

Environmental Protection Agency (Date)

USDA Forest Service (Date)
Region 6

Bureau of Land Management (Date) 2/3/94
Oregon/Washington

US Fish and Wildlife Service (Date)

National Marine Fisheries Service (Date) 2/3/94

Soil Conservation Service (Date) 5/23/94
Oregon

Bureau of Indian Affairs (Date)

State of Oregon (Date) 2-3-94

State of Washington (Date) 2/28/94
Dept. Natural Resources

National Park Service (Date) 2/7/94

State of California (Date) 3/10/94
Division of Forestry

US Geological Survey (Date) 2/3/94

Bureau of Land Management (Date) 3/11/94
California

USDA Forest Service (Date) 3/17/94
Region 5

LOWER COLUMBIA RIVER ESTUARY PROGRAM

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