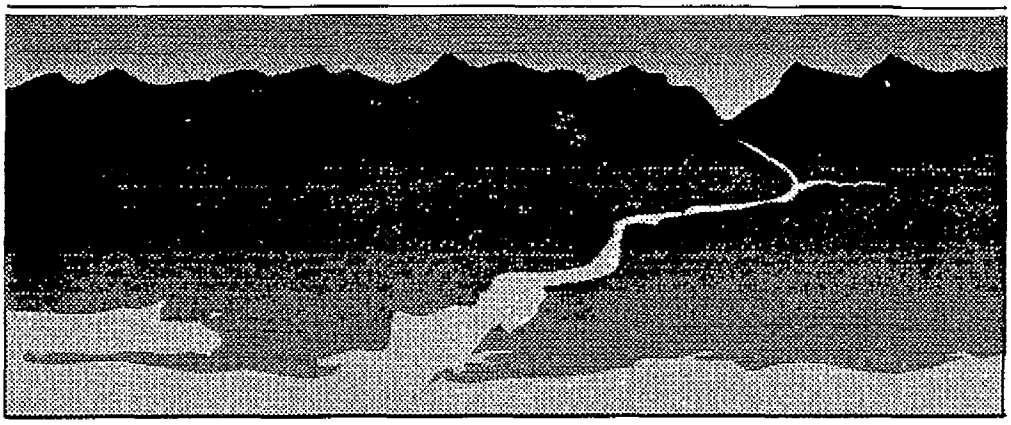
LOWER COLUMBIA RIVER



BI-STATE PROGRAM

RECONNAISSANCE SURVEY OF THE LOWER COLUMBIA RIVER

SAMPLING PLAN

OCTOBER 29, 1991

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Final Report

RECONNAISSANCE SURVEY OF WATER QUALITY LOWER COLUMBIA RIVER: SAMPLING PLAN

by

Tetra Tech, Inc.

in association with

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for

The Lower Columbia River Bi-State Program

October 1991

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1.0 PROGRAM AND SURVEY OBJECTIVES

The Bi-State Lower Columbia River Water Quality Program (Bi-State Program) was formed at the direction of the Washington and Oregon State legislatures. The states entered into an Interstate Agreement that directs a four-year water quality program to characterize water quality in the lower Columbia River, identify water quality problems, determine whether beneficial uses are impaired, and develop solutions to problems found in the river below Bonneville Dam.

These goals will be met by carrying out the following tasks:

- Involve the public through education and public participation.
- Develop work plans that identify the studies needed to characterize the river's water quality.
- Evaluate existing data and conduct reconnaissance surveys.
- Carry out baseline studies.
- Conduct advance studies and recommend long-term monitoring.
- Make recommendations to regulatory agencies.

The Bi-State Program recognizes that the lower Columbia River (the 146 miles below Bonneville Dam) is a small part of a drainage basin which includes parts of seven states and Canada. Therefore, the effects occurring in this portion of the river will be the result of sources both in the study area and upstream, which may be the subject of future study. The Bi-State Program, however, will focus its efforts on identifying problems within the study area.

It is important to define a realistic expectation of what the Bi-State Program can accomplish within its resource and geographic constraints. Priority-setting will be a critical process for the Bi-State Program, and priorities will be defined and reviewed at each major step in the

technical studies. The timeline will not permit an analysis of every issue, but those studied will be based on good science. An underlying principle for the Program is to ensure careful and objective study.

This document presents a sampling plan for the reconnaissance survey mentioned in the third bulleted item above. The reconnaissance survey has several objectives:

1. Provide a reconnaissance of levels of contaminants in water, sediment, and tissue.

2. Fill data gaps.

3. Tentatively identify problem areas.

4. Make recommendations for baseline studies.

This plan has been modified based on comments received on the draft and draft final sampling plans. The draft sampling plan was prepared based on inputs from a workshop held on August 6, 1991, where input on a preliminary draft sampling plan was solicited from technical experts.

2.0 FACTORS IN SURVEY DESIGN

Many factors were considered in developing the proposed sampling plan for the reconnaissance survey. Major categories were water quality problems to be addressed by the Bi–State Program, past and current studies, location and type of pollutant studies, and location and type of beneficial uses.

2.1 WATER QUALITY PROBLEMS TO BE ADDRESSED

In order to develop an effective sampling plan, the water quality problems to be addressed by the survey must be established. These water quality problems are determined in large part by characteristic/beneficial uses of the lower Columbia River. The Bi–State Program is charged with determining whether characteristic/beneficial uses have been impaired, and with making recommendations to protect these uses. For the Bi–State Program, characteristic/beneficial uses of the lower Columbia River have been defined as described in Section 2.4 below.

The Bi–State Program intends to investigate levels of contaminants in three media – water, sediment, and biota – as measures of water quality conditions in the lower Columbia River.

Based on the above considerations (protection of characteristic/beneficial uses, and the Bi–State Program's intent to investigate the quality of water, sediment, and biota), the following water quality problems are considered to be within the scope of the Bi–State Program, and should be addressed by the reconnaissance survey:

1. Levels of toxic chemicals in water and sediments. Toxic chemicals identified by the Bi–State Program include arsenic, zinc, mercury, lead, tributyl tin (TBT), DDT and its derivatives, other pesticides, dioxins and furans, polynuclear aromatic hydrocarbons (PAHs), and PCBs. Levels of other toxic chemicals, such as those on the U.S. Environmental Protection Agency's list of priority pollutants, those known to be discharged by major point sources, and those measured in previous studies on the lower Columbia, should also be addressed.

2. Levels of toxic chemicals in tissues of river biota (bioaccumulation).

3. Levels of radionuclides.

4. Levels of nutrients such as nitrogen and phosphorus in water.

5. Concentrations of pathogenic bacteria and other microbes in water.

6. Levels of biochemical oxygen demand (BOD), resulting in depressed levels of dissolved oxygen (DO).

2.2 PAST AND CURRENT STUDIES

A primary objective of Task 1 (Initial Data Review and Synthesis) of the reconnaissance survey project has been to collect, analyze, and evaluate past and current studies on water quality conditions in the lower Columbia River so that the reconnaissance survey can be designed to complement these other studies. Over 160 documents have been collected and reviewed for data on the water column, sediments, and biota of the lower river that are relevant for use in designing the sampling plan (Tetra Tech 1991a). Studies that meet minimum quality standards (i.e., studies where sample collection, sample handling, quality assurance, and analytical methods were adequate to ensure data accuracy and precision) have been selected for further examination. Selected studies have included both impact assessments and general characterization studies. Although data for many types of media and variables have been evaluated, studies providing data on sediment contaminant levels, water column measurements, tissue bioaccumulation, and benthic infauna communities have been used as input to this sampling design.

To facilitate evaluation of existing and future data, the lower Columbia River has been separated into four major and ten minor river segments (defined in Tetra Tech 1991c) based on similar physical characteristics and processes. Past station locations from each accepted study and for each media have been plotted on the Columbia River base maps. Summary tables of the kinds and concentrations of the parameters measured at each location have been prepared and have been used to select sampling station locations for this reconnaissance survey. Studies that have measured a wide range of parameters have received more consideration in the sampling design than studies measuring only a few parameters. In some cases where a recent study has been performed and has measured a range of chemicals similar to the "Chemicals of Concern" described in later sections, the past station locations have been generally avoided

when selecting the sampling sites [e.g., Oregon Department of Environment Quality (DEQ) sediment, bioaccumulation, and carp enzyme study]. In instances where data are lacking, these areas have been targeted for additional sampling efforts (e.g., downstream from the confluence of the Willamette River) as part of the reconnaissance survey. Where past studies have identified potential areas of concern (e.g., Blahm *et al.* 1980; Century West Engineering 1989, 1990), an effort has been made to locate a station near that area. More specific details on how the past and current studies have been taken into account in designing the sampling plan for each media are discussed in Sections 4.0–7.0.

2.3 POLLUTION SOURCES

The purpose of Task 2 (Inventory and Characterization of Pollutants) has been to inventory and characterize point, non-point, and in-place pollutant sources on the lower Columbia River so that this reconnaissance survey can be designed to account for these sources of pollutants. Tributaries have also been evaluated and considered as a measure of point and non-point pollution input from the drainage sub-basin.

Consideration for the selection of sampling locations has been given primarily to the location of permitted major point source discharges, tributaries, and marinas identified and evaluated in Task 2. Minor permitted discharges have not been considered due to preliminary findings that although these facilities outnumber major facilities (36 to 20), pollutant loading from these facilities is considerably less than from major facilities. The distinction between major and minor discharges is established by the U.S. EPA for municipal/domestic, industrial and agricultural discharges. The criteria for distinguishing between major and minor discharges are discussed in Tetra Tech (1991b). For example, a domestic discharge is considered major if it is greater than 1,000,000 gallons per day (monthly average), or it is from a service population greater than 10,000.

Twenty major and 36 minor permitted point sources to the lower-Columbia River have been identified. These include domestic wastewater, chemical, aluminum, and pulp and paper industry discharges, as well as effluents from seafood processing, fish hatcheries, power generating facilities, wood products industries, and additional miscellaneous industries. Pollutants discharged by these sources include biochemical oxygen demand (BOD), total suspended solids (TSS), fecal coliform bacteria, metals, and organic compounds that include chlorinated organics such as dioxin. Several sampling stations have been selected downstream from point sources of pollution to investigate the effect of these sources on water quality.

Major tributaries to the lower Columbia River have been identified and historical data have been evaluated to assess the potential pollutant loading from these sources. Water quality of several major tributaries will be sampled upstream from their confluence with the lower Columbia River in order to assess the loading of pollutants from tributaries.

It has not been possible to incorporate non-point source pollutant loading in the sampling plan due to the diffuse nature of this source. In-place pollutants (i.e., landfills and hazardous waste sites, including Superfund sites) have only been considered where impacts to the river have previously been documented due to the uncertainty of the in-river location of potential impacts from these sources. Detailed information on the location and extent of impacts to the lower Columbia River has been identified for only one site, the Port of Vancouver, where surface water and sediment have been contaminated with copper and other metals (Tetra Tech 1991b). For this survey, a sediment sampling station has been located near the Port of Vancouver in order to evaluate the impact of this facility on the local sediments.

Marinas along the lower Columbia River were identified in Task 2. Marinas are considered to be potential sources of tributyl tin. Several sediment sampling stations have been located adjacent to marinas and ports in order to evaluate the potential contamination of these sites.

2.4 BENEFICIAL USES

One of the goals of the Bi-State Program is to determine whether beneficial uses of the lower Columbia River have been impaired. Beneficial uses have been defined for the Bi-State Program by combining Oregon's beneficial uses and Washington's characteristic uses of state waters.

1. Water Supply:

   - All domestic water supply systems including PUD and municipal public systems, Indian withdrawal rights, and other surface water extractions used for domestic supply; and

   - Industrial supply including direct withdrawals for manufacturing, processing, or other industrial activity.

2. Agricultural:

- All private or public withdrawals for the purpose of irrigating agricultural crops, orchards, or public lands;

- All withdrawals for the purpose of supplying water to commercial livestock operations; and

- Areas of concentrated withdrawals by private landowners to supply livestock.

3. Fish and Wildlife and Their Habitats:

- Resident fish and wildlife;

- Areas supporting anadromous fish passage, salmonid fish rearing, resident fish, and aquatic wildlife use including national and state refuges;

- Significant riparian habitats, such as backwater marshes and island nesting areas; and

- Unique marine or freshwater habitats, and Natural Heritage Sites.

4. Recreation:

- Hunting, fishing, and boating;

- Primary contact recreation, in general where contact with the water is submergence, such as skin diving, swimming, water skiing, jet skiing, and wind surfing;

- Secondary contact recreation, in general where water contact is limited, such as wading or fishing; and

- Aesthetic quality where senses are involved (i.e., scenic overlooks, unique botanical areas, birdwatching areas, etc.)

5. Commercial:

- Hydropower production;
- Navigation and transportation;
- Marinas and other commercial activities associated with the river; and
- Commercial fisheries.

Major beneficial use areas in the study area are shown in Figures 1 through 4. The locations where these uses occur along the lower Columbia have been a major factor in selecting sampling locations for this reconnaissance survey. Water quality-sensitive uses that have been considered in designing the survey are primary recreation (swimming, waterskiing, board-sailing, etc), shellfish harvesting, fishing, and wildlife use. The ways in which the locations for these uses have been factored into the survey design are described for each water quality medium in Sections 4.0 through 7.0. Examples include siting bacteria sampling stations in primary recreation and shellfish harvesting areas, siting additional water and sediment sampling stations near primary recreation areas and wildlife use areas, and collecting crayfish samples from wildlife use areas. All data collected on beneficial uses in the lower Columbia are presented in Tetra Tech (1991d).

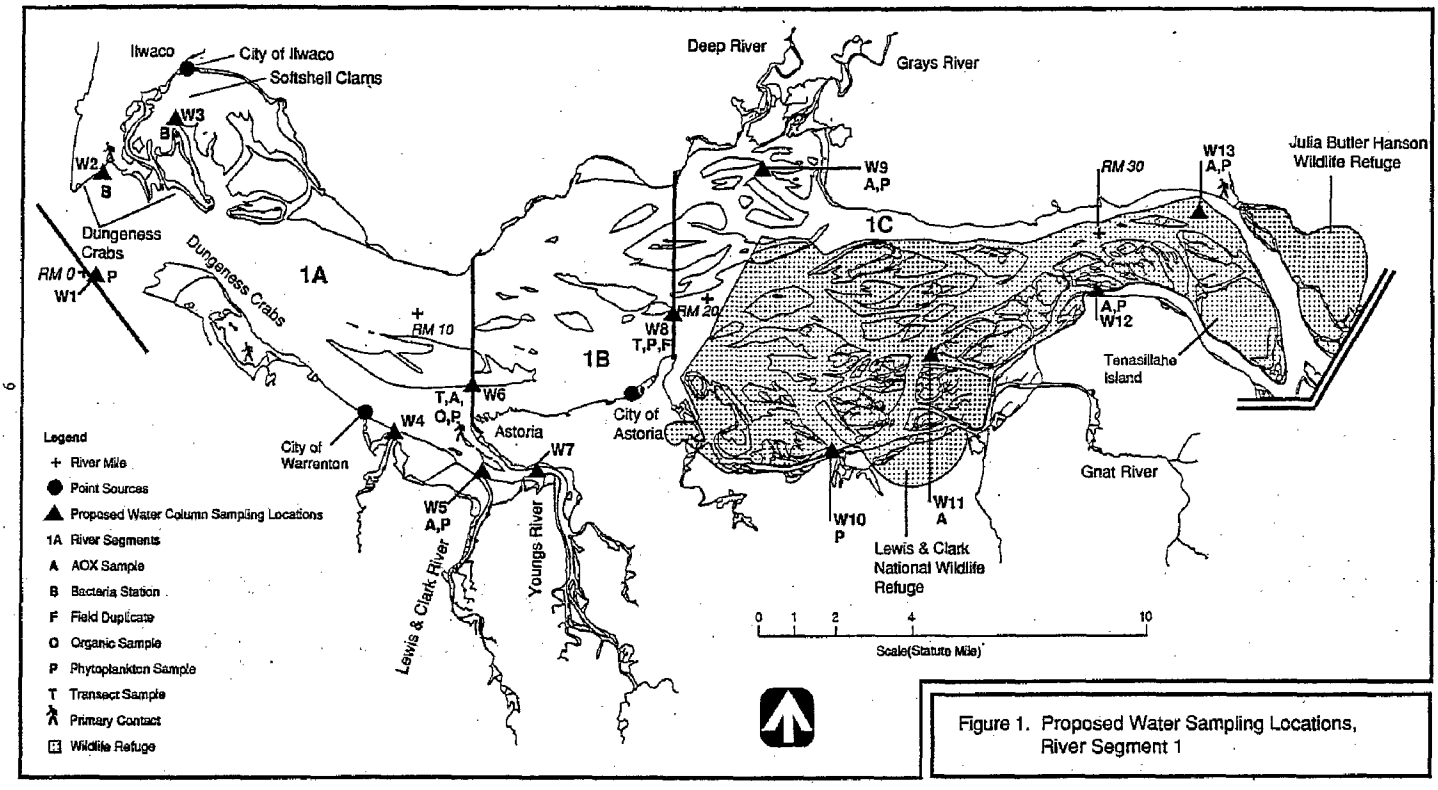

Figure 1. Proposed Water Sampling Locations, River Segment 1

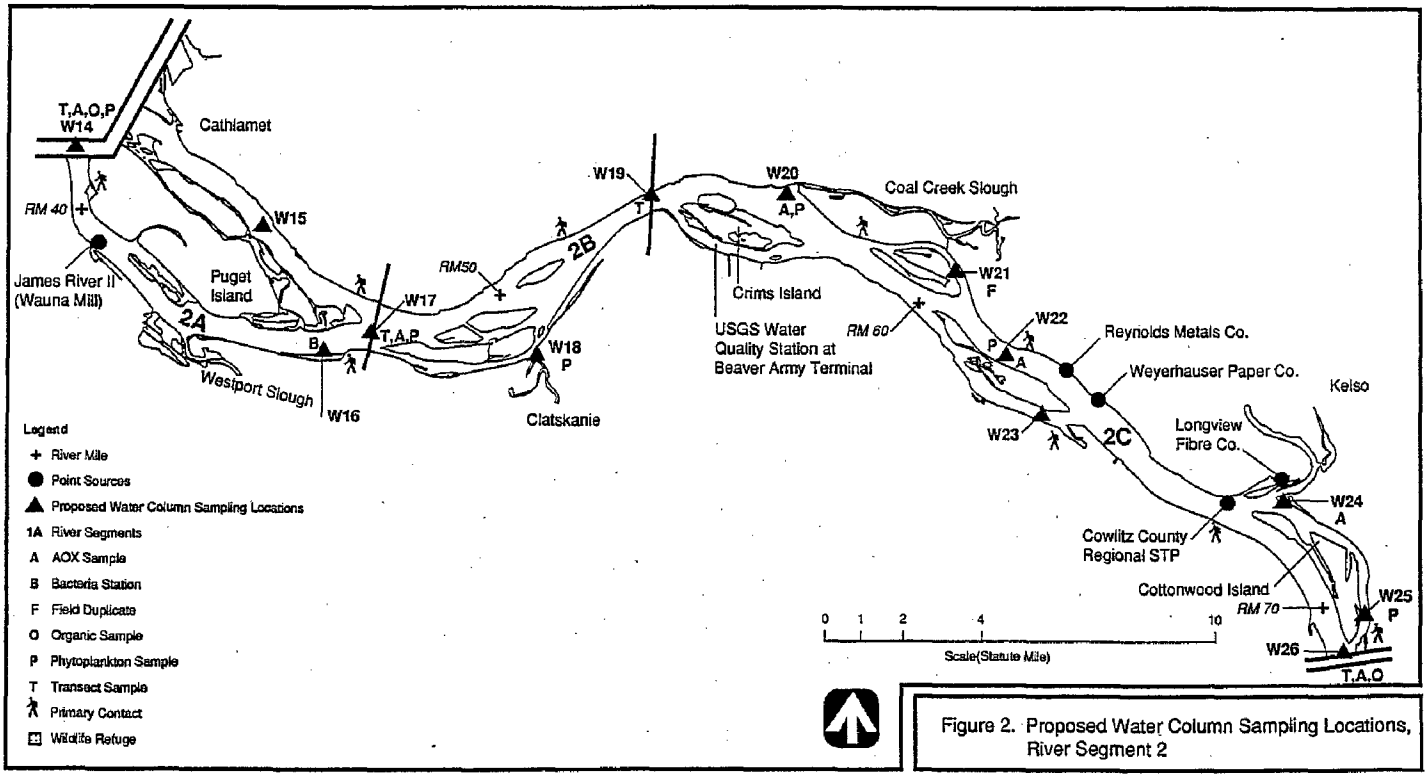

Figure 2. Proposed Water Column Sampling Locations, River Segment 2

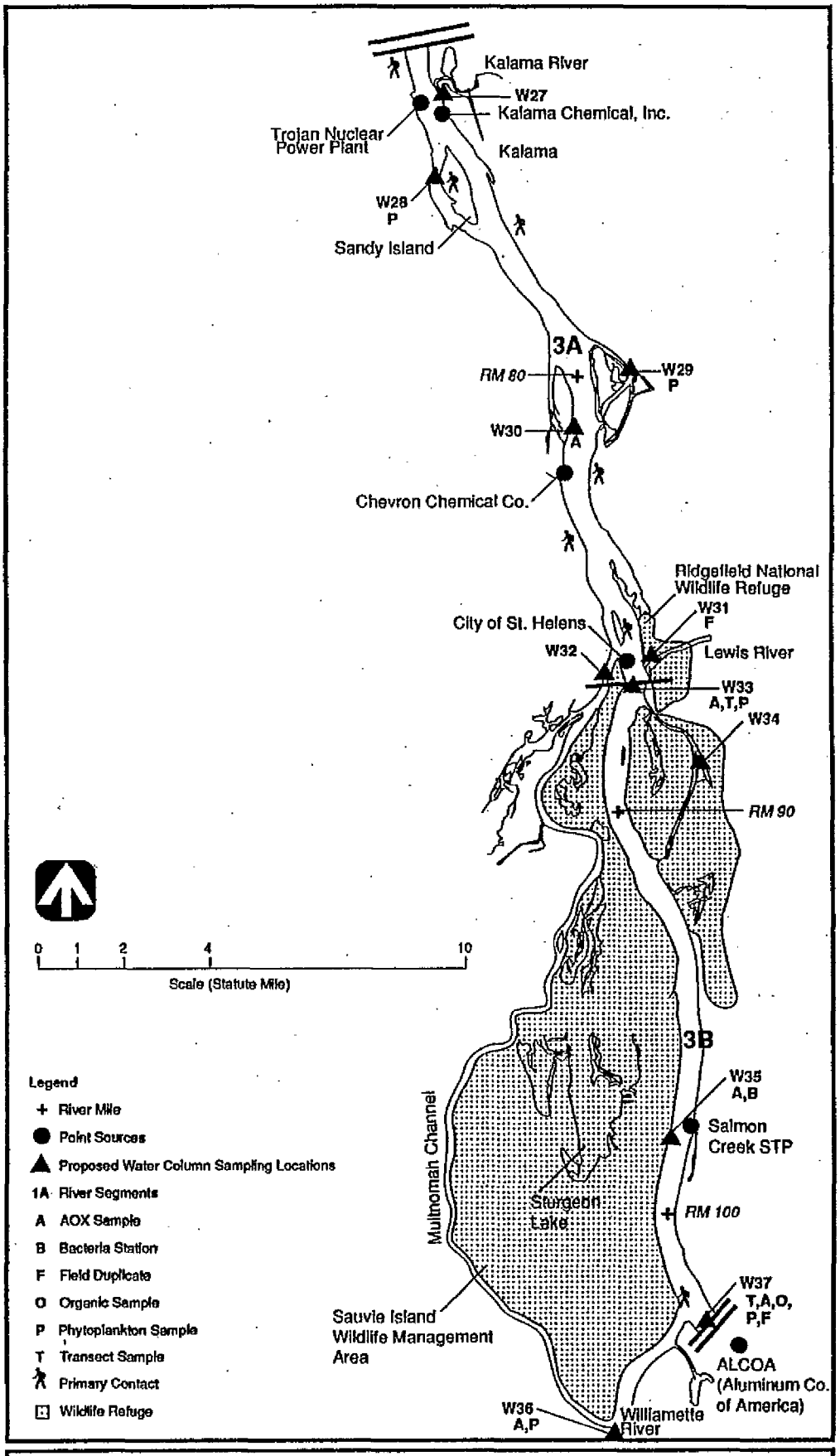

Figure 3. Proposed Water Column Sampling Locations, River Segment 3

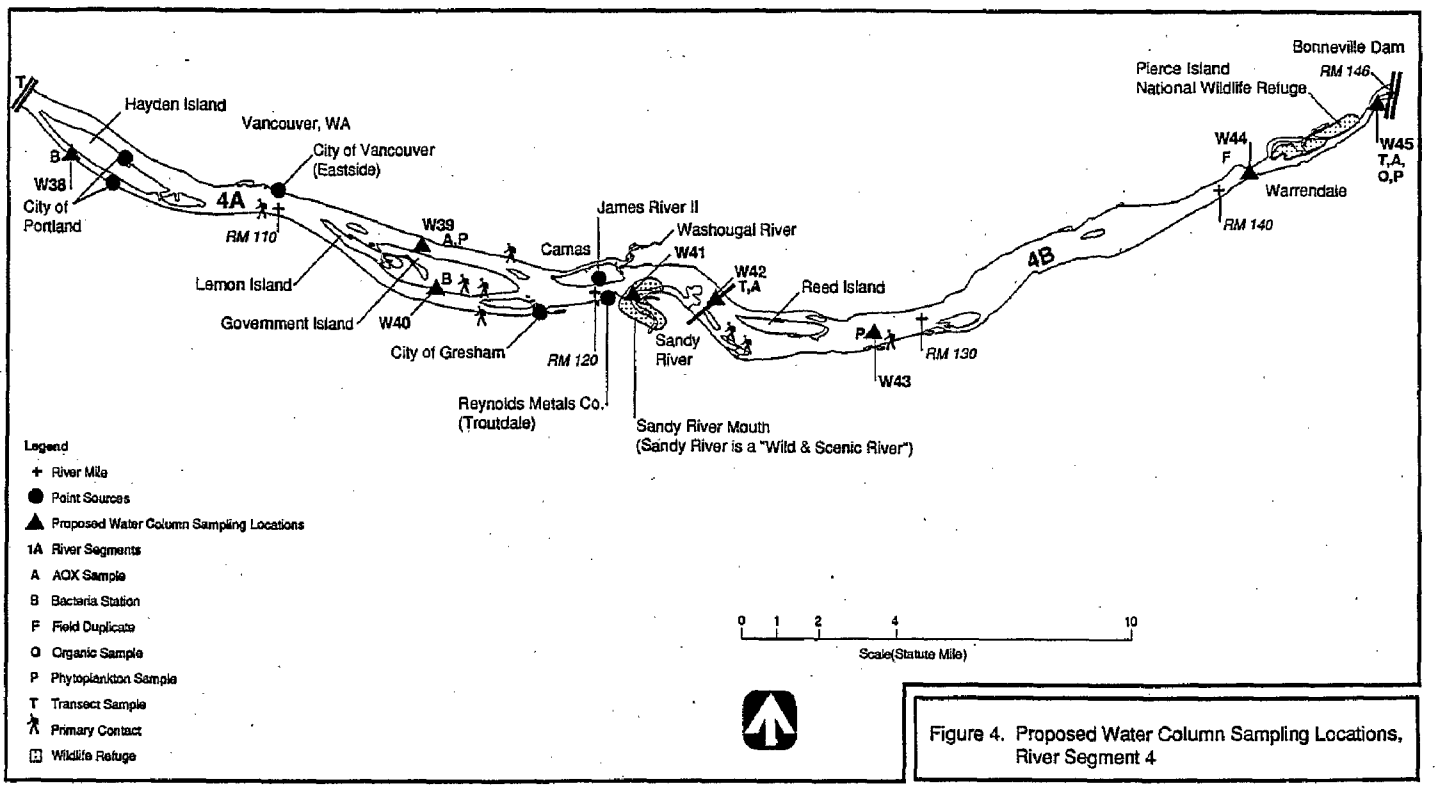

Figure 4. Proposed Water Column Sampling Locations, River Segment 4

3.0 GENERAL PLAN FEATURES

This section describes the strategy and conceptual plan for addressing, in the reconnaissance survey, the water quality problems listed in Section 2.0. Sections 4.0 through 7.0 describe, for each of the water quality media, the objectives and the proposed sampling strategy, sample collection methods, parameters to be analyzed, and sampling locations.

3.1 GENERAL CONSIDERATIONS

The budget for the reconnaissance survey was established in the Tetra Tech team's proposal submitted to the Bi-State Program on April 2, 1991. Although the design of the survey may change, the total cost of the survey (field costs plus laboratory costs) cannot exceed the budget established in the proposal, so that adequate funding is available for the other tasks of the project. A single sampling episode is proposed to provide the best geographical coverage (most samples) of the study area within the established budget. This approach is appropriate for a reconnaissance/screening survey. Seasonal and inter-annual variations in water quality are important and should be addressed in later focused studies. For essentially the same reasons, a single composite sample per station is proposed. This does not allow for statistical comparisons between individual locations. However, this is not a prime objective of a reconnaissance survey. The purpose of taking composite samples is to increase the representativeness of the samples. The manner in which the samples will be composited is described in Sections 4.0 through 7.0. Field duplicate composite samples will be taken at 10 percent of the stations as a check of the homogeneity of the compositing process. The planned single samples are intended to be representative of river segments, and data from samples within each river segment will be grouped so that statistical comparison among segments can be made. In addition, statistical analyses of trends in levels of contamination along the river will also be possible (see Section 8.0).

Within the available budget, the proposed distribution of samples (including an additional ten percent for duplicate samples) among the three media is as follows:

50 water
60 sediment
76 tissue
54 benthos
240

Water, sediment, and tissue samples will be analyzed for levels of organic and inorganic contaminants, and for conventional variables. Sediment sampling is emphasized over water sampling because, in aquatic systems, most contaminants, especially toxic chemicals, tend to be associated with particulate matter. As a result, most contaminants in aquatic systems are located in deposited sediments, and enter the food chain through ingestion of sediment rather than other means. Even in polluted systems, the concentrations of toxic chemicals in the water column are often below detection limits, so that the sediments become the best indicator of pollution levels.

The proposed number of tissue samples is relatively large because 1) relatively little data exists on tissue contamination in the lower Columbia, 2) many toxic chemicals tend to accumulate in tissue, 3) consumption of fish and shellfish is one of the principal pathways for exposure of wildlife and humans to potential water quality problems in the lower Columbia, and 4) several types of fish and shellfish species will be sampled. Target species and contaminants are addressed in Section 6.0.

Sampling of benthos (identification and enumeration of species, not tissue contaminant analysis) is planned because these organisms are expected to be a key biological indicator of water quality conditions in the lower Columbia. Because of their close association with sediment, benthic organisms have been shown to be affected by pollution in aquatic systems. Benthic invertebrates play a key role in stream ecosystems due to their intermediate position linking primary production and higher trophic levels (e.g., fish). Macroinvertebrates are particularly suitable as ecological indicators in river systems for several reasons: 1) benthic communities show cumulative effects of present/past conditions; 2) they have low mobility and relatively long life cycles; 3) their ecological relationships are relatively well understood; 4) sampling procedures are relatively well developed; 5) the group is heterogeneous in that a single sampling technique collects a considerable number of species from a wide range of phyla; and 6) macroinvertebrates are generally abundant. In the lower Columbia River study, benthic communities will provide much needed information on two issues: 1) the types of benthic communities residing in the lower Columbia River, and 2) whether the benthic communities in the lower Columbia River are suitable for use in an environmental monitoring program.

Although they are commonly used as indicators of toxicity and environmental health, sediment bioassays are not proposed for the reconnaissance survey because they are considered a less

direct measure of water quality than the proposed measures, and because they have relatively high costs compared to the other measures. Bioassays should be conducted in later phases of the project.

3.2 SCHEDULE

The sampling is expected to begin on September 23, 1991 and require approximately three weeks for completion. The cruise will begin at Bonneville Dam and proceed down river to the mouth. The principal reason for this is to take advantage of the river's current to minimize travel time between sampling stations. This will minimize the duration of the cruise and the likelihood of delays due to onset of poor weather conditions in October. All events and factors that could affect water quality during the sampling cruise (e.g., operation of Bonneville Dam, tidal cycles, weather, etc.) will be documented and factored into data interpretation.

3.3 CHEMICALS OF CONCERN

Chemicals of concern, which represent the toxic compounds that will be measured in this survey, have been developed for each water quality medium (water, sediment and tissue). These chemicals are listed in Table 1 by medium. These lists were compiled from several sources, including the following:

- EPA's list of priority pollutants.
- Chemicals of concern identified in the Bi-State Program's Four-year Program Plan.
- Comments from the Steering Committee, Scientific Resource Panel, and others on the Preliminary Sampling Plan.
- Chemicals analyzed in DEQ's ongoing study of sediments and tissues in the lower Columbia.
- Chemicals known to be discharged by major point sources along the river.
- Chemicals measured in past studies.

TABLE 1. COLUMBIA RIVER SAMPLING PLAN
CHEMICALS OF CONCERN[g]

Compound	Water	Sediments	Tissues
METALS			
Aluminum	X	X	
Antimony[a]	X	X	X
Arsenic[a,b]	X	X	X
Barium	X	X	X
Beryllium[a]	X	X	
Cadmium[a,b]	X	X	X
Chromium[a]	X	X	
Copper[a,b]	X	X	X
Iron	X	X	
Lead[a,b]	X	X	X
Mercury[a,b,d]	X	X	X
Nickel[a]	X	X	X
Selenium[a,d]	X	X	X
Silver[a]	X	X	X
Thallium[a]	X	X	
Zinc[a,d]	X	X	X
Cyanide[a]	X	X	
Tributyltin[g]		X	
VOLATILES			
Chloromethane	X		
Vinyl chloride[a]	X		
Methylene chloride[a]	X		
1,1-Dichloroethane[a]	X		
Chloroform[a]	X		
1,1,1-Trichloroethane[a]	X		
Bromodichloromethane	X		
trans-1,3-Dichloropropene	X		
Chlorodibromomethane[a]	X		
Benzene[a]	X		
Bromoform[a]	X		
Tetrachloroethylene[a]	X		
Chlorobenzene[a]	X		
Total xylenes	X		
Bromomethane	X		
Chloroethane[a]	X		
1,1-Dichloroethylene	X		
trans-1,2-Dichloroethylene[a]	X		
1,2-Dichloroethane[a]	X		
Carbon tetrachloride[a]	X		
1,2-Dichloropropane[a]	X		
Trichloroethylene[a]	X		
1,1,2-Trichloroethane[a]	X		
cis-1,3-Dichloropropene	X		
1,1,2,2-Tetrachloroethane[a]	X		
Toluene[a]	X		
Ethylbenzene[a]	X		
Methyl chloride[a]	X		
Methyl bromide[a]	X		
2-Chloroethylvinyl ether[a]	X		
1,2-Dichloropropylene[a]	X		

TABLE 1. CONTINUED

Compound	Water	Sediments	Tissues
Acrolein[a]	X		
Acrylonitrile[a]	X		
ADSORBABLE ORGANIC HALIDES (AOX)	X		
ACID EXTRACTABLE ORGANICS			
Phenolic Compounds			
Phenol[a]	X	X	X
2-Methylphenol	X	X	
4-Methylphenol	X	X	
2,4-Dimethylphenol[a]	X	X	
Pentachlorophenol[a]	X	X	X
2-Methoxyphenol	X	X	
2-Chlorophenol[a]	X	X	X
2,4-Dichlorophenol[a]	X	X	X
2,4-Dinitrophenol[a]	X	X	X
2-Nitrophenol[a]	X	X	X
4-Nitrophenol[a]	X	X	
2,4,6-Trichlorophenol[a]	X	X	X
BASE/NEUTRALS (SEMIVOLATILES)			
Halogenated Ethers (Other than those listed elsewhere)			
bis(2-chloroethyl)ether[a]	X	X	X
bis(2-chloroethyoxy)methane[a]	X	X	X
bis(2-chloroisopropyl)ether[a]	X	X	X
4-Bromophenylphenylether[a]	X	X	X
4-Chorophenylphenylether[a]	X	X	X
Nitroaromatics			
2,4-Dinitrotoluene[a]	X	X	X
2,6-Dinitrotoluene[a]	X	X	X
Nitrobenzene[a]	X	X	X
Nitrosamines			
N-nitroso-di-n-propylamine[a,c]	X	X	X
N-nitrosodimethylamine[a]	X	X	X
N-nitrosodiphenylamine[a]	X	X	X
Chlorinated Naphthalene			
2-Chloronaphthalene[a]	X	X	X
Polynuclear Aromatics			
Acenaphthene[a]	X	X	X
Acenaphthylene[a]	X	X	X
Anthracene[a]	X	X	X

TABLE 1. CONTINUED

Compound	Water	Sediments	Tissues
Benzo(a)anthracene[a]	X	X	X
Benzofluoranthenes[a]	X	X	X
Benzo(a)pyrene[a]	X	X	X
Benzo(g,h,i)perylene[a]	X	X	X
Chrysene[a]	X	X	X
Dibenzo(a,h)anthracene[a]	X	X	X
Fluoranthene[a]	X	X	X
Fluorene[a]	X	X	X
Indeno(1,2,3-cd)pyrene[a]	X	X	X
Naphthalene[a]	X	X	X
Phenanthrene[a]	X	X	X
Pyrene[a]	X	X	X
Chlorinated Benzenes			
1,3-Dichlorobenzene[a]	X	X	X
1,2-Dichlorobenzene[a]	X	X	X
1,4-Dichlorobenzene[a]	X	X	X
1,2,4-Trichlorobenzene[a]	X	X	X
Hexachlorobenzene[a]	X	X	X
Hexachlorobutadiene[a]	X	X	X
Hexachloroethane[a]	X	X	X
Hexachlorocyclopentadiene[a]	X	X	X
Benzidines			
3,3'-Dichlorobenzidine[a,e]	X	X	X
Benzidine[a]	X	X	X
Phthalate Esters			
Dimethylphthalte[a]	X	X	X
Diethylphthalate[a]	X	X	X
Di-n-butylphthalate[a]	X	X	X
Butylbenzylphthalate[a]	X	X	X
bis-2-(ethylhexyl)phthalate[a,e]	X	X	X
Di-n-octylphthalate[a]	X	X	X
Pesticides			
o,p'-DDE	X	X	X
o,p'-DDD	X	X	X
o,p'-DDT	X	X	X
4,4'-DDT[a,b,c,e]	X	X	X
4,4'-DDE[a,b,c,d,e]	X	X	X
4,4'-DDD[a,b,c,e]	X	X	X
Heptachlor[a,b,c,d,e]	X	X	X
Heptachlor epoxide[a,b,c,d,e]	X	X	X
alpha-chlordane[a,b,c,d,e]	X	X	X
Aldrin[a,b,e]	X	X	X
Dieldrin[a,b,c,d,e]	X	X	X
Nonachlor	X	X	X
Mirex (dechlorane)	X	X	X

TABLE 1. CONTINUED

Compound	Water	Sediments	Tissues
Dacthal	X	X	X
Dicofol	X	X	X
Methyl parathion	X	X	X
Parathion	X	X	X
Malathion	X	X	X
Toxaphene[a,b,e]	X	X	X
Isophorone[a]	X	X	X
Endosulfan I[a]	X	X	X
Endosulfan II[a]	X	X	X
Endosulfan sulfate[a]	X	X	X
Endrin[a,b,v,f]	X	X	X
Endrin aldehyde[a]	X	X	X
Methoxychlor	X	X	X
alpha-BHC[a,b,c,d,e]	X	X	X
beta-BHC[a,e]	X	X	X
delta-BHC[a]	X	X	X
gamma-BHC (Lindane)[a,b,c,d,e]	X	X	X
PCBs			
Arochlor 1016[a,c,e]	X	X	X
Arochlor 1221[a,c,e]	X	X	X
Arochlor 1232[a,c,e]	X	X	X
Arochlor 1242[a,c,e]	X	X	X
Arochlor 1248[a,c,e]	X	X	X
Arochlor 1254[a,c,e]	X	X	X
Arochlor 1260[a,c,e]	X	X	X
Dioxins and Furans			
2,3,7,8-TCDD[a,c,d,e]		X	X
1,2,3,7,8-PeCDD[c,d]		X	X
1,2,3,4,7,8-HxCDD[d]		X	X
1,2,3,6,7,8-HxCDD[c,d]		X	X
1,2,3,7,8,9-HxCDD[d]		X	X
1,2,3,4,6,7,8-HpCDD[c,d]		X	X
Octachlorodibenzo-p-dioxin[c,d]		X	X
2,3,7,8-TCDF[c,d]		X	X
1,2,3,7,8-PeCDF[c,d]		X	X
2,3,4,7,8-PeCDF[d]		X	X
1,2,3,4,7,8-HxCDF[d]		X	X
1,2,3,7,8,9-HxCDF[d]		X	X
1,2,3,6,7,8-HxCDF[d]		X	X
2,3,4,6,7,8-HpCDF[d]		X	X
1,2,3,4,7,8,9-HpCDF[d]		X	X
Octachlorodibenzofuran[d]		X	X

TABLE 1. CONTINUED

Compound	Water	Sediments	Tissues
Radionuclides			
Americium-241		X	
Cesium-137		X	
Cobalt-60		X	
Europium-152		X	
Europium-154		X	
Plutonium-238-239-240		X	

[a] Priority pollutant.

[b] Target compounds of bioconcentration study by Schmitt and Brumbaugh (1990), and Schmitt et al. (1990).

[c] Currently monitored by Oregon Department of Environmental Quality.

[d] Bioconcentrating compounds monitored in the National Bioaccumulation Study (U.S. EPA 1991a).

[e] Chemicals of highest concern listed by U.S. EPA (1991b).

[f] All dioxin and furan isomers identified by this method will be reported.

[g] Analytical methods and detection limits are provided in the Quality Assurance/Quality Control (QA/QC) Plan (Tetra Tech 1991e) accompanying this sampling plan.

The rationale for the chemicals of concern listed for each medium is given in more detail in Sections 4.0 through 6.0. In addition to the compounds listed in Table 1, the analytical laboratories for this survey will tentatively identify additional compounds detected in the samples.

3.4 RIVER SEGMENTATION

As part of Task 3 (hydrological characterization) of this project, the lower Columbia River has been divided into segments based on hydrological and geographical factors (Tetra Tech 1991c). These segments are also useful in designing the reconnaissance survey. Sampling locations from past studies on the lower Columbia have been patchy in distribution because they have been typically designed to characterize a particular location of concern. For a reconnaissance survey, however, it is important that all areas of the river be adequately covered. By grouping the existing sampling locations in a particular river segment, data gaps can be more readily identified. River segments from which little data have been collected can be assigned a higher sampling priority than segments for which an abundance of data exists.

The lower Columbia River has been divided into four major segments, each of which has been further divided into two or three minor segments. River Segments 1 through 4 are shown in Figures 1–4, respectively. Major segment boundaries have been designed to group areas with similar hydrographic and morphologic characteristics in the same segment. The boundaries between minor segments are depicted by a double line running across the river, perpendicular to the river axis. Minor segment boundaries are generally based on major geographic features such as confluences of major tributaries along the river. A brief description of each major segment is given below.

Segment 1 runs from the mouth of the river at RM–0 to Tenasillahe Island at RM–37, where Cathlamet Channel meets the main navigational channel. This segment encompasses the extent of the salt wedge intrusion from the Pacific Ocean. Segment 2 starts at Tenasillahe Island and ends just upstream of the Cowlitz River at RM–72. The segment boundary has been located several miles upstream of the Cowlitz River so that the periodic flow reversal from the Cowlitz will be contained in a single segment. In Segment 3, the river runs north, from just upstream of the Willamette River (RM–102) to near the Cowlitz River. Other major tributaries in Segment 3 include the Lewis, East Fort Lewis, and Kalama Rivers. Segment 4 runs from upstream of the Willamette River to just below the Bonneville Dam at RM–146. Major tributaries in Segment 4 include the Washougal and Sandy Rivers.

4.0 WATER SAMPLING

4.1 OBJECTIVES AND STRATEGY

The reconnaissance survey will measure concentrations of chemicals of concern (Table 1), bacteria, nutrients, and conventional variables at 45 selected stations in the water column as part of the assessment of the water quality of the lower Columbia River. The water column sampling plan is designed to achieve the following objectives:

- Characterize the levels of chemicals of concern in the water column using river segments to provide an overall assessment of levels in the lower Columbia; provide data for inputs to developing conceptual models on contaminant transport in the river; and provide data for use in estimating pollutant loading to the river.

- Characterize levels of bacteria or other microbes in water near beneficial use areas to assist in evaluating water quality effects on these uses.

- Characterize levels of nutrients to address potential concerns about eutrophication in each river segment, in the vicinity of major point sources, beneficial uses, and major river mouths.

- Characterize levels of conventional variables throughout the lower Columbia River and compare these levels with established criteria and standards to assess the water quality of the river.

- Compare levels of contaminants, nutrients, and conventionals among river segments and potential areas of concern to assess potential impacts to beneficial uses.

- Characterize levels of adsorbable organic halides (AOX) as an indicator of the influence of pulp and paper mills on the lower Columbia.

To achieve the objectives, the following general sampling strategy has been developed:

- Sample at the boundaries of the identified river segments to provide overall characterization and address transport of materials between segments.
- Sample in shallow areas and beneficial use areas to evaluate impacts on beneficial uses.
- Sample upstream and downstream of major source areas to assess the effect of these sources on water quality.
- Sample at mouths of major tributaries (upstream of the Columbia River confluence) to evaluate pollutant loading.
- Analyze all samples for conventional variables, nutrients, and metals.
- Analyze limited number of samples for organic contaminants.
- Analyze selected samples for AOX.
- Analyze bacteria in beneficial use areas.

4.2 SAMPLE COLLECTION

Water samples will be collected as grab samples using 2.5 L Niskin bottles. Grab samples will be collected at five depths: one meter below the surface, one meter above the bottom, at mid-depth, midway between mid-depth and the surface, and midway between mid-depth and the bottom. For samples at major and minor river segment boundaries (11 samples), samples will be collected at three locations along a transect across the river. These three locations will be at the center of the channel and at points halfway between the center and each bank.

Water collected for each water column station will be composited and thoroughly mixed prior to filling the sample containers. Each composited sample will be stored on ice until transport to the laboratory for analysis.

Some conventionals (i.e., temperature, conductivity, DO) will be measured as a depth profile using a salinity–temperature–depth recorder (CTD) with an attached DO probe that is lowered through the water column. pH will be measured for composited samples in the field using portable field equipment (e.g., YSI pH meter).

Since all samples from bacteria stations are expected to be in less than 2 m of water, these samples will be single, subsurface grab samples collected in bottles. Separate samples will be taken for bacteria analysis and for chemical analysis (metals, nutrients and conventionals). Temperature, conductivity, DO and pH will be measured *in situ* with portable field equipment. Collected samples will be stored on ice and delivered to the laboratory within 24 hours.

Because bacterial levels are highly variable in time, it is proposed that samples be collected at each of the 6 bacteria stations on 5 separate days during a 30-day period. This corresponds to the frequency of sampling required by Oregon's surface water regulations. Thus, a total of 30 bacteria samples will be collected. Nutrients, conventionals, and metals will be analyzed for one sample from each bacteria station (six samples).

4.3 PARAMETERS TO BE ANALYZED

Table 2 summarizes the proposed water column samples by parameters to be analyzed. The following parameters will be measured at all water column stations:

- Conventionals (i.e., temperature, conductivity, pH, dissolved oxygen, TSS, turbidity, hardness, and fluoride).

- Nutrients (i.e., total Kjeldahl nitrogen, ammonia, nitrate and nitrite, and total phosphorus).

- Total recoverable metals (includes both dissolved and suspended fractions) (i.e., aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, copper, cyanide, iron, lead, mercury, nickel, silver, selenium, zinc).

The list of parameters to be measured at all stations consists of common water quality parameters measured in most water column studies. In addition, the list consists of a compilation of parameters that have been measured in the existing water quality monitoring studies on the river (e.g., USGS stations). While the above list is not a complete list of all parameters ever

TABLE 2. SUMMARY OF PARAMETERS ANALYZED AT WATER COLUMN STATIONS[a]

Parameters Analyzed	Number of Samples
Number of Water Sampling Stations	50
Total Number of Samples Analyzed for Conventionals, nutrients, and metals	50
Additional Analyses[b]	
Organics	5
AOX	20
Bacteria	30[c]
Phytoplankton	20
Field Duplicates[d]	5

[a] Station locations are shown in Figures 1-4.

[b] Five at each of six stations.

[c] Field duplicates analyzed for conventionals, nutrients, and metals.

[d] Numbers of samples add to more than 50 because more than one of the additional analyses (organics, AOX, bacteria, and phytoplankton) are conducted at some stations. In addition, conventionals, nutrients, and metals will be measured on only six bacteria samples (one at each of the six bacteria stations).

measured on the river, the listed parameters provide the most information for the limited budget available. For example, in past studies, many metals have been measured separately in the dissolved and suspended fractions. In order to perform similar analyses within the existing budget as part of the reconnaissance survey, the number of stations in the reconnaissance survey would have to be reduced by one half. Total (dissolved fraction plus suspended fraction) analysis for water column samples is considered most appropriate for this reconnaissance survey as it maximizes the number of stations and geographical coverage within the available budget. Thus, in keeping with the objectives of the reconnaissance survey, only total recoverable metals (i.e., combined dissolved and suspended fractions) will be measured. Partitioning of contaminants into the dissolved and suspended fractions is important and should be considered for focused water column studies later in the program.

Of the 50 water column samples (45 stations plus 5 field duplicates), additional analyses will be performed at a subset of 5 stations. These additional analyses will include the following:

- Volatile organic priority pollutants.
- Acid extractable organics and base/neutral semivolatile priority pollutants.
- Priority pollutant PCBs/pesticides, plus the additional compounds listed in Table 1.
- Total organic carbon (TOC).

The rationale for including these additional analyses relates to the objectives of the reconnaissance survey; namely, to characterize the levels of contaminants in the river segments to provide an overall assessment of the contaminant levels in the river. Analysis of the priority pollutants at a limited set of stations is justified because most contaminants are not expected to be present in detectable levels in water; however, to adequately assess these concentration levels it is necessary to do the full analyses at a limited set of stations. The five stations selected for full analyses will include four stations at the upstream boundaries of each of the four major river segments, plus one station in the estuary. These stations will provide input data for development of conceptual models of contaminant transport in the river. Measurement of TOC will allow normalization of organic contaminants to organic carbon.

The priority pollutant volatile organic compounds (VOCs), as a class of potential contaminants, are much more soluble than most of the non-polar semivolatile organic compounds; however, they are volatile in surface water and have a limited tendency to accumulate in sediments and

biological tissues. As a result, the VOCs are relatively short-lived in surface water. In addition, this group of compounds is also of lower acute toxicity to aquatic organisms than many of the toxic elements and semivolatile organic compounds. Because of their high rate of loss from the water and low toxicity, the VOCs pose a limited threat to aquatic organisms. However, many of these substances are known or suspected human carcinogens, and their presence at even low concentrations can limit the suitability of the contaminated water as a potable water supply. Therefore, measurement of VOCs is recommended at a limited set of stations.

Organic halides are volatile and semivolatile organic compounds containing chlorine, fluorine, bromine or iodine. Many of these compounds are found in effluents from pulp and paper mills. These mills are often required to measure adsorbable (to particulate matter) organic halides (AOX) in their effluent. For this survey, Tetra Tech proposes to measure AOX in samples from 20 selected water column stations as a measure of the influence of pulp and paper mills on water quality in the lower Columbia.

Analyses for radionuclides, dioxins, furans, and tributyl tin, which will be conducted for sediments (see Section 6.3), are not recommended for water samples. These contaminants tend to be present at even lower concentrations in water than the organic priority pollutants discussed above, because 1) like most other contaminants, they are associated with particulate matter, and 2) their levels in the lower Columbia system in general are lower than many organic priority pollutants. Because of the very low probability of these contaminants being present at detectable levels, analysis of even a limited set of water samples for these contaminants is not justifiable.

One way to deal with the low levels of contaminants in the water column is to extract particulate matter from large volumes of water, determine the quantities of contaminants in the extracted particulate matter and then back-calculate the concentration of contaminants in the volume of water sampled. This approach was used in a study by the Washington Department of Ecology in Lake Roosevelt on the upper Columbia River, in which sediment was centrifuged from 4,000 gallons of water over a 57-hour period. Although this type of approach is appealing, it is not feasible for this reconnaissance survey because there is not time to acquire and set up the necessary equipment for this year's dry-season sampling, and because the need to sample for a long period at (presumably) several locations would disrupt the logistics of the rest of the sampling cruise. However, this is a promising technique for addressing low concentrations of certain contaminants in the water column. It will be considered for possible recommendation for focused water column studies later in the program.

Bacteria samples will be analyzed for fecal coliforms and *Enterococcus*, which are commonly used indicators for pathogenic microbes. Fecal coliforms are the bacterial indicators used in the surface water regulations of Oregon and Washington.

Chlorophyll *a* is a parameter that is sometimes used as a measure of eutrophication, instead of or in addition to nutrients such as nitrogen and phosphorus. For several reasons, measurement of chlorophyll *a* is not proposed for this study. First, chlorophyll is a measure of plant biomass in the water, living and dead, including actively producing phytoplankton, phytoplankton that is not producing due to lack of light or other reasons, and plant debris of aquatic and terrestrial origin. In most of the study area, (the riverine portion), much of the primary production occurs in attached macrophytes. Therefore, chlorophyll *a* levels are expected to be a relatively poor measure of primary production. In addition, chlorophyll *a* levels are particularly variable in time and in space. A measure of chlorophyll at a single point in time and space (as all the measures in the survey) will be less meaningful than most other parameters measured. Finally, measurement of chlorophyll *a* will require setting up a separate water filtering system on the research vessel. This will increase the water sampling effort by approximately 25 percent, requiring a reduction in the number of water stations by 10 to 15 percent. For these reasons, measurement of chlorophyll *a* is not proposed.

The abundance and composition of phytoplankton will be addressed by conducting phytoplankton enumeration on water samples from 20 stations (Figures 1–4). In these samples, density (number of phytoplankton cells/mL) will be determined, phytoplankton volume will be estimated, and composition will be evaluated based on identification of phytoplankton in subsamples to the lowest possible taxon. In addition, total Kjeldahl nitrogen (TKN), which will be measured in all water samples, is a measure of organic nitrogen, including that contained in phytoplankton. TKN levels will include a measure of plant biomass, the biological variable measured by chlorophyll *a*.

4.4 SAMPLING LOCATIONS

A total of 45 water column stations will be sampled during the reconnaissance survey. As part of Task 3, the lower Columbia River has been divided into four major river segments and ten minor segments on the basis of a variety of physical considerations (e.g., estuarine vs. freshwater, extent of tidal reversals, major slope changes) (see Figures 1–4). To characterize levels of chemicals of concern in each segment and provide data for development of conceptual models of contaminant transport in the river, one water quality station will be located at the upstream boundary of each of the ten segments. All of these samples will be analyzed for

conventional variables, nutrients, and metals. The four samples taken at the upstream boundary of each major segment, plus one sample in the estuary (see Figures 1–4), will also be analyzed for organic chemicals of concern (see Table 1). These samples will be collected along transects across the river at the boundary locations. Samples from five depths (as described in Section 4.2) will be collected at three points along each transect and combined to form a composite sample for that transect.

Ten additional stations will be located in the mouths of major tributaries to the river (Figures 1–4) in order to assess the pollutant contributions from each tributary. These data will be used for estimating pollutant loading to the river from these nonpoint sources. These samples will be taken from five depths at a single location, composited, and analyzed for conventionals, nutrients, and metals. All of these samples will be collected on the ebb tide and/or far enough up the tributary that only water from the tributary is sampled, and not a mixture of tributary and Columbia River water. For rivers entering the Colombia near its mouth, such as the Youngs and Lewis and Clark rivers, it may not be feasible to avoid a mix of tributary and Columbia River water, even at ebb tide.

Additional composite samples will be collected at 19 points in beneficial use areas and other generally shallow and backwater areas along the river (Figures 1–4). These stations have been selected to evaluate water quality in beneficial use areas, upstream and downstream of industrial areas, near point sources, and at tributary river confluences. Samples collected from these stations will also complement the complete-channel samples taken at the river segment boundaries for the purposes of overall water quality characterization. These 19 samples will be analyzed for conventionals, nutrients and metals.

The 20 stations (a subset of the total of 45 stations) where AOX will be measured in the water column (Figures 1–4) have been selected downstream of major pulp and paper mill discharges and other industrial areas, and at appropriate reference locations throughout the four river segments.

Single subsurface grab samples for bacteria will be taken at six beneficial use areas along the lower river (Figures 1–4). These stations have been placed near locations of water quality-sensitive uses: primary contact recreation (swimming, waterskiing, boardsailing, etc.) and shellfish harvesting. Although surface water extraction for municipal/domestic use is considered water quality-sensitive, there are no known significant withdrawals of surface water from the lower Columbia for municipal/domestic use. Additionally, no bacterial sampling stations have been proposed near these uses because bacterial levels are reduced to acceptable levels through treatment prior to municipal/domestic use.

The location of past and current water column studies has not played a major role in siting stations for this survey. This is because most of these studies are limited either in parameters analyzed or in sampling dates, so that their locations cannot be assumed to be adequately characterized for the purposes of this reconnaissance survey. One exception is the U.S. Geological Survey (USGS) station at Warrendale, Oregon, where comprehensive water quality data were collected from 1973 to 1989. This survey plan includes a complete water quality sample at Warrendale for comparison to this historical data set, and to serve as an upstream reference site for the study area. The transect sample proposed for the upstream boundary of river segment 2B is located very near the new USGS water quality station at Beaver Army Terminal, Oregon.

To the extent possible, water column stations have been sited near sediment stations so that within-location relationships between the two media can be evaluated. Table 3 lists the water column stations, with parameters to be analyzed at each and the rationale for station location.

TABLE 3. PARAMETERS TO BE MEASURED AT WATER COLUMN SAMPLING STATIONS, AND FACTORS CONSIDERED IN LOCATING STATIONS

Water Quality Sampling Station[a]	Approximate River Mile	Parameters Sampled	Nearby Beneficial Uses[b]	Nearby Point Sources	Other Factors Affecting Station Location[c]
W1	0	Conventionals, nutrients, metals, phytoplankton			Characterize water quality at river segment boundary
W2	2	Bacteria, conventionals, nutrients, metals	Primary contact area		
W3	3	Bacteria, conventionals, nutrients, metals	Softshell clam beds	City of Ilwaco WWTP	
W4	11	Conventionals, nutrients, metals, phytoplankton		City of Warrenton WWTP	Characterize discharge of Skipanon River
W5	13	AOX, conventionals, nutrients, metals, phytoplankton	Primary contact area		Characterize discharge of Lewis and Clark River
W6	13	Organics, TOC, AOX, conventionals, nutrients, metals	Primary contact area		Characterize water quality at river segment boundary
W7	13	Conventionals, nutrients, metals	Primary contact area		Characterize discharge of Youngs River
W8	19	Conventionals, nutrients, metals, phytoplankton		City of Astoria WWTP	Characterize water quality at river segment boundary
W9	22	AOX, conventionals, nutrients, metals, phytoplankton	Wildlife refuge		Near confluence of Deep and Grays Rivers

TABLE 3. CONTINUED

Water Quality Sampling Station	Approximate River Mile	Parameters Sampled	Nearby Beneficial Uses[b]	Nearby Point Sources	Other Factors Affecting Station Location[c]
W10	23	Conventionals, nutrients, metals, phytoplankton	Wildlife refuge		Characterize backwater area
W11	27	AOX, conventionals, nutrients, metals	Wildlife refuge		Near confluence of Gnat River
W12	31	AOX, conventionals, nutrients, metals, phytoplankton	Wildlife refuge		Characterize backwater area
W13	33	AOX, conventionals, nutrients, metals, phytoplankton	Wildlife refuge, primary contact area		
W14	38	Organics, TOC, AOX, conventionals, nutrients, metals, phytoplankton	Primary contact area	Downstream of James River Wauna Mill	Characterize water quality at river segment boundary
W15	44	Conventionals, nutrients, metals			Characterize river reach
W16	45	Bacteria, conventionals, nutrients, metals	Primary contact area	Upstream of Wauna Mill	
W17	47	AOX, conventionals, nutrients, metals, phytoplankton		Upstream of Wauna Mill	Characterize water quality at river segment boundary
W18	50	Conventionals, nutrients, metals, phytoplankton			Characterize discharge of Clatskanie River
W19	54	Conventionals, nutrients, metals			Characterize water quality at river segment boundary Near new USGS station at Beaver

TABLE 3. CONTINUED

Water Quality Sampling Station	Approximate River Mile	Parameters Sampled	Nearby Beneficial Uses[b]	Nearby Point Sources	Other Factors Affecting Station Location[c]
W20	56	AOX, conventionals, nutrients, metals, phytoplankton		Downstream of Longview sources	Characterize discharge of Coal Creek Slough
W21	60	Conventionals, nutrients, metals		Downstream of Longview sources	Characterize backwater area
W22	62	AOX, conventionals, nutrients, metals	Primary contact area	Downstream of Longview sources	
W23	63	Conventionals, nutrients, metals	Primary contact area		
W24	68	AOX, conventionals, nutrients, metals	Primary contact area	Longview Fibre Co.	Characterize discharge of Cowlitz River
W25	71	Conventionals, nutrients, metals, phytoplankton	Primary contact area		Characterize backwater area
W26	72	Organics, TOC, AOX conventionals, nutrients, metals		Kalama Chemical, Inc. Trojan Nuclear Power Plant	Characterize transport across river reach boundary
W27	73	Conventionals, nutrients, metals			Characterize discharge from Kalama River
W28	75	Conventionals, nutrients, metals, phytoplankton	Primary contact area		
W29	80	Conventionals, nutrients, metals, phytoplankton			Characterize backwater area
W30	81	AOX, conventionals, nutrients, metals		Chevron Chemical Co. City of St. Helens WWTP	

TABLE 3. CONTINUED

Water Quality Sampling Station	Approximate River Mile	Parameters Sampled	Nearby Beneficial Uses[b]	Nearby Point Sources	Other Factors Affecting Station Location[c]
W31	87	Conventionals, nutrients, metals	Wildlife refuge		Characterize discharge of Lewis River
W32	88	Conventionals, nutrients, metals			Characterize discharge of Multnomah Channel
W33	88	AOX, conventionals, nutrients, metals, phytoplankton			Characterize water quality at river segment boundary
W34	91	Conventionals, nutrients, metals	Wildlife refuge		Characterize backwater area
W35	98	AOX, bacteria, conventionals nutrients, metals	Wildlife refuge	Salmon Creek WWTP	
W36	102	AOX, conventionals, nutrients, metals, phytoplankton	Primary contact area		Characterize discharge of Willamette River
W37	102	Organics, TOC, AOX, conventionals, nutrients, metals, phytoplankton		ALCOA (Vancouver) and other Portland/Vancouver sources	Characterize water quality at river segment boundary
W38	104	Bacteria, conventionals, nutrients, metals	Primary contact area	City of Portland auxiliary WWTP outfall	Near large urban area
W39	114	AOX, conventionals, nutrients, metals, phytoplankton		James River II, Inc. (Camas)	
W40	115	Bacteria, conventionals, nutrients, metals	Primary contact area	City of Gresham WWTP	

TABLE 3. CONTINUED

Water Quality Sampling Station	Approximate River Mile	Parameters Sampled	Nearby Beneficial Uses[b]	Nearby Point Sources	Other Factors Affecting Station Location[c]
W41	121	Conventionals, nutrients, metals			Characterize discharge of Sandy River
W42	125	AOX, conventionals, nutrients, metals			Characterize water quality at river segment boundary
W43	129	Conventionals, nutrients, metals, phytoplankton	Primary contact area		Reference station
W44	141	Conventionals, nutrients, metals	Wildlife refuge		For comparison with existing data from USGS Warrendale. Reference station
W45	146	Organics, TOC, AOX, conventionals, nutrients, metals, phytoplankton			Characterize water quality at upper end of study area (reference station)

[a] Corresponds to water stations shown on Figures 1-4.

[b] Definition of Primary Contact Area includes at least one of the following uses: swimming, waterskiing, boardsailing or wading.

[c] Existing water quality data very limited, generally not useful for determining station location. One comparative station was located at Warrendale.

5.0 SEDIMENT SAMPLING

5.1 SAMPLING OBJECTIVES AND STRATEGY

The objectives of the sediment sampling program for the reconnaissance survey are multifold and include:

- Determination of the substances present in the sediments of the lower Columbia River that could pose a threat to natural resources or have an impact on biota.
- Characterization of major spatial trends in the distribution of chemicals of concern.
- Identification of potential problem areas and reference areas.
- Evaluation of the relationship between biological effects and sediment contaminant concentrations.

The strategies used to address these objectives are based on a number of considerations regarding our current understanding of the accumulation of contaminants in sediments and characteristics of the Columbia River.

First, the sediment sampling strategy is based on the fact, established in many studies in other systems, that many contaminants of anthropogenic origin tend to accumulate in high concentrations in sediments compared to the concentrations found in the ambient water. The sediments thus represent a potential long-term reservoir for these substances, 1) resulting in exposure of bottom-living organisms to potentially toxic conditions, and 2) serving as a source for the bioaccumulation of the substances into organisms exposed to the sediments. In addition, toxic substances are more readily detected in sediments than in water because of the higher concentrations per volume of material, and thus, collection and analyses of sediments are favored in broad-scale surveys to determine the types and locations of contaminant inputs to a system. Finally, data from other systems have also established that the toxic substances accumulate primarily on the surface of the sediments. This process results in finer-grained sediments

accumulating higher concentrations of toxic substances than coarser material, due to their higher surface area per mass. The sampling will therefore focus on soft-bottom depositional areas that are expected to represent the major deposits of toxic substances, and de-emphasize sampling in the coarser sands and gravel of the non-depositional areas. However, to verify this strategy, samples of a range of sediment types (i.e., non-depositional areas) will be collected from each segment of the river.

Depositional areas mostly occur in backwaters and in isolated areas on the river. In particular, wetland areas and sloughs adjacent to the river are the most likely areas to collect fine-grained materials. Many of these areas are located relatively far from known sources of contaminant loading, because those sources tend to be located in high energy areas where the effluent is rapidly dispersed. Therefore, sampling predominantly in depositional areas raises concerns about how representative the results of the sampling will be in the context of the river system. This is a valid concern because many of the lower Columbia River sediments are composed of coarse sands. Although there is a significant loading of fine-grained material to the river, it tends to move through the lower Columbia fairly rapidly and is either flushed into the ocean or is transported into the depositional areas. The fine-grained sediment that is deposited in these sloughs and wetlands may provide a source of contamination to biota and probably represents the worst case conditions on the river. Therefore, by sampling predominantly in these areas, the worst case conditions on the river will be identified.

To meet the second objective of the sediment sampling program (i.e., to characterize the major spatial trends in the distribution of chemicals of concern) and because a comprehensive, full-river survey of the concentrations of multiple contaminants has not been previously performed, the reconnaissance survey will take samples in all reaches of the river from below the Bonneville Dam to the mouth. Consistent with the other parts of the strategy, the majority of samples will be collected from depositional areas, while a limited number of samples will be collected in non-depositional areas. Sampling intensity will be greater in areas near known major sources.

The third objective of the sediment sampling program (i.e., to identify potential problem areas and reference areas) is not intended to mean that focused studies will be performed around any one specific point source. Resources are not available to the reconnaissance survey to identify and delineate all of the potential "hot spots" (i.e., localized areas with substantially elevated concentrations of toxic substances) or reference areas on the lower Columbia River. However, as has also been noted in studies in other areas, contamination is nearly always more concentrated near the source than farther from it. Therefore, the sediment sampling will attempt to delineate the broad aspects of the contamination, if any, in the river by sampling

areas representing depositional zones downstream of multiple sources or major source areas (e.g., Portland/Vancouver and Kelso/Longview reaches), as well as locations assumed to be distant (generally upstream) from source areas.

Finally, as noted in the first point, the sediments may provide a reservoir of contamination that both provides a residual source to resident biota and may indicate the relative strength of ongoing inputs of contamination to an area. In either case, the concentrations of toxic substances in the sediments have been found in other studies to be related to the biological effects observed in resident biota, including bioaccumulation. This relationship will also be tested in the reconnaissance survey by collecting sediment samples at the same locations where the benthic and tissue samples are collected to provide data to correlate effects with the sediment concentrations. Such data can be very useful later in the program for developing sediment-quality control strategies, as well as cost-effective monitoring approaches.

Another objective of the sediment sampling program is to address public concerns about specific contaminants that may be present in the river system. The presence of tributyl tin in sediments near marinas and ports, as well as the perception of continued radionuclide inputs to the river, are two of the main areas of public concern. To address these public concerns, sampling for tributyl tin will be conducted at a limited number of locations near marinas and ports throughout the river. At six of the sediment stations, additional sediment samples will be collected for analysis of selected radionuclides.

Sixty sediment samples (54 stations and 6 field duplicates) will be collected according to the factors discussed above and analyzed for conventional variables and chemicals of concern (Section 5.2). At a subset of the 60 sediment stations, tissue samples will be collected for analysis of chemicals of concern (see Table 1 and Section 6.0). The specific parameters to be measured at each location will be discussed in Sections 5.3 and 5.4.

5.2 SAMPLE COLLECTION

Sediment sampling will be conducted by compositing the surface sediments from three grab samples at each sampling location to obtain a single sample for analysis. The use of a single composite grab sample is a compromise between characterizing field variability at each location and broad coverage of the river in as many locations as possible for the available resources. By compositing several grab samples, the effects of field variability are addressed to some degree. However, for a reconnaissance survey this compromise is justified.

Surface sediments (i.e., the top 2 cm) will be collected from each grab sample. The top 2 cm of sediment has been selected as the appropriate depth because it is consistent with other studies and because it will provide an analysis of the most recently deposited material (in depositional areas), thereby providing a worst-case scenario of the sediment quality in the lower Columbia River. By collecting only the surface sediments, contaminants that are located deeper in the sediments may be missed. However, given the dynamic nature of the river bottom and bioturbation, one would expect contaminants to be periodically mixed into the sediments to at least 10 cm. The mixing tends to homogenize the sediments and the associated contaminants in the mixed layer, therefore a specific sample depth in the 1 to 10 cm range may not be important. In predominantly depositional areas that are periodically subject to erosion, surface sediments may not always be recently deposited. However, because sampling will occur in low flow/low energy conditions, the surface sediments in most cases will reflect deposition of the most recent contaminants. In predominantly erosional areas, the depositional age of the surface sediments will not be known, but they will be the sediments most biologically available and most in contact with the water column.

An alternative to sampling the surface sediments is to collect sediment cores, vertically subdivide each core, and analyze the different depths separately. While this alternative is also of value for characterizing sediment contaminant levels, there are several drawbacks to using it as part of the reconnaissance survey. First, by analyzing several different depths for each core, the number of stations where the analyses are performed will have to decrease, resulting in fewer stations to characterize the river. Second, taking a single core at several locations will not be very informative unless a way of dating each depth horizon is incorporated into the analysis. Finally, because of the differences in sedimentation/erosion rates, interpretation of the results will be difficult and the relationship of the results to other areas of the river will be unclear. Thus, no coring will be conducted for the reconnaissance survey but the results of the survey should provide an indication of locations where coring may be done in future studies.

General station locations in depositional areas have been identified and will be discussed in greater detail in Section 5.4. The exact station location within a depositional area will be determined by 1) locating the boat in the general depositional area; 2) using the depth and echo sounder to tentatively identify bottom type and maneuver to a more precise location; 3) taking a test grab sample at the selected location to determine if the sediments are actually depositional. If the test grab indicates non-depositional sediments, the boat will be relocated to another location within the general area and the process repeated until an appropriate location is identified or five test grabs have been made without locating depositional sediments. If no appropriate sediments are located after five attempts, the Chief Field Scientist will

determine whether additional effort is warranted or whether the station should be relocated. If the station is relocated, it will be moved to the nearest downstream depositional area (See Figures 5–8 for alternate depositional locations).

Sediment sampling will follow the protocols developed for EPA in Puget Sound (Tetra Tech 1986), as described briefly below. This procedure uses a $0.1m^2$, modified, stainless–steel van Veen grab sampler. This sampler will operate well in soft sediments and in sand, is heavy enough to operate in channels with strong flows, and will collect sufficient sample for most of the testing without a high level of resampling.

The sampler will be deployed from a boat at all locations. The grab will be slowly lowered through the water column to prevent the sampler from flipping during descent and from creating a pressure wave sufficient to disturb bottom sediments. After contact with the bottom, the grab will be raised at a constant rate, carefully retrieved once it is at the surface, and placed in a level position on a sieving stand.

The sample will be evaluated for acceptance based upon the degree of disturbance, penetration depth, and amount of leakage from the grab. Samples with a minimal disturbance of surface sediments and adequate penetration depth will be accepted. Minimum penetration depths required for sample acceptance vary by sediment type as follows:

- 4 cm for medium to coarse sand
- 6 cm for fine sand
- 10 cm for silt and clay

Once on board, the overlying water will be siphoned from the sampler and the depth of sample measured by inserting a stainless steel ruler. Notes will be made on the depth of sediments in the sampler, as well as general observations of sediment color, texture, odor, and any other distinguishing characteristics such as the presence of oil sheen, wood debris, organisms, shell fragments, etc. If the sample does not meet the minimum depth or quality assurance (QA) requirements, it will be rejected and an additional grab will be collected. This process will be repeated at each station until three acceptable grab samples are collected, or it is determined that the station be relocated.

After the sample is described, surface sediments will be removed from the grab to a depth of 2 cm using a stainless steel spatula. Only portions of the sample away from the edges of the grab will be collected. The sediment will be placed in a pre–cleaned (solvent rinsed) stainless–steel bowl and carefully homogenized until uniform color and consistency are achieved. After

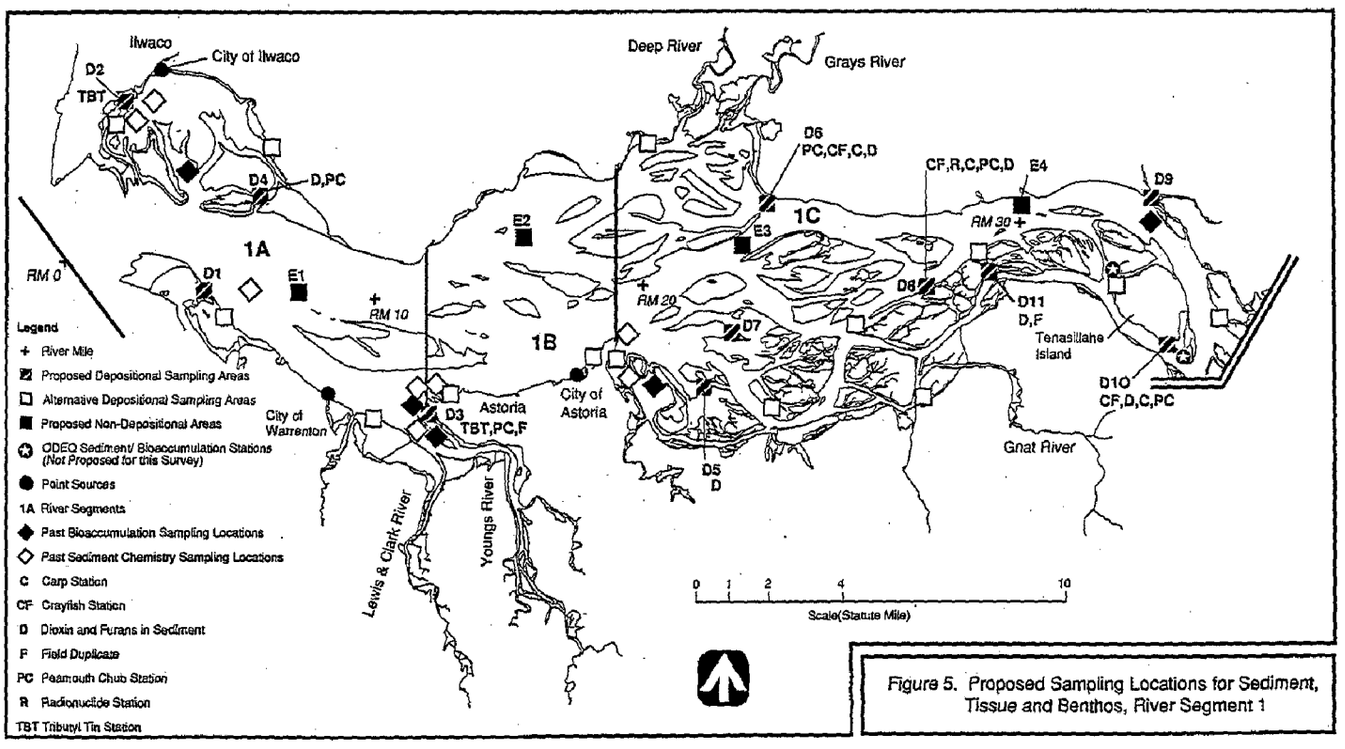

Figure 5. Proposed Sampling Locations for Sediment, Tissue and Benthos, River Segment 1

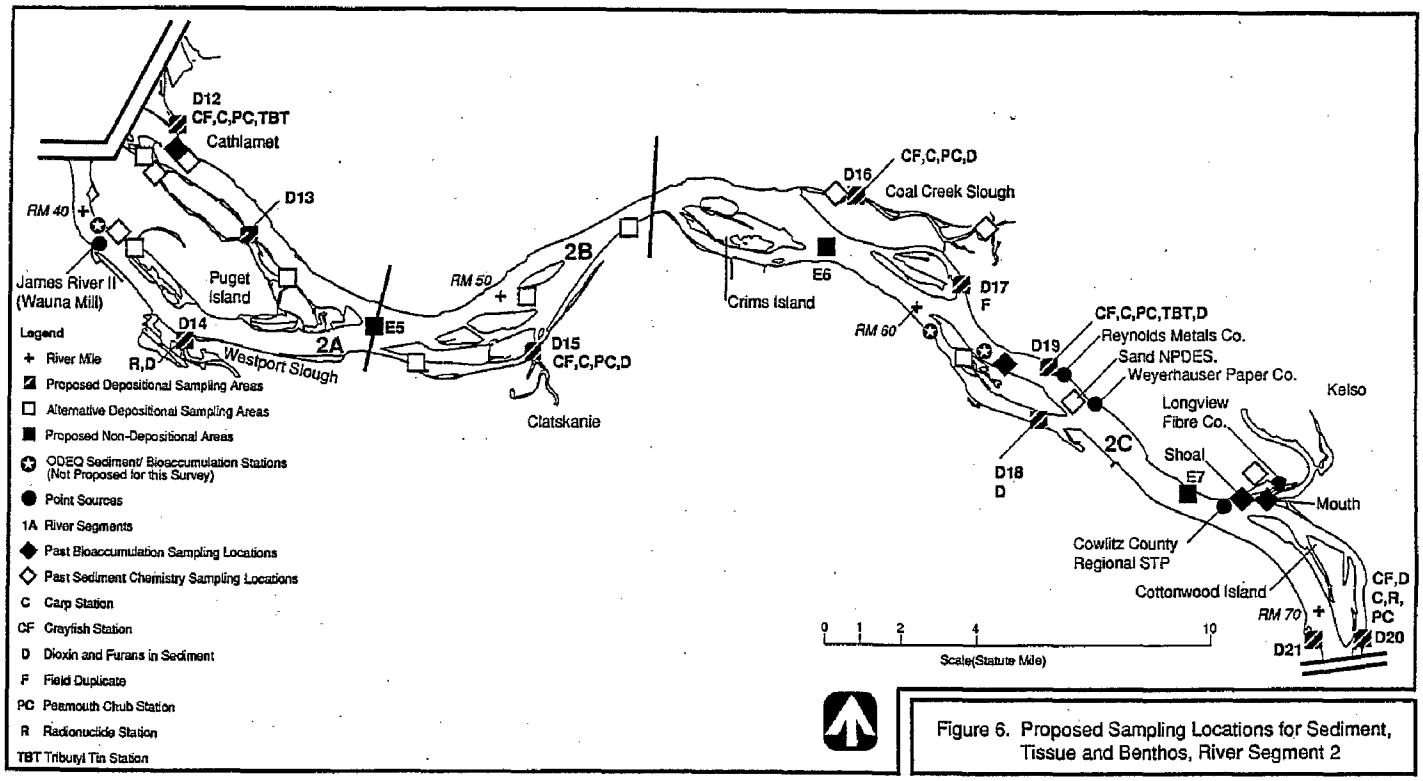

Figure 6. Proposed Sampling Locations for Sediment, Tissue and Benthos, River Segment 2

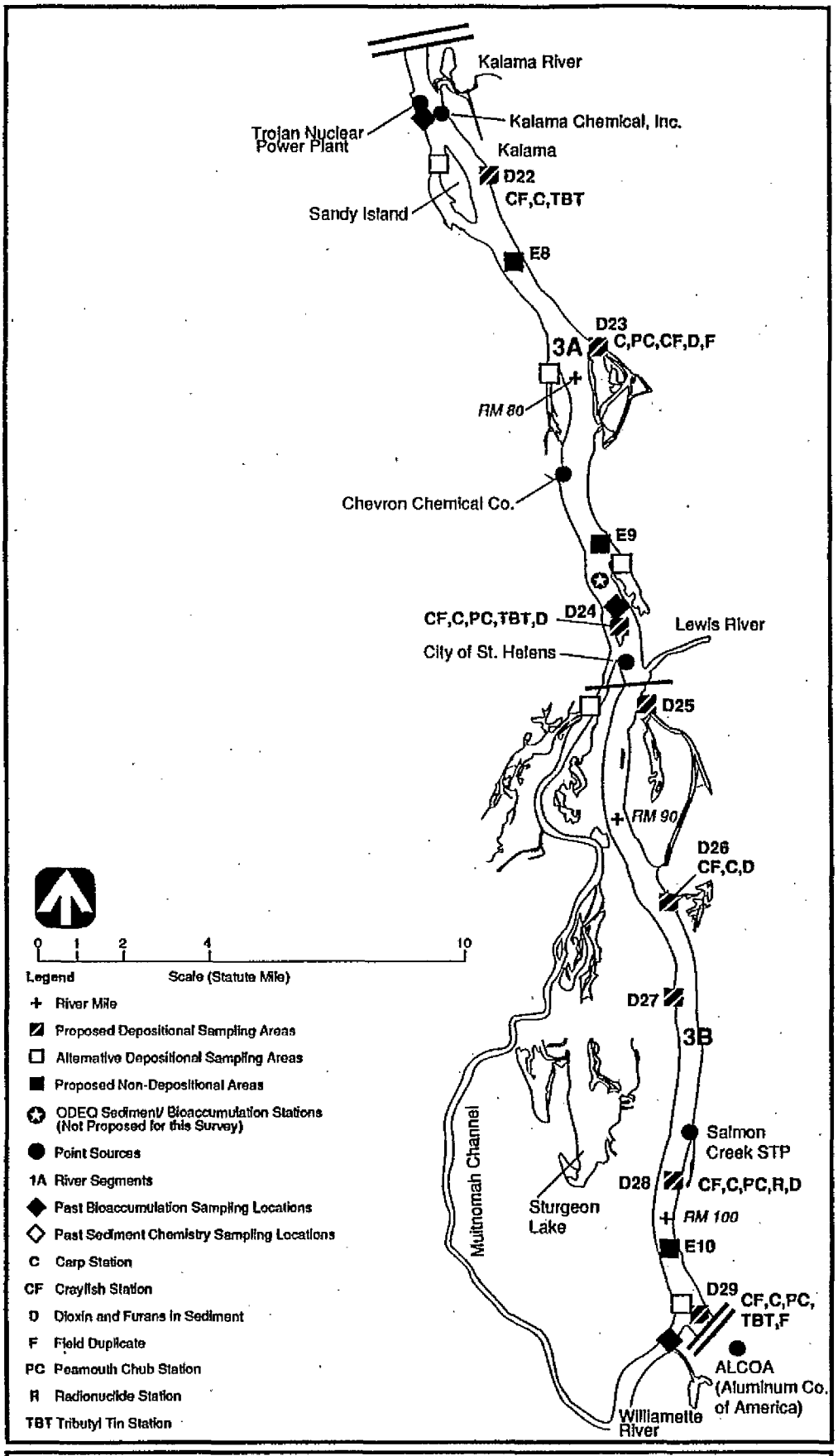

Figure 7. Proposed Sampling Locations for Sediment, Tissue and Benthos, River Segment 3

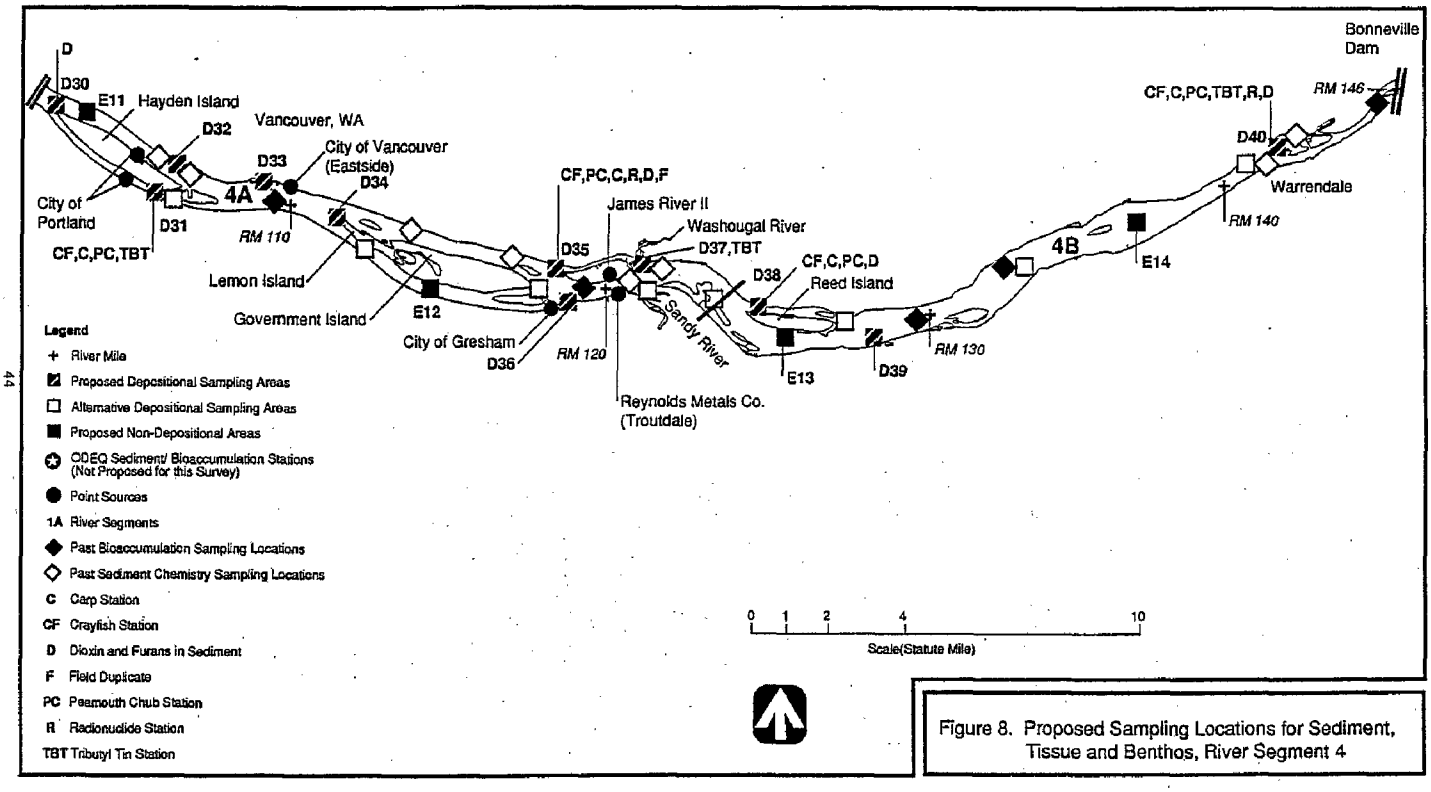

Figure 8. Proposed Sampling Locations for Sediment, Tissue and Benthos, River Segment 4

the sediment sample has been removed, the sediment remaining in the sampler will be examined again to refine the description of the sediment characteristics, particularly through the remaining depth of the sample.

Composite sediment samples will be obtained at all stations from a minimum of three grabs. Sediments from the additional grabs will be added to the bowl and homogenized before any aliquots are removed, to ensure that all aliquots contain similar material. The interstitial water salinity will be measured for each composite sample using a hand-held refractometer. The homogenized sample will then be placed in the sample collection containers.

Field duplicate samples will be collected from 10 percent of the station locations selected randomly before the sampling cruise begins. Field duplicates will be collected from the homogenized composite sample.

5.3 PARAMETERS TO BE MEASURED

The parameters that will be measured in the sediment samples are presented in Table 1 and include the priority pollutants, contaminants of concern identified by the Bi-State Program, tributyl tin (TBT), and indicators of pulp mill effluents. The priority pollutants are being measured to provide a characterization of sediment quality over a broad range of contaminants. The additional chemicals of concern (e.g., pesticides) have been identified by the Bi-State Program, as well as from summaries of the existing studies conducted on the river, and considerations of land use activities (e.g., agriculture). TBT was listed by the Bi-State Program in the Program Plan as a chemical of concern because of its high toxicity to biota and its past use in antifoulant paints used on boat hulls and other aquatic structures. The highest level of concern about TBT effects is in areas near marinas and boatyards. Two classes of compounds, dioxins and furans, that are tracers of pulp and paper mill effluents are included in Table 1. (The compounds reported in Table 1 are those of most concern, other isomers will also be reported). These compounds are included at selected stations because of the major influence of the pulp and paper mill discharges to the lower Columbia River. Selected radionuclides will also be measured at several sediment locations to determine if there continues to be a contribution of radionuclides from upstream sources and to address public concerns about these contaminants. In addition to the parameters listed in Table 1, the laboratories will also report the tentatively identified compounds (TIC) (e.g., the ten highest peaks for each run). The TICs will provide a qualitative measure of the compounds that are present but that are not being analyzed.

Conventional variables (i.e., grain size, total organic carbon, total solids, acid volatile sulfides) and chemicals of concern will be measured for all samples; TBT will be measured in 10 samples; dioxins and furans will be measured in 20 samples; and radionuclides will be measured for 6 selected samples. All analyses will conform to standard EPA-approved protocols and the necessary QA/QC backup information will be available to verify the data (see QA/QC Plan, Tetra Tech 1991e).

Table 4 summarizes the number of sediment samples by parameters to be analyzed, and Tables 5 and 6 summarize the parameters to be analyzed for each station.

5.4 SAMPLING LOCATIONS

A total of 54 stations will be established in the lower Columbia River with sediment chemistry and benthic infauna samples being collected at each station. Tissue collections will be made at a subset of the sediment stations. Paired collections will permit an analysis of the relationships between sediment chemistry and benthic communities and between tissue levels of contaminants. As noted above, sediments will be collected from all reaches of the river in this reconnaissance survey, and an attempt will be made to sample all types of habitats except areas with gravel and rock bottoms. The proposed sediment stations are shown on Figures 5 through 8. Single composite sediment samples will be collected at all stations. Field duplicate samples will be collected at 6 of the 54 stations (10 percent) to provide for QA of the field collection techniques (a total of 60 samples). The proposed locations of depositional and non-depositional sediment samples are shown in Figures 5-8, and the rationale for their location is summarized in Tables 5 and 6. The specific locations of samples will be determined in part during the actual cruise, based on direct observations of substrate and habitat characteristics as discussed above in Section 5.2. Stations have been distributed among Segments 1 through 4, with the number of stations in each segment a function of the length of the individual segment and the amount of existing data on sediment contaminant levels. This distribution of sediment locations will permit an assessment of sediment quality conditions in both depositional and non-depositional habitats throughout the river. Forty stations (75 percent) have been located in depositional areas and 14 stations (25 percent) are located in non-depositional areas. As determined from the literature review, non-depositional areas in the lower Columbia River have been the most studied habitats. Contaminants are not expected to be at high levels in these areas, therefore, fewer samples are required in these habitats (see Section 5.1). In general, within each segment, specific depositional station locations have been selected based on evaluation of the locations of existing data (or data gaps), of major point sources and tributaries, and of beneficial use areas including wildlife habitats. Non-depositional stations

TABLE 4. SUMMARY OF PARAMETERS ANALYZED AT PROPOSED SEDIMENT SAMPLING STATIONS[a]

	Number of Samples
Chemicals of Concern [a]	1
Dioxins and Furans Included (Chemicals of Concern Excluding TBT and Radionuclides)	14
TBT Included (Chemicals of Concern Excluding Dioxins and Furans and Radionuclides)	7
Radionuclides Included (Chemicals of Concern Excluding Dioxins and Furans and TBT)	2
Both Dioxins and Furans and TBT Included (Chemicals of Concern Excluding Radionuclides)	2
Both Dioxins and Furans and Radionuclides Included (Chemicals of Concern Excluding TBT)	3
Dioxins and Furans, TBT, and Radionuclides Excluded	25
Field Duplicates	6
TOTAL	60
Total Dioxin and Furan Samples	20
Total TBT Samples	10
Total Radionuclide Samples	6

[a] Station locations are shown in Figures 5-8.

[b] Chemicals of Concern are listed in Table 1.

TABLE 5. CHEMICAL AND BIOLOGICAL PARAMETERS MEASURED AT DEPOSITIONAL SAMPLING STATIONS, AND FACTORS CONSIDERED IN LOCATING STATIONS

Depositional Area[a]	Approximate River Mile	Parameters Sampled	Nearby Beneficial Uses	Nearby Point Sources	Other Factors Affecting Station Location
D1	6-7	Benthos, sediment	Within a Dungeness crab area	Approximately 4 miles downstream from City of Warrenton Wastewater Treatment Plant	
D2	1-2	Benthos, sediment, tributyltin	Near softshell clam and Dungeness crab areas	Near Ilwaco Sewage Treatment Plant Outfall	Adjacent to Port of Ilwaco Marina Comparison to previous studies in main channels
D3	12-13	Benthos, sediment, tributyltin, peamouth chub			Located at upper boundary of River Segment 1A Near Port of Astoria Located at the mouths of the Youngs River and Lewis and Clark River
D4	5	Benthos, peamouth chub, dioxin[b], sediments	Near Dungeness crab and softshell clam areas		Located near the mouth of the Chinook River Comparison to previous studies in Chinook Channel Baker Bay is a major depositional area.
D5	20	Benthos, dioxin[b], sediments	Adjacent to Lewis and Clark National Wildlife Refuge	Slightly upstream from Astoria Wastewater Treatment Plant	Located in depositional complex of estuary Previously unsampled area
D6	22-23	Crayfish, carp, peamouth chub, benthos, sediment, dioxin	Across river from Lewis and Clark National Wildlife Refuge		Located near the mouths of the Grays River and Deep River Previously unsampled area

TABLE 5. CONTINUED

Depositional Area[a]	Approximate River Mile	Parameters Sampled	Nearby Beneficial Uses	Nearby Point Sources	Other Factors Affecting Station Location
D7	22	Benthos, sediment	Located within Lewis and Clark National Wildlife Refuge		Located in depositional complex of estuary Previously unsampled area
D8	26-27	Crayfish, carp, peamouth chub, benthos, dioxin, radionuclides, sediment	Located inside Lewis and Clark National Wildlife Refuge Approximately 1-2 miles downstream from Oregon Dept. Fish and Wildlife Big Creek hatchery		Located in depositional complex of estuary Previously unsampled area
D9	34	Benthos, sediment	Adjacent to Skamokaw Vista Park, Julia Butler Hanson Wildlife Refuge, and Lewis and Clark National Wildlife Refuge	Downstream of James River II Wauna Mill	Located near the mouth of the Brooks Slough Previously unsampled area
D10	37-38	Crayfish, carp, peamouth chub, benthos, dioxin, sediment	Located inside Lewis and Clark National Wildlife Refuge Across river from Julia Butler Hanson Wildlife Refuge	Approximately 4 miles downstream from James River Pulp and Paper Mill (Wauna) Approximately 4 miles downstream and across river from Cathlamet Wastewater Treatment Plan	Comparison with past study - sediment chemistry
D11	28-29	Benthos, dioxin[b], sediment	Located inside Lewis and Clark National Wildlife Refuge Approximately 2 miles upstream from Oregon Dept. Fish and Wildlife Big Creek hatchery	Downstream of James River II Wauna Mill	Located in depositional complex of estuary Previously unsampled area
D12	40	Crayfish, carp, peamouth chub, benthos, tributyltin, sediment		Adjacent to Cathlamet Wastewater Treatment Plant	Located at mouth of Elochoman Slough Adjacent to marina

TABLE 5. CONTINUED

Depositional Area[a]	Approximate River Mile	Parameters Sampled	Nearby Beneficial Uses	Nearby Point Sources	Other Factors Affecting Station Location
D13	43-44	Benthos, sediment			Located in Cathlamet Channel Previously unsampled area
D14	37-38	Benthos, sediment, radionuclides, dioxin[b]		Approximately 2 miles upstream of James River Pulp and Paper Mill in Wauna	Located at mouth of Westport Slough Comparison with past study - benthos.
D15	50	Carp, crayfish, peamouth chub, benthos, dioxin, sediment		Near Clatskanie Wastewater Treatment Plant 4 miles downstream from Portland Gas and Electric Beaver Power Plant	Located at mouth of Clatskanie River.
D16	57	Benthos, Crayfish, dioxin[b], sediment, peamouth chub, carp		Just upstream from Portland Gas and Electric Beaver Power Plant Downstream from many industrial sources in Longview	Popular Crayfish collection site Comparison with past study - sediment chemistry
D17	61	Benthos, sediment		Approximately 2 miles downstream from Reynolds Metals Co. Downstream from many industrial sources in Longview	Located in slough Previously unsampled area
D18	62-63	Benthos, sediment, dioxin[b]		Directly downstream from Reynolds Metals Co.	Downstream of Cowlitz River confluence Previously unsampled area

TABLE 5. CONTINUED

Depositional Area[a]	Approximate River Mile	Parameters Sampled	Nearby Beneficial Uses	Nearby Point Sources	Other Factors Affecting Station Location
D19	62-63	Crayfish, carp, peamouth chub, benthos, tributyltin, dioxin, sediment		Directly downstream from Reynolds Metals Co. Less than 5 miles downstream from numerous industrial and domestic sources	Located downstream from the Port of Longview
D20	72	Carp, crayfish, peamouth chub, benthos, radionuclides, dioxin, sediment		Approximately 2 miles downstream from Trojan Nuclear Power Plant Approximately 3 miles downstream from Kalama Chemical Co.	Located in slough Previously unsampled area
D21	72	Benthos, sediment		Approximately 1 mile downstream from Trojan Nuclear Power Plant Approximately 2 miles downstream from Kalama Chemical	Previously unsampled area
D22	74-75	Crayfish, Carp, benthos, sediment, TBT		Approximately 1 mile upstream from Trojan Nuclear Power Plant Just upstream from Kalama Chemical Co.. Approximately 2 miles downstream from Virginia Chemicals and Town of Kalama Wastewater Treatment Plant	Adjacent to Port of Kalama Marina Previously unsampled area
D23	79	Crayfish, carp, peamouth chub, benthos, dioxin, sediment		Approximately 1-2 miles downstream across river from Chevron Chemical Co. Downstream of City of St. Helens/Boise Cascade Outfall	Located in slough Previously unsampled area

TABLE 5. CONTINUED

Depositional Area[a]	Approximate River Mile	Parameters Sampled	Nearby Beneficial Uses	Nearby Point Sources	Other Factors Affecting Station Location
D24	86	Crayfish, carp, peamouth chub, benthos, dioxin, tributyltin, sediment	Adjacent to Ridgefield National Wildlife Refuge Adjacent to downstream edge of Sauvie Island Wildlife Management Area	Just downstream from City of St. Helens/Boise Cascade Outfall	Located downstream of Multnomah Channel and Lewis River confluence Adjacent to St. Helens Marina Comparison with past study - sediment chemistry
D25	86-87	Benthos, sediment	Adjacent to Ridgefield National Wildlife Refuge Adjacent to Sauvie Island Wildlife Management Area	Approximately 1 mile upstream from City of St. Helens/Boise Cascade Outfall	Near mouth of Lewis River Just upstream of Multnomah Channel confluence
D26	92	Crayfish, carp, benthos, dioxin[b], sediment	Between Sauvie Island Wildlife Management Area and Ridgefield national Wildlife Refuge	None	Previously unsampled area
D27	94	Benthos, sediment	Adjacent to Sauvie Island Wildlife Management Area	None	Downstream of Willamette River confluence Previously unsampled area
D28	99	Carp, crayfish, peamouth chub, benthos, dioxin, sediment, radionuclides	Adjacent to Sauvie Island Wildlife Management Area	Approximately 1 mile upstream of salmon Creek Wastewater Treatment Plant Approximately 5 miles downstream from ALCOA Vancouver Smelter	Downstream of Willamette River confluence Downstream of Portland-Vancouver industrial area
D29	102	Carp, crayfish, peamouth chub, benthos, sediment, TBT		Approximately 2 miles downstream from ALCOA.	At Willamette River confluence Downstream of Portland-Vancouver industrial area

TABLE 5. CONTINUED

Depositional Area[a]	Approximate River Mile	Parameters Sampled	Nearby Beneficial Uses	Nearby Point Sources	Other Factors Affecting Station Location
D30	103	Benthos, sediment, dioxin[b]		Approximately 3 miles downstream from 8 major Portland and Vancouver point sources	Comparison with past study - benthos
D31	106	Crayfish, carp, peamouth chub, tributyltin, sediment, benthos			Located in a complex of marinas
D32	108	Benthos, sediment		Just upstream from 8 major point sources in Portland and Vancouver Approximately 2 miles downstream from the Vancouver Eastside Wastewater Treatment Plant	Comparison with past study - sediment chemistry
D33	109-110	Benthos, sediment		Slightly downstream from the City of Vancouver Eastside Wastewater Treatment Plant	Comparison with past study - sediment chemistry
D34	111	Benthos, sediment	Approximately 1 mile downstream from Vancouver Trout Hatchery	Downstream from James River II Camas Mill	Adjacent to Portland International Airport
D35	118-119	Carp, crayfish, peamouth chub, benthos, radionuclides, dioxin, sediment		Less than 1 mile downstream from James River II Camas Mill, James River II Sundial (Chip Reloading Facility), and Reynolds Metals Across river from City of Gresham Wastewater Treatment Plan	Comparison of results to previous study in non-depositional area.
D36	118	Benthos, sediment		Slightly upstream from City of Gresham Wastewater Treatment Plan Approximately 1 mile downstream of James River II Sundial Chip Reloading Facility	Previously unsampled area

TABLE 5. CONTINUED

Depositional Area[a]	Approximate River Mile	Parameters Sampled	Nearby Beneficial Uses	Nearby Point Sources	Other Factors Affecting Station Location
D37	121	Benthos, sediment, tributyltin		Just downstream from City of Camas Wastewater Treatment Plant	Located at mouth of the Washougal River Comparison with previous studies - sediment chemistry Adjacent to Port of Camas-Washougal
D38	124-125	Benthos, crayfish, carp, peamouth chub, sediment, dioxin		Upstream of Camas point sources	Has been used as a reference station in previous sediment quality studies
D39	129	Benthos, sediment			Reference station for survey
D40	141	Carp, crayfish, peamouth chub, benthos, dioxin, radionuclides, tributyltin, sediment	In Pierce Island National Wildlife Refuge		Farthest upstream depositional area in study area Reference station for survey 3 miles downstream of Bonneville dam

[a] Corresponds to depositional areas shown on Figure 5-8.

[b] Dioxin analysis conducted in sediments only.

TABLE 6. PARAMETERS MEASURED AT NON-DEPOSITIONAL STATIONS AND NEARBY BENEFICIAL USES AND POLLUTION SOURCES[a]

Non-depositional Area[a]	Approximate River Mile	Parameters Sampled	Nearby Beneficial Uses	Nearby Point Sources
E1	9	Sediment[b], Benthos	Dungeness Crab	City of Warrenton
E2	17	Sediment, Benthos		
E3	22	Sediment, Benthos	Wildlife refuge	
E4	30	Sediment, Benthos	Wildlife refuge	
E5	46	Sediment, Benthos		Upstream of James River Wauna Mill
E6	58	Sediment, Benthos		Downstream of Longview sources
E7	65	Sediment, Benthos		Longview Fibre Co., Cowlitz Co. WWTP
E8	88	Sediment, Benthos		Chevron Chemical Co.
E9	83	Sediment, Benthos		City of St. Helens
E10	100	Sediment, Benthos	Wildlife refuge	ALCOA (Vancouver), other Portland/Vancouver sources
E11	104	Sediment, Benthos		City of Portland WWTP, other Portland/Vancouver sources
E12	114	Sediment, Benthos		City of Gresham, upstream of Portland/Vancouver, downstream of Camas
E13	127	Sediment, Benthos		Reference site
E14	137	Sediment, Benthos		Reference site

[a] Because they are not likely to be pollutant sinks, non-depositional areas were located primarily to provide overall characterization of sediment quality and benthos in areas of this type.

[b] All sediment to be analyzed for conventionals and chemicals of concern excluding dioxin, TBT and radionuclides.

have been located within each segment to provide broad scale, even coverage within each major river segment.

Information gained from evaluation of data from existing studies has also influenced where specific stations are located. For example, sediment monitoring studies were conducted by the James River Corp. (Young et al. 1987, 1988) in the general vicinity of their Camas Mill (River Segment 4; Figure 8) in non-depositional areas. The sediment stations were located along transects across the main river channel at several locations both upriver and downriver from the Camas Mill. A large suite of parameters was measured at each station; however, all stations were located in non-depositional areas and the analytical results do not indicate any potential problems. Another study by DOE (Johnson and Norton 1988) located a sampling station in finer-grained material than the study by Young et al. (1987, 1988) and found elevated levels of metals and resin acids. These studies indicate that additional data from depositional stations are needed in the area to evaluate whether contaminants are collecting in areas not measured by Young et al. (1987, 1988) and to compare results with the study by DOE. A non-depositional station has also been located in the area; on the opposite side of the river from previous sampling locations for comparison to the results of Young et al. (1987, 1988).

Oregon DEQ is conducting a study of sediment contaminant concentrations and bioaccumulation of contaminants in fish tissue in the vicinity of several major pulp and paper mills. The station locations from both past and ongoing studies by DEQ generally have not been selected in the reconnaissance survey sampling plan in order to avoid duplication of efforts. Another example of using existing data to avoid placing a sampling station is in the vicinity of Tongue Point, where the U.S. Army Corps of Engineers (COE) has conducted several sediment studies in both depositional and non-depositional locations. By identifying existing data at these locations that will be comparable to the data collected as part of the reconnaissance survey, limited resources can be distributed more efficiently.

Similarly, the lack of data in certain areas has influenced location of sediment stations for this survey. There have been few studies in the reach below the confluence of the Willamette River; therefore, several stations have been selected in this reach. In the upper estuary, several stations have been placed in the depositional areas of the wildlife refuge to extend the sampling points sampled by DEQ below the James River Wauna Mill.

In general, the number of stations is greater near areas of known inputs; e.g., near Portland and the Kelso–Longview area, than in non-developed reaches. Some stations have been placed above and below the confluences of major rivers and sloughs. The samples for radionuclide analysis have been located in major depositional areas (in all major river segments) considered most likely to have accumulated radionuclides. Samples for TBT have been located at depositional stations near marinas and ports. The station locations for dioxin/furan sampling have been selected to test for the effects of pulp and paper mill effluent. These stations have been located at stations upstream from known sources, and at the most upstream station in the reconnaissance survey which is located in the Pierce Island Wildlife Refuge. This station has been selected as the upstream reference station and all analyses are being performed at this station to document the conditions just below the dam.

6.0 TISSUE SAMPLING

The introduction of certain types of chemicals into the aquatic environment can result in the accumulation of these substances in the tissues of fish, shellfish, and wildlife. These organisms accumulate these chemicals by two distinct processes: 1) absorption from the water through gills or epithelial (surface) tissues, and 2) consumption of contaminated sediment and organic matter (plant and animal prey).

The bioaccumulation of chemicals in biota is of concern for two primary reasons. First, elevated tissue levels in biota can impair survival and reproductive success. These "ecological" impacts can potentially alter aquatic community dynamics (e.g., changes in species diversity and dominance) as well as wildlife that feed on affected aquatic organisms. Alterations in aquatic and terrestrial biota can affect aesthetic, recreational, and commercial riverine uses. Second, bioaccumulation of chemicals is also of concern from the standpoint of human health. Consumption of fish and shellfish containing these chemicals will result in the accumulation of these substances in human tissues.

Bioaccumulation of contaminants in biota tissue is evaluated differently depending upon whether the emphasis is to evaluate ecological risk or human health risk. To evaluate ecological risks, whole-body contaminant levels should be measured for biota that occupy a key position in the food web. The species selected for analysis should ideally be either important prey species or upper trophic level consumers. Levels of tissue contaminants in prey species allow an assessment to be made regarding potential impacts to higher trophic level consumers, while tissue concentrations in higher trophic level organisms can provide a measure of the maximum contaminant levels being attained.

To evaluate human health risks, contaminant levels are typically measured only for edible portions of the organisms. For fish, steaks or fillets are the portions usually analyzed. The species selected for analysis should be those consumed by the public or subgroup being evaluated.

6.1 OBJECTIVES AND STRATEGY

The reconnaissance survey will measure tissue concentrations of chemicals of concern in selected biota (Table 1) as part of the assessment of water quality in the lower Columbia River. This survey is designed to achieve the following objectives:

- Characterize the tissue concentrations of chemicals of concern in river segments to provide an overall assessment of levels in selected biota, and identify potential reference areas and areas of concern.

- Address both ecological health and human health implications of tissue concentrations of chemicals of concern.

- Compare contaminant levels in the tissue of selected biota with the concentrations of these substances in sediment near the area of collection.

Another objective of the survey was to evaluate the relationship between the concentration or activity in fish liver enzymes known to be induced by certain contaminants (dioxins and furans, and PCBs), and the level of these contaminants in tissues of the same fish. However, this analysis was omitted from this survey in favor of other, higher priority bioaccumulation analyses. In addition, Oregon DEQ has an ongoing study that is investigating this relationship in carp in the lower Columbia.

The sampling survey will attempt to achieve these objectives for river biota by following the strategy indicated below:

- Species selected for analysis of contaminants will include ones that are consumed by humans and wildlife.

- Whole-body analysis of contaminants will be made for the species selected to evaluate ecological risk. Because edible tissue generally has a lower tendency to accumulate contaminants than some internal organs, whole-body samples are also a "worst case" measure of bioaccumulation of contaminants.

- Contaminants will be measured in edible tissue for species that are consumed by humans.

- Sampling locations will be widely distributed throughout the study area to provide overall characterization.

- Some sampling locations will be located at potential problem areas.

- Sampling sites for biota that have relatively limited ranges will coincide with locations where sediment samples will be analyzed for contaminants of concern.

6.2 SAMPLE COLLECTION

To achieve the objectives outlined in Section 6.1, four species of biota (crayfish, carp, pea-mouth chub, and white sturgeon) will be collected from selected sites within the study area and analyzed for contaminants of concern. The rationale for the use of these species and the collection procedures that will be used are discussed in this section.

6.2.1 Crayfish

Crayfish are a food source for aquatic and terrestrial wildlife and have been selected as an indicator organism to address "ecological" risk. There are several reasons why crayfish have been selected and these are indicated below:

- Oregon DEQ has measured contaminant levels in crayfish tissue from several sites within the lower Columbia River (DEQ 1990). These data will supplement data collected during the reconnaissance survey, provide a basis for comparison, and allow a greater coverage of the study area.

- Crayfish inhabit depositional areas which are expected to have higher sediment contaminant concentrations than erosional areas.

- Crayfish have relatively limited ranges; therefore, these organisms are good candidates for examining the correlation between sediment contaminant concentrations and levels in tissue.

- Crayfish are commercially harvested from the lower Columbia River for human consumption.

- Crayfish can be easily collected using baited traps.

Eighteen crayfish samples will be collected from depositional areas using baited traps. A single composite sample will be collected from each site. A composite sample will consist of 10 to 20 individuals. The individual weights, total weight of the sample, and number of individuals in the sample will be documented. Crayfish will be wrapped in aluminum foil, placed on dry ice, and shipped to the analytical laboratory. Whole-body analyses of contaminants of concern (Table 1), dioxins, and furans will be measured on 12 of the 18 samples. As part of the QA/QC procedures for crayfish sampling, duplicate measurements of contaminants will be made for 2 of the 18 samples (total of 20 sample analyses). For the remaining six samples, dioxins and furans will not be measured and only tissue levels of contaminants of concern will be measured.

6.2.2 Carp and Peamouth Chub

Carp and peamouth chub have been selected for whole-body analysis of tissue concentrations of contaminants. As noted above in Section 6.1, whole-body analysis addresses ecological risk (consumption of contaminated fish by wildlife and other fish) and is a worst-case measure of bioaccumulation of toxicants.

Carp have been selected because they 1) tend to inhabit depositional areas, where contaminants collect; 2) they have a relatively high lipid content and have been documented to readily bioaccumulate hydrophobic organic pollutants (Schmitt *et al.* 1990); and 3) they have been used successfully as indicators of bioaccumulation in other studies in the Columbia River (Oregon DEQ 1990). Carp are representative of a lower trophic level fish. The foods eaten by this species include algae, plant fragments, zooplankton, aquatic insects, clams, and miscellaneous organic and inorganic matter (Wydoski and Whitney 1979).

Peamouth chub are somewhat distinct from carp trophically in that they feed on pelagic organisms such as zooplankton and small fish, as well as benthic organisms such as snails. Peamouth chub have been selected as indicators of bioaccumulation because they occur throughout the study area including most of the estuary, and because they are consumed by bald eagles and other wildlife, and by other fish. Peamouth chub are also being collected and analyzed as part of DEQ's ongoing sediment/bioaccumulation study in the lower Columbia, which will make comparison and synthesis of data from the two studies possible.

Carp and peamouth chub will be collected from 18 depositional areas by gill netting. Carp have approximately the same range as crayfish in the lower Columbia, and will be collected at the same 18 sites as crayfish (excluding the outer estuary) (Figures 5-8). Peamouth chub will be collected at two stations in the outer estuary where carp and crayfish will not be collected,

and chub will not be collected at two upriver carp/crayfish stations (Figures 5–8). At each site, five individuals will be collected. The sex, length, and weight of the fish will be recorded, and the scales will be removed for determination of age. The five fish collected for each species at each site will be wrapped in aluminum foil, placed in a single large plastic bag, placed on dry ice, and transported to the laboratory. Each collection of five whole fish will be composited into a single sample in the laboratory for chemical analysis.

6.2.3 White Sturgeon

White sturgeon are harvested commercially and recreationally from the lower Columbia River. This fish has been selected as an indicator organism to address potential risks to human health. There are several reasons why white sturgeon have been selected:

- White sturgeon inhabit the entire study area, from Bonneville to the mouth of the Columbia River.
- White sturgeon are commonly consumed by humans.
- Commercially caught sturgeon range in size from four to six feet. Fish of this size are approximately 10 to 20 years old (Wydoski and Whitney 1979). Given the age of these fish, tissue levels of chemicals that bioaccumulate may reach levels of concern to human health.
- Oregon DEQ has some data on tissue concentrations of contaminants of concern for white sturgeon collected in the lower Columbia River.

White sturgeon will be collected from commercial gillnet fishermen operating on the lower Columbia during the gillnetting season from September 23 to approximately November 1. This will ensure collection of fish of commercially legal size (4–6 ft in length) and therefore the size consumed by humans. Tetra Tech personnel will accompany the fishermen, if possible, when the sturgeon are collected, or take other steps to get good data on location and size of each collected fish and to ensure proper handling of fish after collection. As discussed in Section 6.4, four sturgeon will be collected from each of the four river segments (total of sixteen fish), from locations providing the most feasible overall coverage of each segment. Each fish will be measured (length), weighed, and aged using pectoral spines. Steaks from each of these fish will be placed in glass containers, placed on dry ice, sent to the analytical laboratory, and analyzed individually for the contaminants of concern listed in Table 1. In addition, tissue concentrations of dioxins and furans will be measured for two of the fish from each river region (total of eight fish). As part of the QA/QC procedures for sturgeon

sampling, duplicate measurements of contaminants will be made for 2 of the 16 samples analyzed (i.e., 10 percent duplication).

6.3 PARAMETERS TO BE ANALYZED

Table 7 summarizes the organisms, number of samples, and parameters that will be analyzed during the lower Columbia River reconnaissance survey.

6.3.1 Chemicals of Concern

Biota can accumulate chemicals by direct absorption through gills and surface tissues or by the consumption of contaminated sediment and prey. Not all pollutants can accumulate in tissue. The chemicals of concern to be measured in tissue during the reconnaissance survey of the lower Columbia River are listed in Table 1. This list represents a consolidation of the U.S. Environmental Protection Agency list of those chemicals of highest concern which can bioconcentrate (U.S. EPA 1991), the U.S. Fish and Wildlife Service list of organochlorine chemicals and metals measured in freshwater fish as part of the National Contaminant Biomonitoring Program (Schmitt et al. 1990; Schmitt and Brumbaugh 1990), and the DEQ list of chemicals measured in crayfish and fish tissue collected during the 1990 investigation of toxins in the Columbia River basin (DEQ 1990).

6.3.2 Dioxins and Furans

Chloro-dibenzo dioxins and furans refer to two similar groups of compounds consisting of 75 and 135 different compounds, respectively. Only a small subset of these compounds are of interest when examining accumulation in aquatic biota. These "biologically active" compounds consist of the tetra-, penta-, hexa-, and hepta-chlorodibenzo dioxins and furans. Table 1 identifies these 17 dioxin and furan congeners. These compounds are believed to be available for uptake into biological systems and may pose a risk to human health (NATO/CCMS 1988). These 17 chemicals, as well as other dioxin and furan congeners that can be quantified and identified using EPA Method 1613, will be measured in biota collected during the reconnaissance survey.

6.3.3 Lipids

The percentage of lipids in crayfish and fish tissue will be measured for all samples. Because the contaminants tend to accumulate in lipids, those organisms with higher percentages of lipids may have higher concentrations of contaminants. Therefore, lipid data will be used to adjust the contaminant data to facilitate comparisons among samples.

TABLE 7. PROPOSED TISSUE SAMPLES, BY SPECIES AND PARAMETERS ANALYZED.[a]

Species	Chemicals of Concern[b]	Chem. of Concern excl. Dioxins & Furans	Field Duplicates[c]	Total
Crayfish[d]	12	6	2	20
Carp[d]	12	6	2	20
Peamouth chub[d]	12	6	2	20
White sturgeon[e]	8	8		16
TOTAL	44	26	6	76

[a] All samples will be analyzed for lipid
[b] Chemicals of concern are listed in Table 1
[c] Field duplicates will be analyzed for chemicals of concern excluding dioxins and furans
[d] Composite samples (whole-body)
[e] Samples from individual fish (edible tissue)

6.4 SAMPLE LOCATIONS

The sample locations for tissue have been selected to achieve the objectives stated in Section 6.1. Biota collection locations have been selected based on a combination of factors that include existing and ongoing studies on the river, major point sources, and beneficial uses. The specific locations are identified in Figures 5 through 8. Table 5 indicates the proximity of these locations to beneficial use areas and major point sources. The specific rationale for station placement will be discussed separately for each of the species being collected.

6.4.1 Crayfish

As indicated in Section 6.2, crayfish have been selected as an invertebrate organism to address the concept of "ecological" risk. Eight of the 18 crayfish collection sites have been located in depositional areas that are near beneficial use areas consisting of wildlife habitat [Stations D6, D8, D10, D24, D26, D28, D29 and D40) (Table 5)]. Sediment contaminants will be measured along with crayfish tissue at all of these sites. This will allow evaluation of the correlation between sediment and tissue contaminant concentrations. Dioxins and furans will be measured in sediment and crayfish tissue at twelve of the depositional areas [Stations D6, D8, D10, D15, D19, D20, D23, D24, D28, D35, D38, and D40 (Table 5)].

Twelve crayfish collection sites are located in depositional areas in the vicinity of, or potentially influenced by, major point sources of pollution [Stations D10, D12, D15, D16, D19, D20, D23, D24, D28, D29, D31, and D35 (Table 5)]. Three of these sites are located near wildlife habitat [Stations D24, D28, and D29 (Table 5)]. These point sources are shown on Figures 5 through 8. Sediment contaminants will be measured along with crayfish tissue at all of these sites. This will allow evaluation of the correlation between sediment and tissue contaminant concentrations. Dioxins and furans will be measured in sediment and crayfish tissue at eight of the depositional areas located in the vicinity of major point sources [Stations D10, D15, D19, D20, D23, D28, D35, and D40 (Table 5)].

The two crayfish sampling sites located nearest to Bonneville Dam [Stations D38 and D40 (Figure 8)] are not thought to be influenced by major pollution sources; therefore, contaminant tissue levels measured for crayfish collected from these locations may serve as a reference.

6.4.2 Carp and Peamouth Chub

As indicated in Section 6.2, carp and peamouth chub will be collected using gill nets at 18 locations selected to provide overall coverage of each river segment and the lower river as a whole, and to emphasize shallow-water and beneficial use areas such as wildlife refuges. An

effort has been made to co-locate carp and chub stations with crayfish stations to facilitate comparisons of bioaccumulation among these species. As with crayfish, all carp and chub stations are planned to coincide with sediment stations so that sediment and tissue concentrations of contaminants can be compared.

The selection of sites where carp and chub will be sampled has also taken into account sampling sites that have been sampled this year by DEQ (see Figures 5 through 8). Carp, chub, and other fish collected at these sites were analyzed for tissue contaminants. Given the recent collection of data from these sites, it is not necessary to repeat sampling in these areas. Data collected during the DEQ study will be analyzed along with data obtained during this reconnaissance survey to provide an overall assessment of contaminant levels in carp.

Carp will be collected from 18 locations within the study area (see Figures 5 through 8 and Table 5). The sampling sites are all in depositional areas and are located in positions designed to complement the existing bioaccumulation study being conducted by Oregon DEQ by providing an overall coverage of the river.

The 18 sampling stations for peamouth chub have been selected by essentially the same rationale as for carp. Because chub occur farther into the estuary than carp, however, two chub collection locations have been selected at estuary stations where collection of carp is not proposed (Figure 5). As a result, chub will not be collected at two upriver stations where carp will be collected (Figures 6–8).

6.4.3 White Sturgeon

As indicated in Section 6.2, white sturgeon have been selected as an indicator organism to address potential risks to human health. The rationale behind the collection of white sturgeon is to obtain fish from all four river segments included within the lower Columbia River.

As discussed in Section 6.2, sturgeon will be obtained from commercial gillnet fishermen. Four fish will be collected from each of the four river segments (total of sixteen fish). An attempt will be made to collect the four fish for each segment from as many different locations as possible that are dispersed over the segment. Knowledge of local fishermen, fishery agency scientists, and other sources will be used as an aid to identifying locations for collecting sturgeon.

Sturgeon tagged within the Columbia River have usually been captured close to the tagging location; however, fish appear to migrate upstream during fall and downstream in late winter and spring (Wydoski and Whitney 1979). The mobility and age of the fish that will be

collected suggests that the sampling location is not critical, as the tissue contaminants present in the fish will represent the integrated effect of exposure to all sources encountered during the lifetime of the fish.

7.0 BENTHIC INVERTEBRATES

7.1 OBJECTIVES AND STRATEGY

The objectives of the benthic invertebrate sampling are as follows:

- To characterize the benthic invertebrate communities in the lower Columbia River.
- To use the benthic invertebrate community data, along with physical, chemical and other biological data, to establish ecological zones.
- To determine whether benthic invertebrate communities or individual taxa will be useful indicators of environmental stress in specific ecological zones in the lower Columbia River.

The benthic invertebrate communities in the Columbia River exhibit spatial and temporal variation in large part because of chemical (e.g., salinity) and physical (e.g., substrate) factors. Survey designs can focus on small localized areas to provide a detailed assessment of problems in a discrete area or can provide a broad characterization of the benthic invertebrate communities in various river reaches through a widespread distribution of sampling stations. The benthic invertebrate sampling plan has been modified to fit the second approach, because it will best address the three objectives presented above.

7.2 SAMPLE COLLECTION

Benthic samples will be collected using a modified van Veen (0.06 m^2) grab sampler. The grab will be attached to a hydraulic winch cable with a swivel to prevent twisting movements during sampler deployment and to ensure proper contact with the bottom. The grab will be slowly lowered through the water column to prevent the sampler from flipping during descent and from creating a pressure wave sufficient to disturb bottom sediments. After contact with the bottom, the grab will be raised at a constant rate, carefully retrieved once it is at the surface, and placed in a level position on a sieving stand. The sample will be evaluated for

acceptance based upon the degree of disturbance, penetration depth, and amount of leakage from the grab. Samples with a minimal disturbance of surface sediments and adequate penetration depth will be accepted. Minimum penetration depths required for sample acceptance vary by sediment type as follows:

- 4 cm for medium to coarse sand
- 6 cm for fine sand
- 10 cm for silt and clay

Upon acceptance, the overlying water in the grab will be removed using a siphon and the sediments will be characterized with respect to color, odor, type, and presence of non-sediment materials (e.g, shell, wood debris).

Three replicate 0.06 m^2 samples will be collected at each of the 54 stations, for a total of 162 samples. Initially, a single replicate from each station will be processed and invertebrates will be identified. This will permit an assessment of the cost per sample and additional information on types of communities and distribution of invertebrates in the lower Columbia River. Subsequently, a minimum of one station from each of the three main habitat types (sand, mud, and gravel) in the freshwater reach of the river (Areas 2 to 4) will be selected for processing and identification for the remaining two replicates. The stations selected will be located in areas found to be free from contamination in order to provide data on natural community variability. No replicates from the estuary will be selected in this group, since there are extensive data on that area that can be used for determining natural variability. If there are additional funds available after the benthos samples are processed, additional stations will be selected for processing of replicates. Freshwater stations will get priority since there are very little data on this reach.

The exact stations to be processed will depend on the outcome of the initial benthic invertebrate analysis and the contaminant data. If, for example, it is found that there is a 25-mile reach of river where the benthic communities have a high similarity, then only replicate samples from a single station will be analyzed. In areas where there is little similarity, on the other hand, several stations will be selected for replicate analysis to capture the variability of the various communities. This process will be continued until all the stations are completed or funds run out.

Each replicate will be processed separately. All sediments from each replicate will be washed into a 0.5-mm mesh sieve and gently rinsed with water to remove all fine materials. The material remaining on the screen will be rinsed into a thick plastic bag using a minimal

volume of water. A 10 percent solution of buffered formalin will be used for initial preservation of biological material. Sample containers will be labeled internally and externally with indelible ink on water-resistant paper. Samples will be inventoried, chain-of-custody forms will be completed, and samples will be sealed for shipment to the taxonomy laboratory.

7.3 PARAMETERS TO BE ANALYZED

Upon arrival at the lab, all samples will be reinventoried and checked against chain-of-custody forms. If a sample consists of multiple containers, all containers will be located and processed as a group. Samples will be rescreened after being held in formalin for a minimum of 24 hours to ensure adequate preservation of the organisms. Individual samples will be gently rinsed with fresh water into a 0.25-mm mesh screen to remove the formalin from the sediments. Use of a screen with half the mesh size of the screen used in the field will ensure retention of all organisms and fragments. Screens will only be partially filled while rinsing a specific sample, to maximize washing efficiency and prevent loss of material. All material retained on the screen will be transferred to glass or plastic jars, covered with 70 percent ethanol, and lightly agitated to ensure mixing of the alcohol with the sediments. All internal and external labels will be transferred to the sample jars. A screening log will be filled out as each sample is completed and will include sample number, date and time rescreened, and number of sample jars used.

Standard techniques will be used for sorting organisms from the sediments. Each sample will be sorted in its entirety by a single individual to facilitate quality assurance and control checks. Sample aliquots will be placed in a petri dish and examined under a 6-10 power magnification dissecting microscope. The petri dish will be scanned systematically and all animals and fragments will be removed using forceps. Each petri dish will be sorted twice to ensure removal of all animals.

All organisms will be counted and identified to the lowest practical taxonomic level, generally genus or species; some groups, like the Oligochaeta will only be identified to higher taxonomic levels due to the complexity of the group. If animal fragments are present, only anterior portions will be counted. Identifications will be performed by regional taxonomic experts. Taxonomists will maintain a notebook with all data and information about a sample or a specimen. Taxa will be compared against specimens in the E.V.S. permanent reference collections for confirmation and consistency of identifications. A voucher collection representing all taxa collected during the baseline survey will be prepared and archived by major taxonomic groups.

The following quality assurance and control (QA/QC) procedures for both sorting and taxonomy will be rigorously followed. A minimum of twenty percent of each processed sample will be resorted to check sorting efficiency and accuracy. Sorting QA/QC will be done using 25 power magnification by someone other than the original sorter. A sample will pass if the number of organisms found during the QA/QC check does not represent more than a five percent difference of the total number of organisms found in the entire sample. If the number of organisms found is greater than five percent of the total number, the entire sample will be resorted. In addition, all other sorting work performed by the sorter responsible for the error will be checked.

Taxonomic QA/QC is achieved by sending five percent of all samples out for independent re-identification by a qualified regional expert. Verified specimens will be added to the reference collection assembled for the project.

7.4 SAMPLING LOCATIONS

Benthos and sediment will be sampled at a total of 54 stations in the lower Columbia River. Paired collections will permit an analysis of the relationship between benthic communities, or individual invertebrate taxa, with sediment quality. Stations have been distributed among Reaches 1 through 4, with the number of stations in each reach a function of the length of the individual reach and amount of benthic invertebrate community data already available. This will permit an assessment of benthic communities in all the major reaches and habitat types throughout the river. As discussed in Section 5.4, 75 percent of the stations have been located in depositional areas and 25 percent in erosional habitats. Erosional habitats in the lower Columbia River are characteristically less diverse than depositional areas due to physical restrictions, therefore fewer stations are needed. This sampling plan will permit adequate assessment of the benthic invertebrate communities that inhabit these two major habitat types. Based on these initial results it can be determined whether either or both of the habitats will be suitable in a biomonitoring program.

The selection of station locations has been partially based upon existing benthic community data. Stations to be sampled in the survey are located either in between or opposite the river from existing stations. While data from past studies and the present survey may not be able to be combined due to the wide variety of sampling methods used in past studies, the previous data will be useful to augment the data to be collected.

8.0 DATA ANALYSIS

In general, analysis of data will include the following:

1. Calculation of summary statistics (mean and standard deviation) for each measured parameter for each river segment.

2. Comparison of means among river segments.

3. Evaluation of possible trends in parameter values along the lower river.

4. Comparison of parameter values for each station and river segment to appropriate reference values. Comparison to both within-river reference values and "external" reference values such as established standards will be considered.

The following sections provide additional detail on analyses that will be conducted or considered, including more information on potential reference values for each medium.

8.1 WATER

Reference values will be Washington and Oregon surface water quality standards, and EPA water quality criteria for fish consumption.

8.2 SEDIMENT

1. Within-river reference values will include those identified from previous studies in Task 1, plus any reference values that become apparent in the survey data.

2. External reference values for contaminants will include the Washington state sediment Standards (as these marine criteria may be appropriate for the Columbia River); effects-based values (ERLs and ERMs) from NOAA's *National Status and Trends Pro-*

gram (Long and Morgan 1990); and the freshwater sediment criteria currently being developed by the U.S. Fish and Wildlife Service. The selection and use of appropriate external reference values will be made in conjunction with the Bi-State Committee.

8.3 TISSUE

1. The correlation between concentrations of contaminants in sediments and concentrations in the tissues of carp and crayfish from the same location will be evaluated.

2. Reference values for tissue concentrations of contaminants are likely to be external, such as the EPA reference toxicant concentrations. Human health risks will be estimated using the risk factors from EPA's *National Bioaccumulation Study* (Tetra Tech 1990).

8.4 BENTHOS

1. The benthic invertebrate data will be assessed in relation to community structure, which will include total abundance, taxa richness, and community composition.

2. While none of the stations will have enough replicate samples to obtain an accurate measure of variability, analyzing the three replicates from a subset of the stations will permit an initial assessment of variance. Once ecological zones are determined, individual stations within any one ecological zone can be combined to provide information on the variance in a particular type of habitat.

3. Multivariate techniques will be used to delineate the various communities. Initially, a cluster analysis will be performed using the data on the individual taxa collected. This technique will identify similar communities among stations. Principal component analysis will then be used to assist in determining what factors may be contributing to any of the groupings in benthic communities. Use of cluster and principal component analyses will assist in identifying the relationships among communities and habitat types as well as identifying anomalous or impacted communities.

4. Correlation analysis will be used to determine the relationship between particular community measures (e.g., taxa richness) and physical (e.g. substrate types) or chemical measures (e.g. sediment contaminants).

9.0 REFERENCES

Century West Engineering Corp. 1990. Verification sampling summary: bulk loading facility Port of Vancouver. Port of Vancouver, WA. 10 pp + appendices.

Johnson, A., and D. Norton. 1988. Screening survey for chemical contaminants and toxicity in sediments at five lower Columbia River ports – September 22–24, 1987. Washington State Department of Ecology, Olympia, WA. 20 pp.

Long, E.R. and L.G. Morgan. 1990. The potential for biological effects of sediment-sorbed contaminants tested in the National Status and Trends Program. NOAA Technical Memorandum NOS OMA 52. NOAA, Seattle, WA. 175 pp. + appendices.

Oregon Department of Environmental Quality 1990. Draft 1990 work plan for the investigation of toxins in the Columbia River basin.

NATO/CCMS (North Atlantic Treaty Organization, Committee on the challenges of modern society). 1988. International toxicity equivalency factor (I-TEF) method of risk assessment for complex ;mixtures of dioxins and related compounds. Report No. 176.

Schmitt, C.J. and W.G. Brumbaugh. 1990. National contaminant biomonitoring program: concentrations of arsenic, cadmium, copper, lead, mercury, selenium, and zinc in U.S. freshwater fish, 1976–1984.

Schmitt, C.J., J.L. Zajicek, and P.H. Peterman. 1990. National contaminant biomonitoring program: residues of organochlorine chemicals in U.S. freshwater fish, 1976–1984.

Tetra Tech. 1991a. Task 1: summary of existing data and preliminary identification of problem areas and data gaps. Prepared for Lower Columbia River Bi-State Water Quality Program. Draft Report. Tetra Tech, Inc., Bellevue, WA. 1,245 pp. plus appendices.

Tetra Tech. 1991b. Task 2: data analysis report, inventory and characterization of pollutants. Prepared for Lower Columbia River Bi-State Water Quality Program. Draft Report. Tetra Tech, Inc., Bellevue, WA. 105 pp. plus appendices.

Tetra Tech. 1991c. Task 3: review of hydraulic, hydrologic and geomorphic characteristics of the Lower Columbia River. Prepared for Lower Columbia River Bi-State Water Quality Program. Draft Report. Tetra Tech, Inc., Bellevue, WA. 41 pp. plus appendix.

Tetra Tech. 1991d. Task 5: Beneficial use descriptions and locations. Prepared for Lower Columbia River Bi-State Water Quality Program. Draft Report. Tetra Tech, Inc., Bellevue, WA. 66 pp. plus appendices.

Tetra Tech. 1991e. Reconnaissance survey of the Lower Columbia: quality assurance/quality control plan. Tetra Tech, Inc., Bellevue, WA. 119 pp. plus appendices.

U.S. Environmental Protection Agency. 1991a. Bioaccumulation of selected pollutants in fish, a national study. Office of Water Regulations and Standards. EPA 506/6-90/D01a. Two volumes.

U.S. Environmental Protection Agency. 1991b. Assessment and control of bioconcentratable contaminants in surface waters. U.S. Environmental Protection Agency, Office of Water. Washington DC.

Wydowski, R.S. and R.R. Whitney. 1979. Inland fishes of Washington. University of Washington press, Seattle, WA. 220 pp.

Young, S.R. 1988. Columbia River sediment. Unpublished. File II.F.5, Env. Department, James River Corp., Vancouver, WA.

Young, S.R. 1987. Columbia River survey. Unpublished. File II.F.5, Technical Dept., James River Corp., Vancouver, WA.