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Puget Sound Estuary Program

The Urban Bay Action Program Approach: A Focused Toxics Control Strategy

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THE URBAN BAY ACTION PROGRAM APPROACH: A FOCUSED TOXICS CONTROL STRATEGY

For

U.S. Environmental Protection Agency
Region 10, Office of Puget Sound
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LIST OF ACRONYMS

AET	apparent effects threshold
BMP	best management practices
CERCLA	Comprehensive Environmental Response, Compensation and Liabilities Act
CSO	combined sewer overflows
EAR	elevation above reference
Ecology	Washington Department of Ecology
EPA	U.S. Environmental Protection Agency
Metro	Municipality of Metropolitan Seattle
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
PAH	polycyclic aromatic hydrocarbons
PSEP	Puget Sound Estuary Program
QA/QC	quality assurance/quality control
RCRA	Resource Conservation and Recovery Act

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EXECUTIVE SUMMARY

The objective of this report is to provide an overview of a strategy for controlling sources of toxic contamination and associated biological effects in estuarine environments. Known as the *urban bay approach*, this toxics control strategy has been applied in bays throughout Puget Sound. This report is intended to serve as a guide to the urban bay approach for managers of environmental regulatory programs. The approach was developed and refined in the Puget Sound region, and is recommended for application in other estuaries. Specific recommendations are included throughout the report and examples from the Puget Sound region are used to illustrate the application of the approach.

The objectives of the urban bay action program are to identify specific toxic areas of concern, identify historical and ongoing sources of contamination, rank "problem areas" and sources in terms of priority for corrective action, and implement corrective actions to reduce current contamination sources. An approach similar to the one described here for controlling toxic contaminants can also be applied to reduce microbial contamination and eutrophication.

The urban bay approach can be effective in identifying, prioritizing, and controlling many kinds of sources, including the following:

- Discharges from municipal sewage treatment plants and combined sewer overflows, pulp mills, chemical industries, metal plating shops, and other industrial facilities
- Nonpoint source runoff and groundwater seepage from industrial sites (e.g., cargo handling areas, tank farms, and log sort yards), hazardous waste sites, and landfills
- Leaks from petroleum storage tanks
- Fugitive emissions (e.g., sandblast materials) from boat yards
- Storm drain runoff (e.g., from city streets and highways).

The urban bay approach emphasizes taking immediate action by using available data to prioritize toxic contamination problems. Corrective actions are developed and implemented in phases to take advantage of new scientific data and emerging ideas about practical solutions to environmental problems. The three basic phases of an urban bay toxics action program are 1) compilation of available data and initial identification of problem areas; 2) description of current agency activities, identification of management gaps, and development of an action plan (i.e., documentation of planned actions to control contaminant sources or clean up contaminated sediments); and 3) implementation of source controls or sediment remedial actions and monitoring the results of the action program.

The success of the urban bay approach results primarily from achievement of the following objectives:

- Focus assessment and regulatory efforts on specific pollutant sources and contaminated sites
- Establish action teams to work in specific geographic areas

- Facilitate remedial actions (without excessive studies and delays) by use of available data and coordination among state and local agencies

- Define specific commitments of agencies for permitting, inspections, sampling, and other remedial activities

- Establish mechanisms for accountability of participating agencies (e.g., involve citizens, business-industrial organizations, public interest groups, and scientists in decisionmaking to maximize support and accountability for the program)

- Use field inspections and personal contact with polluters to encourage cooperation in finding innovative, cost-effective solutions to toxic contamination problems

- Quickly escalate regulatory and enforcement activities if warranted

- Transfer technologies and solutions to new urban bays with similar problems.

The benefits of an urban bay action program include the formation of a more efficient environmental regulatory and management network; increased cooperation of industries, wastewater dischargers, and other responsible parties in controlling sources of contaminants; and rapid response by responsible parties to site-specific environmental problems. By providing a common forum for public agencies, private industries, and informed citizens to address toxic contamination problems, the urban bay approach also enhances the effectiveness of existing regulatory programs.

INTRODUCTION

The objective of this report is to provide an overview of a strategy for controlling sources of toxic contamination and associated biological effects in estuarine environments. Known as the *urban bay approach*, this toxics control strategy has been applied to solve water-quality and sediment-quality problems in several bays throughout Puget Sound, Washington. The process undertaken in each urban bay action program in Puget Sound involves 1) compilation and synthesis of available data on water, biota, and sediment quality, 2) identification and prioritization of potential sources of contaminants and associated environmental problems, and 3) design and implementation of remedial actions. Remedial actions may involve control of contaminant sources and possibly sediment cleanup (e.g., removal or capping) in selected problem areas. This report is intended as a guide to the urban bay approach for managers of environmental regulatory programs, and local and state agencies involved in programs to control contamination in estuaries throughout the United States. This guidance is provided as a general introduction for anyone interested in establishing a program to control sources of chemical contaminants in urban bays. The approach described in this report represents a proposed ideal urban bay program based on considerable experience with the approach used in the Puget Sound region.

Urban bays are typically the receiving waters for various wastes related to human activities in coastal areas. Industrial facilities such as shipyards; pulp, paper, and lumber mills; oil refineries; and chemical plants are commonly located on or near the water's edge in urban bays, in part because of easy access to marine, rail, and highway transportation. Such facilities may release toxic chemicals directly into urban bays via the discharge of effluent and indirectly via runoff, nonpoint sources, or groundwater seepage from landfills, open dumps, and treatment or storage facilities. Urban bays may also experience conditions of nutrient enrichment (i.e., eutrophication) that can lead to algal blooms, low dissolved oxygen, and fish kills; and microbial contamination (e.g., contamination by bacteria and viruses). These conditions frequently result from inputs of treated or untreated domestic waste (sewage) and other inputs of organic matter, including urban runoff.

The complex contamination problems often found in urban bays are traditionally managed by an inefficient system of rules and regulations implemented independently by many local, state, and federal government entities. The urban bay approach was developed for the Puget Sound region as an integrated program for consolidating and coordinating multi-agency efforts to control contaminant sources. The approach was developed in 1985 and was formally adopted by the Puget Sound Water Quality Authority in 1987 for long-term implementation throughout Puget Sound [Elements P-6, P-7, P-8, P-13, P-14, P-20, and S-8 of the Puget Sound Water Quality Management Plan; PSWQA (1987, 1989b)].

At the core of the urban bay approach are the urban bay action teams. Each action team is a task force that focuses on specific pollutant sources and environmental problem areas within an urban embayment. In addition to its responsibilities in securing control of pollutant discharges, each action team coordinates the activities of environmental regulatory and resource management agencies to achieve practical solutions to water quality and sediment quality problems.

The scope and approach of an urban bay action program may vary with the size, composition, and experience of the action team as well as available funding. The lowest level of effort may simply involve shoreline surveys to identify contaminant sources and reviews of existing National Pollutant Discharge Elimination System (NPDES) permits. A single part-time or full-time action team member may be sufficient staff to initiate an urban bay action program. However, additional staff and funding allow for a more efficient use of resources by facilitating use of historical data and preventative measures [e.g., advice to industries on best management practices (BMPs)]. Subsequent increasing levels of effort may involve (in preferred order of implementation) initiation of a public participation program, sampling and analysis of contaminant sources (e.g., tracing sources of contamination within storm drain systems), and detailed characterization of environmental problems. Assessments of environmental problem areas are used to demonstrate adverse effects of contamination and to focus evaluation of sources and remedial actions on the most degraded areas.

Benefits of an urban bay action program include:

- Establishing a more efficient environmental regulatory and management network by providing a common forum for public agencies, private industries, and the general public to address contamination problems; and by reducing duplication of effort in regulatory, monitoring, and research programs
- Increasing cooperation of industries, wastewater dischargers, and other responsible parties by simplifying the regulatory environment and by establishing cooperative relationships with regulatory entities
- Expediting source control and environmental protection through the formation of dedicated action teams that focus corrective actions on high priority problem areas.

This report provides a general description of the urban bay approach as a toxics control strategy. The description of the urban bay approach in this report focuses on toxic contamination for two reasons. First, the approach was initially developed in the Puget Sound region as a primary tool to control sources of toxic contaminants that cause adverse environmental effects. Second, solutions to toxic contamination problems are often extremely complex compared to other environmental problems. Even though toxic contamination is the focus of this report, the urban bay approach has also been used effectively to address eutrophication and microbial contamination problems.

Subsequent sections of this report describe various technical and administrative aspects of the urban bay approach and provide a summary of the major steps of the approach. Examples from urban bay action programs implemented in the Puget Sound region are used to illustrate the application of the approach. Recommendations for refinements of the approach are included throughout the report to support the broader use of this approach outside of the Puget Sound area. Key participants of urban bay programs in Puget Sound contributed information and professional opinions about the approach during workshops and telephone interviews and by responding to a questionnaire.

BACKGROUND AND OVERVIEW

In 1983, the U.S. Environmental Protection Agency (EPA) and the Washington Department of Ecology (Ecology) identified chemical contamination of Puget Sound as a high priority problem. Inner harbors and waterways of Puget Sound were found to be severely contaminated by toxic chemicals discharged from industrial facilities, urban storm drains, and other sources. Scientists of the National Oceanic and Atmospheric Administration (NOAA) and the National Marine Fisheries Service (NMFS) documented high prevalences of liver and kidney lesions in bottomfish such as English sole and starry flounder in the industrialized areas of several embayments in Puget Sound (Malins et al. 1980, 1982). In 1981, the Commencement Bay nearshore/tideflats area in Tacoma (located 30 miles south of Seattle) was designated as a National Priorities List site under the Comprehensive Environmental Response, Compensation and Liabilities Act (CERCLA) primarily because of sediment contamination and associated biological effects (Tetra Tech 1985). The approach to data analysis, problem identification, and site prioritization used in the Commencement Bay program served as a cornerstone in the development of the urban bay approach.

In 1985, in response to widespread concern over the environmental health of Puget Sound, EPA and Ecology joined forces to form the Puget Sound Estuary Program (PSEP). The primary objective of PSEP is to minimize contamination of Puget Sound and to protect its living resources, such as fish, shellfish, birds, and mammals. As one of the key elements of PSEP, the urban bay action programs focus on site-specific pollution control measures within the well-defined bodies of water and associated drainage basins. This toxics control strategy was first applied by PSEP in 1985 in Elliott Bay and the lower Duwamish River. It evolved partly from previous water quality control programs of the Municipality of Metropolitan Seattle (Metro) and Ecology. Metro and other agencies had been working to improve water quality in the Duwamish River since the early 1960s by installing new sewer lines, expanding the capacities of wastewater treatment plants, and developing an areawide water quality management plan [i.e., the Duwamish Clean Water Plan, developed in 1983 using a federal Clean Water Act 208 grant (Sample 1987)]. The storm drain sampling program implemented in 1984 as part of the Duwamish Clean Water Plan (Hubbard and Sample 1988) was especially relevant to the development of the PSEP urban bay approach.

The urban bay action programs in Puget Sound are founded on the following premises:

- Chemical contamination is a threat to environmental quality. For example:
    - Toxic chemicals discharged in estuaries may accumulate in sediments and may cause disturbances to bottom-dwelling populations, or liver tumors and other abnormalities in fish.
    - Potentially harmful chemicals in water or sediments may accumulate in fish, shellfish, and their predators (e.g., sea lions, killer whales, and birds).
    - Long-term consumption of contaminated seafood by humans may pose health risks.
- Sediment contamination and associated biological effects are reliable indicators of environmental degradation.

- Data must be adequate to determine that particular sources are causing adverse environmental impacts and to provide for viable enforcement.
- Immediate actions may be taken even when more data are needed.
- Control of point sources to prevent contamination near discharge locations (e.g., storm drains, sewage discharges) will minimize impacts of those sources on the entire system.
- Actions are developed and refined as part of an iterative process.

In the PSEP urban bay programs, sediment chemistry, toxicity bioassays, and alterations of benthic macroinvertebrate assemblages have proved useful in identifying high priority problem areas and associated sources. Sediment variables have been widely used as indicators of environmental degradation from toxic chemicals (e.g., Malins et al. 1980, 1982, 1984; Meiggs 1980; Long and Chapman 1985; Chapman et al. 1985, 1987; Hubbard and Sample 1988). Many toxic contaminants discharged to urban bays (e.g., heavy metals, polychlorinated biphenyls, and polycyclic aromatic hydrocarbons) are relatively insoluble in water and readily adsorb onto particulate matter. Contaminated particulate matter in the water column eventually becomes incorporated into bottom sediments. Toxic contaminants are generally present at much higher concentrations (often >1,000 times higher) in sediments than in water. Observations worldwide have linked sediment contamination to various environmental disorders, including liver lesions in bottomfish; bioaccumulation of contaminants in several species of invertebrates, fish, birds, and mammals; and altered communities of bottom-dwelling invertebrates. Contaminated sediments have also proven to be directly toxic in various laboratory bioassays.

The strength of the urban bay approach comes from its geographic focus, use of action teams in the field, and use of available data to minimize wasteful or redundant studies and maximize immediate action. The approach uses all available regulatory and enforcement tools, including water quality laws, land use regulations, BMPs, solid waste and hazardous waste regulations, and air quality control laws. The efficiency of existing contaminant control programs is maximized by focusing multi-agency actions on specific prioritized contaminated sites.

The major components of the approach for managing chemical contamination problems are data compilation and assessment, problem area definition, source evaluation, and development of recommendations for remedial action or additional data collection (Figure 1). In the first phase of an urban bay action program, a preliminary assessment of potential contaminant sources may be achieved by a shoreline reconnaissance survey. However, the efficiency of source identification efforts can be improved by first compiling and analyzing available data on sources, sediment and water contamination, tissue contamination, and biological effects. Available data summarized in an action assessment matrix (Figure 1) can be used to identify priority problem areas and focus source evaluation efforts.

The concept of an interim action plan, which has been used in some PSEP urban bay action programs, is shown in Figure 2. An interim plan may be developed for immediate control of known pollutant sources, inspection of industrial facilities, revision of wastewater discharge permits, and/or coordination of further sampling and analysis. Based on available data, the interim plan emphasizes early action to address the highest priority toxic contamination problems. Corrective actions are developed and implemented in phases to take advantage of new scientific data and emerging ideas about practical solutions to environmental problems. The scope of field

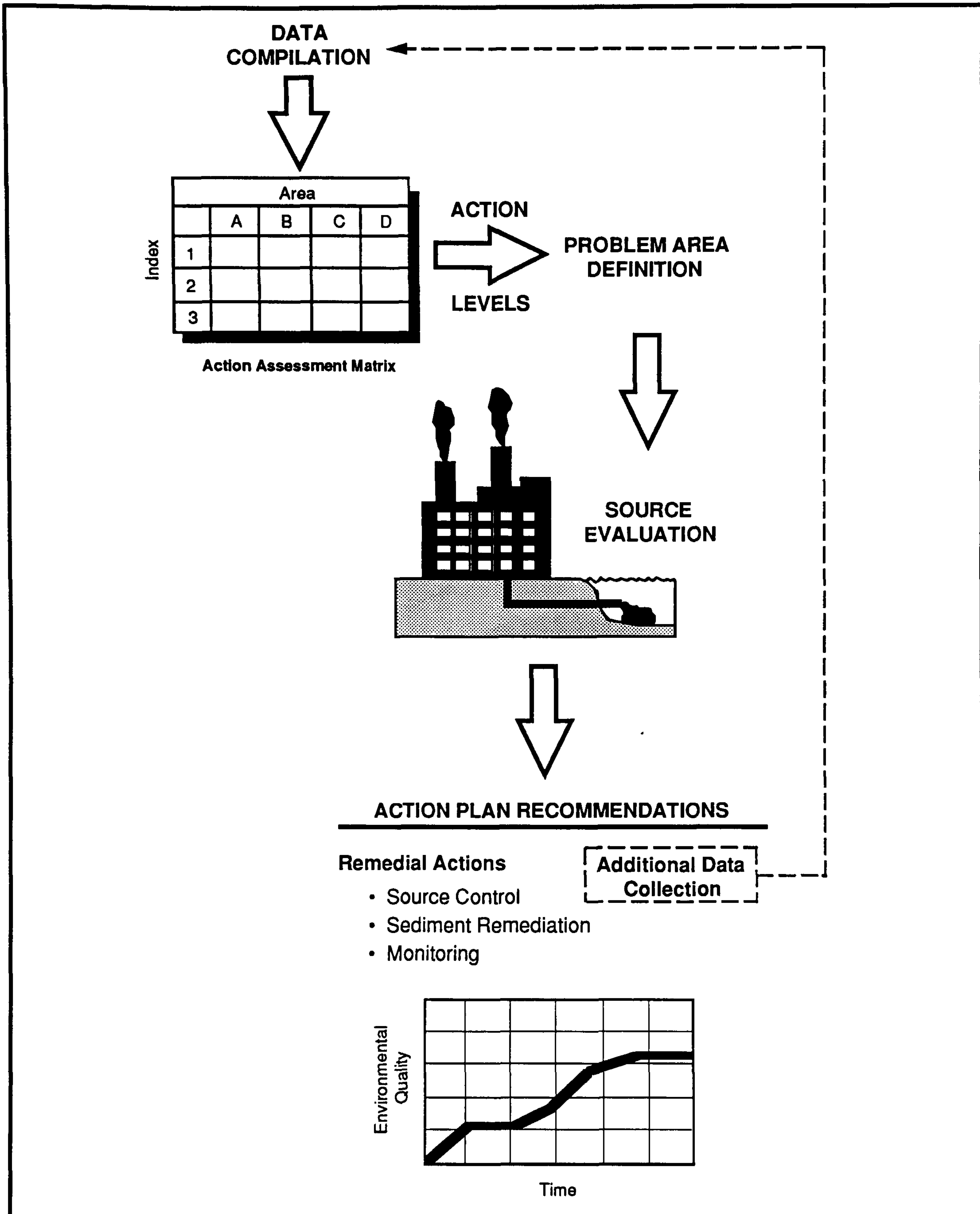

Figure 1. Overview of urban bay approach

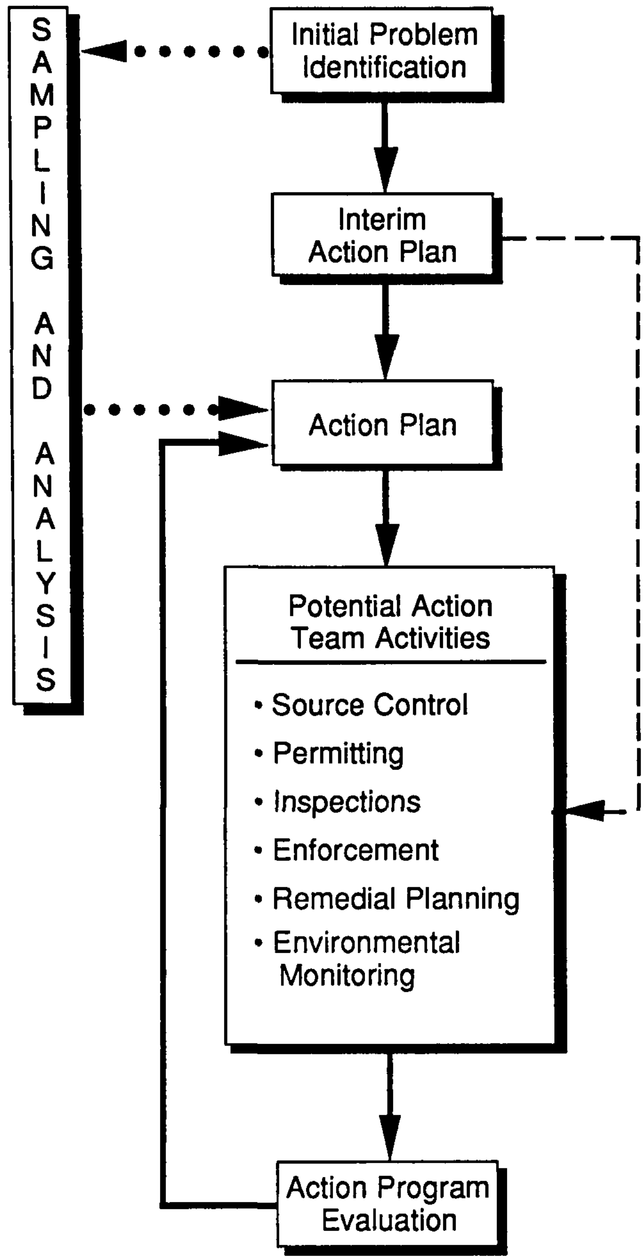

Figure 2. Elements of the urban bay action program

surveys depends on funding level, amount and kind of available data, magnitude of contamination and biological effects, size of the urban bay, and complexity of contaminant sources. New data may be collected as part of ongoing surveys and monitoring programs sponsored by agencies participating in the action program, by wastewater dischargers or parties responsible for contaminated sites, or by academic researchers. A baywide survey to identify priority problem areas and sources may be warranted, especially when historical data are limited. The value of a baywide survey in providing consistent, up-to-date information for prioritization of problem areas and sources needs to be weighed against the cost of sampling and analysis relative to available funding.

Finally, as new information is generated, action plans are revised to update priorities for remedial activities. Because each action plan is a record of agency commitments to future remedial activities and data acquisition, the action plan reflects current agency policies and funding constraints. Corrective actions primarily involve source controls to reduce or eliminate inputs of toxic contaminants. Efficient application of existing environmental regulations and enforcement tools in an urban bay action program may lead to substantial reductions in pollutant loading to an estuarine system. Subsequently, sedimentation of clean particles may result in capping of contaminated sediments through a process of natural recovery. Sediment remedial actions may be warranted in some areas of severe and persistent contamination, especially where the environmental benefits outweigh the cost of sediment remediation. Examples of sediment remedial activities include removing contaminated sediments by dredging, and capping contaminated sediments with clean materials. Sediment remediation is an expensive and complex process that requires considerable site-specific data and review of environmental effects during the planning process. Generally, source controls should be implemented before sediment remedial actions are taken to avoid recontamination of an area that has been cleaned up. Regardless of the kind of remedial action, site-specific monitoring should be considered for evaluation of the effectiveness of remedial efforts (Figure 2).

Urban bay action programs have been implemented in seven areas of the Puget Sound region: Commencement Bay, Elliott Bay, Everett Harbor, Sinclair and Dyes Inlets, Budd Inlet, Bellingham Bay, and the Lake Union/ship canal system (Figure 3). Accomplishments of the urban bay action programs include the following:

- Identification and prioritization of problem areas
- Control of sources through enforcement actions or negotiation with responsible parties, and incorporation of BMPs or limits on toxic substance loading in NPDES discharge permits
- Enhanced pretreatment of industrial wastes
- Implementation of BMPs for nonpoint sources
- Site cleanup activities.

Ryan (1987) provides specific examples of accomplishments of the urban bay programs in Puget Sound (also see Appendix A). Benefits of source controls as part of the Elliott Bay Action Program and other concurrent programs (e.g., the Duwamish Clean Water Plan) are also demonstrated by the recent reduction in contaminant loading from the Duwamish River to Elliott Bay (Paulson et al. 1989). The urban bay approach can be effective in controlling many kinds of sources, including the following:

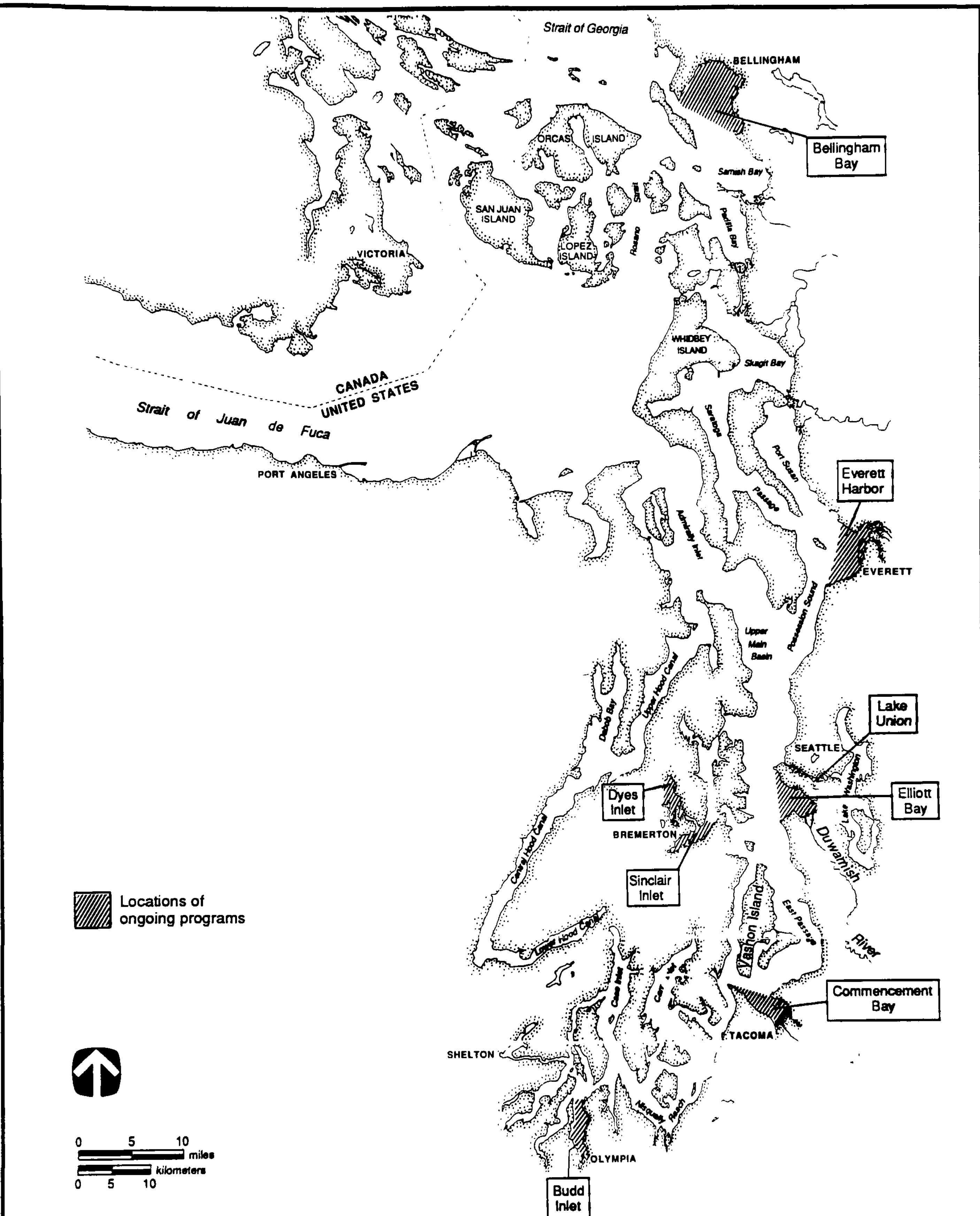

Figure 3. Locations of urban bay programs in Puget Sound

- Discharges from municipal sewage treatment plants and pulp mills, chemical industries, metal plating shops, and other industrial facilities
- Nonpoint source runoff and groundwater seepage from industrial sites (e.g., cargo handling areas, tank farms, and log sort yards), hazardous waste sites, and landfills
- Leaks from petroleum storage tanks
- Fugitive emissions (e.g., sandblast materials) from boat yards
- Urban storm drain runoff.

A successful urban bay action program can be achieved through effective interagency and interprogram coordination, efficient data collection and problem identification, implementation of cost-effective remedial actions, and effective public participation. These processes are described in detail in subsequent sections of this report.

INTERAGENCY AND INTERPROGRAM COORDINATION

In an urban bay action program, interagency and interprogram coordination are achieved primarily through an action team, an interagency work group, and a citizens advisory committee (Figure 4). This section describes the composition and function of these groups. Current mechanisms for enhancing communication and coordination in PSEP urban bay action programs and options for increasing coordination and ensuring accountability are also discussed.

URBAN BAY ACTION TEAMS

An *action team* is a field task force composed of technical staff (e.g., environmental engineers, resource biologists) from appropriate regulatory and planning agencies. The action team identifies pollutant sources; performs site inspections; issues and revises discharge permits; encourages BMPs; and initiates regulatory responses such as administrative orders, consent orders, and penalties. An action team may require wastewater dischargers or parties responsible for contaminated sites to characterize and control contaminant sources. Specifications of sampling and analysis designs (e.g., collection of data on effluent and ambient environmental conditions) may be incorporated into discharge permits or other regulatory options. These regulatory options can range from informal verbal requests to enforcement orders or consent decrees.

Key members of an action team should have training and/or experience with appropriate regulatory programs, including experience with permits and enforcement actions. Ideally, an action team should include individuals with qualifications in the following areas:

- Knowledge of environmental chemistry and toxicology sufficient to identify potential pathways of contaminant transport and fate, and potential impacts to biota and human health
- Specific experience in investigating contaminated sites
- Experience with treatment technologies for stormwater, groundwater, municipal wastewater, and various industrial processes
- Training or experience with the review, design, and implementation of BMPs
- Training or experience in community relations and negotiation to enhance the effectiveness of site inspections, the potential for voluntary compliance, and public participation and education.

The leader of an action team, as well as most of its other members, should represent lead enforcement agencies such as state resource or environmental protection agencies, and municipalities. Local jurisdictions such as health departments, city and county engineering departments, sewer utilities, and other regulatory bodies that have permitting, source identification, and source control programs should be included in action team activities.

The number of individuals on an action team depends primarily on the size of the embayment and the complexity of its environmental problems. For example, in Elliott Bay and Commencement

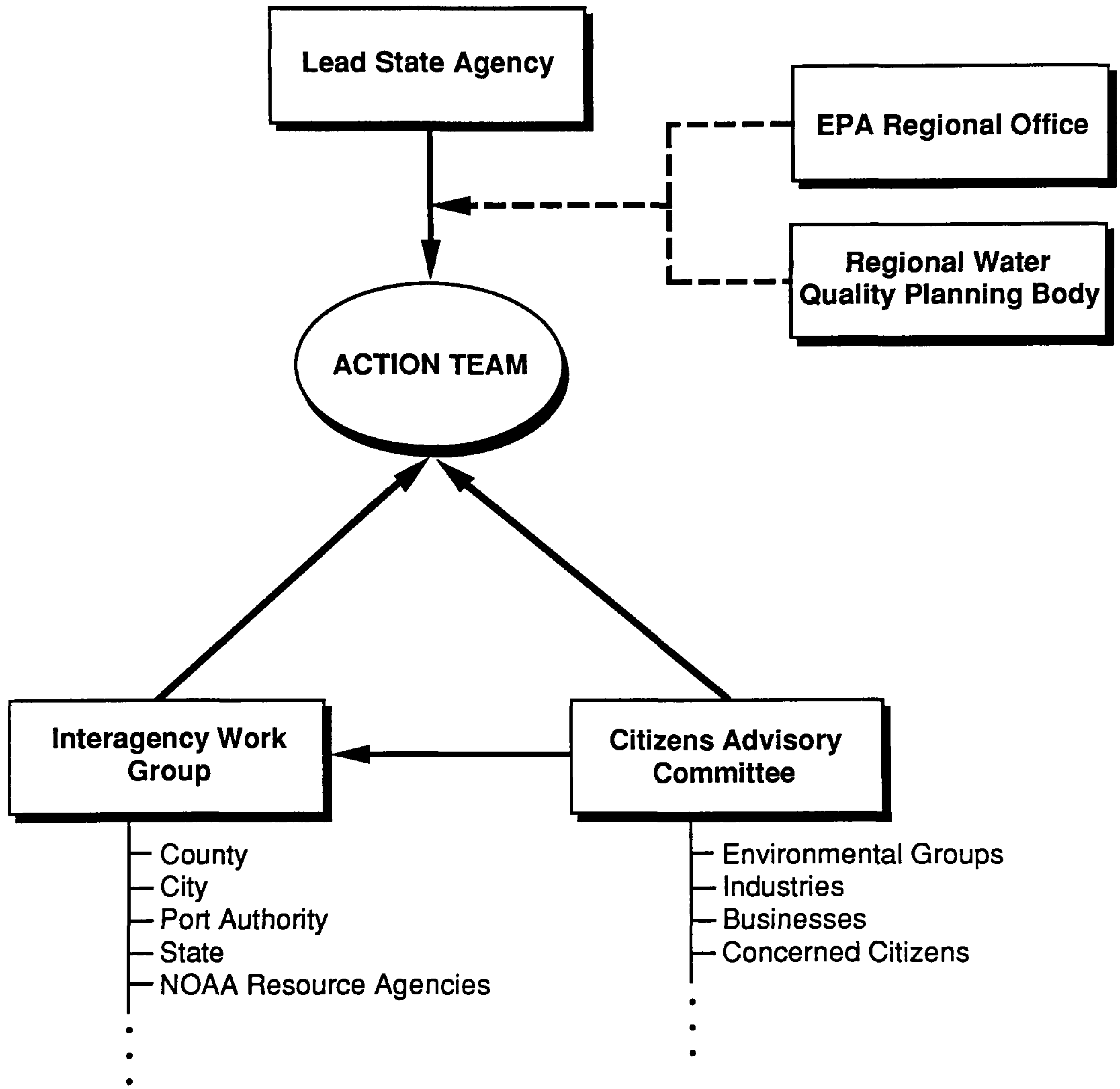

Figure 4. Effective organizational network for an urban bay action program

Bay, each action team is currently composed of approximately four full-time staff members. Experience indicates that 8-10 staff members from various key agencies may be needed to efficiently implement the most active phases of an action program in these large urban bays that have many diverse sources. Although fewer team members would result in a slower and perhaps less efficient program, substantial benefits may still be achieved with a small action team and a limited budget.

Regulatory authority for an action team stems primarily from discharge permit programs and inspection requirements under federal and state water quality regulations (e.g., the federal Clean Water Act), hazardous substance control regulations [e.g., CERCLA (Superfund), Resource Conservation and Recovery Act (RCRA), and state or county regulations for solid waste and hazardous waste, and health department regulations]. Additional regulatory authority in the state of Washington is derived from state laws on hazardous and solid waste sites (e.g., the Model Toxics Control Act), the state delegated NPDES program, and the state combined sewer overflows (CSO) control statute (Washington Administrative Code 173-245). In Washington, local or regional sewer utilities are responsible for enforcement of industrial pretreatment requirements for discharges to sanitary sewer systems. The action teams work closely with these agencies to identify problems and solutions related to pretreatment programs. Effectiveness of an action team is enhanced by representation of each major regulatory agency on the team.

INTERAGENCY WORK GROUPS

At the start of an action program, an *interagency work group* is formed to contribute to the scoping and technical development of the program. The role of the interagency work group is to assist the action team in:

- Securing commitments of agency resources for problem identification, and source evaluation and control efforts (through new budget allocations or by altering priorities)
- Providing technical data and reports from related projects
- Coordinating related program activities within agencies
- Developing corrective actions, schedules, and funding bases
- Reviewing progress, technical results, and work plans of member agencies or support contractors.

Agency participation in the interagency work group varies among urban bays and depends primarily on the predominant regulatory and enforcement environment (e.g., types of sources and degree of involvement of state and local governments). At a minimum, the work group should be composed of representatives from lead federal and state agencies (e.g., EPA, Ecology, and other toxic substance or waste permitting agencies in the Puget Sound region) and appropriate authorities responsible for municipal wastewater treatment (e.g., city, municipal, or county governments). In most areas, it is also advisable to include representatives from other branches of local government, native American tribes, and port authorities. Although the role of local government is likely to vary greatly from one area to another, many local government activities have significant implications for source control actions. For example, cities and counties may have surface water management utilities responsible for stormwater runoff control; engineering departments may be responsible for sewage collection systems; and planning departments may be responsible for implementing BMP ordinances for particular land uses. Where applicable, it is appropriate to encourage participation of regional planning bodies. In the Puget Sound region, the Puget Sound Water Quality Authority is represented on each interagency work group because of its role in regional water quality planning and oversight of state programs. Other examples of potentially important regional planning bodies are city and county associations such as county planning departments, public works, and conservation districts. The work group should be chaired by the leader of the action team.

The composition and size of the interagency work group is likely to change over time depending on the kinds of contributions needed from agency representatives. For example, technical experts within each agency may participate mainly in meetings at which technical findings are presented, whereas a subcommittee of the work group composed of budget planners from various agencies may contribute to development of schedules and commitments for an action plan. An official representative should, however, be identified for each participating agency. This representative, who serves as the point of contact for questions from other work group members and support contractors, is the individual responsible for communication of action program information to the participating agency. Official agency representatives should maintain consistent attendance at all work group meetings.

The interagency work group should meet either monthly or every other month. The particular bay, the phase of the project, the consultant's scope of work, or other factors may all affect the frequency of work group meetings. Activities of the work group include the following:

- A kickoff meeting to define objectives and review the work plan of the lead agency or support contractor for each phase of the action program
- Review of technical report(s) defining problems based on available data
- Review of sampling and analysis plans and results (if further data collection is needed)
- A series of two to four workshops to develop site-specific remedial activities to be included in an action plan, associated budgets, and agency commitments
- Review of draft action plan(s).

Participation in an urban bay action program is predicated on volunteerism and the good will of the participants in combining resources and programs for a common goal. However, the effectiveness of the program depends in part on the regulatory presence of the lead agency and peer pressure among agency and citizen participants. Upper-level managers within the participating agencies should attend kickoff meetings and annual review meetings of the interagency work group. Formal agreements among agencies (e.g., memorandums of understanding or interagency agreements) may be needed to ensure participation of key organizations or to secure resource sharing agreements (e.g., funding or staff transfers among agencies). In the Puget Sound area, formal agreements have been successful in some cases. Under a formal agreement in the Elliott Bay program, Metro granted money to Ecology to hire action team staff to focus on priority problem areas. Formal agreements may also be useful to ensure implementation of the action plan. However, formal interagency agreements have sometimes been cumbersome and time consuming to draft; implementation of these agreements has not always been successful; and the agreements are not always legally binding.

CITIZENS ADVISORY COMMITTEES

Public participation in an urban bay action program is achieved primarily through *citizens advisory committees*. The role of the citizens advisory committee is to:

- Provide comments to the interagency work group on program objectives and proposed actions
- Identify public concerns and issues relevant to agency roles identified in the action plan
- Disseminate action plan information to members of organizations represented on the committee and to local, state, and federal policymakers
- Help ensure the accountability of program participants responsible for performing remedial actions or investigations.

Citizens advisory committees should be composed of representatives of public interest groups and individuals interested in the urban bay environment. Generally, membership on citizens advisory committees should be open to all interested participants, including:

- Environmental groups such as Sierra Club, Audubon Society, Greenpeace, and Friends of the Earth
- Industrial associations such as maritime business coalitions
- Representatives of private industries such as pulp mills, chemical plants, shipyards, and marinas
- Representatives of commercial and recreational groups such as fishermen and boaters
- Chambers of commerce
- Community clubs and neighborhood groups
- League of Women Voters.

The citizens advisory committee may meet separately or jointly with the interagency work group. In some cases, the citizens advisory committee may hold separate meetings and form subcommittees to address key issues. Alternatively, citizens may choose to participate in work group meetings without having a formal committee structure of their own. In several urban bay programs in Puget Sound, citizens participated directly in the work group and no separate advisory committee was established. At the start of an urban bay action program, the mechanism for citizen participation should be defined by the lead agency in consultation with members of the interagency work group and representatives from public interest and community groups.

MECHANISMS FOR ENHANCING COMMUNICATION AND COORDINATION

Interagency communication on funding commitments, field investigations, and source control activities are essential for a successful urban bay action program. The meetings of the action team, interagency work group, and citizens advisory committee serve as the primary forums for communication among program participants. Proceedings of each meeting should be documented and distributed to all program participants. Each action plan documents the planned activities and commitments of each agency. Examples of remedial actions and data acquisition activities in an action plan document are shown in Table 1. Action plans should ideally be updated every other year. The frequency of revision may vary among urban bays. Newsletters and press releases published by the action team are particularly effective for rapid communication to other programs and the general public. Evaluation of the action program and its accomplishments should be documented annually by the lead agency (e.g., see Ryan 1987) and announced in press releases.

The communication link between the citizens advisory committee and the interagency work group is established through several mechanisms. First, the citizens advisory committee chair should be responsible for presenting the views of the committee to the work group. Second, meetings of the work group should be open to all members of the citizens advisory committee. Third, direct participation in the work group is an option when the citizens advisory committee is small.

Documentation of technical and programmatic information is another important aspect of interagency and citizen communication in the urban bay program. The documentation requirements of any given program will depend on the complexity of environmental problems and sources, and the status of source control actions (e.g., degree of existing interagency coordination). The following kinds of documents have been useful in PSEP urban bay action programs:

- An *initial data summary and problem identification* document includes all historical data and defines problem areas and important data gaps. This document typically includes an evaluation of potential contaminant sources. This document provides the interagency work group and the citizens advisory committee with a basic understanding of the problems in the specific bay.

- A *current activities summary* can be developed to describe current data gathering and pollution control efforts occurring in the urban bay area. This document provides the basis for developing additional actions during negotiations with work group members and private parties.

- An *interim action plan* can be developed based on the initial problem identification and source evaluation efforts. An interim action plan may be useful in bays with complex administrative structures (e.g., numerous agencies) and contaminant sources. The interim action plan documents initial agency commitments for remedial activities and additional sampling efforts.

- A *sampling and analysis design* can be developed where additional data collection is necessary. This document describes future sampling efforts and quality assurance/quality control (QA/QC) procedures to address data gaps.

- An *analysis of toxic problem areas* can be documented separately if significant additional sampling and analysis has been completed after production of the initial data summaries. This document assists in refining source evaluations and remedial activities.

- An *evaluation of potential sources* document may be useful if additional sampling and analysis has been completed. This document refines information on potential sources and prioritizes source control activities.

- A revised or updated *action plan* documents commitments of agencies to implement remedial actions or further sampling and analysis.

TABLE 1. EXAMPLE FORMAT OF ACTION PLAN SUMMARY TABLE

North Harbor Island I Problem Area

Potential Source	Status	Actions	Responsible Entity	Implementation Date
11th Avenue S.W. CSO (077)	Low priority. Emergency overflow/storm drain. No criteria exceedances in offshore sediments.	Implement work plan for source investigation/sediment characterization	Harbor Island Superfund, EPA/City of Seattle	10/88
Metro pretreatment permits				
Metals salvage yard	Major discharge (see West Waterway I)			
Shipyard 1, Plant I	Minor discharge			
Tug and Barge Company	Pathway: groundwater, surface runoff Superfund list (CERCLIS) site: low priority			
Oil tank farm 1	Pathway: groundwater CERCLIS site: low priority	EPA remedial investigation (see West Waterway II for other investigations by Ecology)	Harbor Island Superfund, EPA/Oil company	Ongoing
Oil tank farm 2	Pathway: surface runoff, groundwater NPDES permit: surface runoff On Ecology's hazardous site list for petroleum Inspection report - little activity, area clean, four tanks active	Update bulk petroleum storage facilities NPDES permits	Ecology	FY 89[a]
Shipyard 2	Pathway: surface runoff, fugitive emissions NPDES permit: new permit being issued Underground Storage Tank: mineral spirits and solvent tank leaks adjacent to West Waterway. Tanks removed 9/86.	Inspect/renew NPDES permit Investigate groundwater contamination	Ecology Harbor Island Superfund/ Shipyard 2	FY 89[a]
Shipyard 1, Plant II	Pathway: surface runoff (private storm drains), fugitive emissions Facility closed, equipment sold	Inspect/cancel permit Conduct soils and groundwater investigation	Ecology Harbor Island Superfund/ Shipyard 1	FY 89[a]
Private storm drains	Potential sources, many poorly characterized	Continue source identification and sample key storm drains	Harbor Island Superfund, EPA/City of Seattle	1988/1989

[a] FY 89 = 1 July 1988 through 30 June 1989.

Note: Blanks indicate items for which actions, responsible entity, or implementation dates have not been determined.

In addition to the above, long-term implementation of an action plan might benefit from the development and documentation of environmental monitoring designs. Procedures and formal interagency agreements that ensure periodic review and revision of action plans need to be developed. Also, mechanisms for evaluation of remedial alternatives should be documented.

OPTIONS FOR INCREASING COORDINATION

Regional Urban Bay Program Office

Coordination of multiple urban bay action programs with each other and with other state programs is an essential element of a successful urban bay approach. Based on experiences with the urban bay programs in Puget Sound, it is recommended that a regional urban bay program office be established within a branch of the state lead agency and be given responsibility for administering these programs. The regional office should serve as the focal point for interagency and interprogram coordination.

Activities of a regional urban bay program office should include informing action teams of changes in agency programs and policies that affect their activities; coordinating CSO and stormwater control plans, NPDES and dredging permits, grants for field investigations, and actions of other program offices with the urban bay programs; maintaining and updating a comprehensive BMP manual; and implementing a tracking system for field inspections. A comprehensive and systematic decision process should be developed as an aid for inspectors to determine the following:

- Regulations or programs (e.g., Superfund, hazardous waste or pesticide regulations, federal Clean Water Act) applicable to each facility, discharge, and waste site
- Violations of toxic substance regulations
- Compliance or noncompliance of discharges with permit specifications
- Priorities for corrective actions.

The proposed decision process should include consideration of dangerous waste generation, handling, and disposal; underground storage tank regulations; water quality standards; discharge permit limits; wetlands protection laws; and other water resource issues. The state water quality program should also include a permit-training program to address typical water quality permit inspections.

Enhancement of Program Effectiveness

Use of technology transfer workshops is one option for enhancing coordination and overall program effectiveness. For example, the key implementing organizations could maximize technology transfer through community outreach programs (e.g., trade shows where private organizations can anonymously obtain advice on the handling, transport, and disposal of hazardous materials). Also guidance manuals may be published on BMPs for specific industries, such as shipbuilding or commercial construction.

Staff replacement within participating agencies and organizations can affect coordination and program continuity. An urban bay action program would benefit from requirements for minimizing discontinuity, especially for staff who are members of the interagency work group or urban bay action team. Requirements should include recommended reading lists and briefing of work group members (at work group meetings or by mail) of intended staff changes and the anticipated effects. If the urban bay action team coordinator is replaced, special care is needed to ensure program continuity. Departing coordinators should provide a written status report of all ongoing projects as well as outstanding issues which need to be addressed but are not identified in any program documents (e.g., the action plan). Departing coordinators or other personnel should also provide some training to incoming coordinators which might include information or historical developments of the program, issues or problems in the bay, and a status of activities in the action plan.

Some urban bay action programs may benefit from a phased approach to planning and agency involvement. In the first phase of the program, participation by a wide range of organizations and public interest groups would be solicited for scoping and design of the technical and institutional aspects of the program; the membership of the interagency work group would reflect these needs. The second phase would occur during program implementation when participation of agencies with regulatory authority and representatives of the regulated community is most important; the membership of the interagency work group would be refined to reflect the changing needs of the program.

Long-term success and continuity of an urban bay action program can be fostered by obtaining funding commitments for the program from the state legislature. This enables agencies to hire staff and necessary technical support. State funding also increases opportunities for initiating priority actions. The ease with which funding can be obtained for a program depends to a large extent on the degree of public support. Therefore, mechanisms should be used to foster public support during program implementation (e.g., public meetings, press releases, and briefing of legislators or their staff on progress of the program). It is advisable for program managers of participating agencies to meet annually to establish agency commitments, funding levels, and responsibilities.

OPTIONS FOR ENSURING ACCOUNTABILITY

Accountability for implementation of an urban bay program is a critical element in the long-term effectiveness and success of the urban bay approach. Accountability in this sense applies to agencies making resource commitments and following through on those commitments. Often, no formal mechanism (e.g., an enforcement order) exists to ensure accountability throughout a given urban bay. Rather, techniques based on citizen and agency peer pressure are likely to be the main methods available. The first step in ensuring accountability is to get an initial commitment of staff and/or resources and address high priority problems. Once a commitment has been made, it is essential to document this commitment in various ways. Public documentation of commitments in an action plan helps ensure that agencies follow through on commitments by providing a public record for later comparison with achievements.

Some possible options for ensuring accountability for implementation include:

- Public meetings could be held periodically to inform the public of the completion of significant milestones (e.g., implementation of remedial actions for a major source of contaminants)
- A quarterly or semiannual urban bay newsletter could be published to document intended actions, status of these actions, and successes or failures
- Annual reports or articles could be published for the press, interested citizens, and environmental groups on the status of action plan implementation
- Directors or senior policymakers in participating organizations (especially those making a commitment of resources to the urban bay action program) could sign the action plan as an indication of good will and as a matter of public record
- The lead implementing agency or lead regulatory agency could get formal or informal agreements from agency personnel concerning intended agency activities under the urban bay program
- Awards could be given to selected industries that have implemented progressive or innovative cleanup actions
- Press releases could be issued on industries that have not met their cleanup commitments
- In some cases, a formal regulatory requirement such as a consent decree or enforcement order may be issued by a regulatory agency.

DATA COLLECTION AND PROBLEM AREA IDENTIFICATION

The PSEP urban bay action programs rely on a preponderance-of-evidence approach to identify and rank toxic problem areas and contaminant sources (i.e., use of multiple indicators of environmental quality). Study areas that exhibit high values of multiple indicators of contamination and adverse biological effects receive a ranking of "high priority" for evaluation of pollutant sources and remedial actions. The data for environmental variables and contaminant sources are used to target priority sources for further evaluation or remediation. Available funds can then be allocated to the highest priority problems first to achieve cost-effective source controls and environmental improvements.

The following sections describe the process used to evaluate contaminant sources and environmental problem areas. First, the framework for the technical evaluation (i.e., the decisionmaking or prioritization approach) is described. This is followed by descriptions of the key steps in the decisionmaking approach. Finally, alternative approaches are described that may be used to streamline the overall process.

OVERVIEW

The preponderance-of-evidence approach used in urban bay programs is implemented in a step-wise manner to identify toxic problem areas and associated contaminant sources (Figure 5). This approach focuses on sediment assessment techniques because of the value of sediment variables as indicators of toxic chemical contamination and biological effects (for rationale, see *Background and Overview* section). Nevertheless, a similar approach could be applied to water column variables. Information is incorporated into an assessment matrix and evaluated to identify and prioritize problem areas, problem chemicals, and potential pollutant sources. The available data are evaluated relative to action level guidelines (i.e., criteria for defining and ranking toxic problem areas) and sediment quality values are developed from quantitative relationships between sediment contamination and biological effects. Problem chemicals may then be linked to specific sources.

The general approach may be applied to either a small data set derived from previous studies or a comprehensive data set collected as part of an urban bay action program. A series of data collection activities could be implemented in a tiered fashion to correspond with increased funding over time. For example, Tier 1 could be a shoreline reconnaissance survey of potential sources and initial source evaluation; Tier 2 could involve meeting with industries to discuss efficient industrial management practices and additional data needs for source prioritization; Tier 3 could involve inspections of industrial facilities for compliance with toxic substance regulations and an evaluation of potential sources of contaminants; and Tier 4 might involve more extensive field sampling and the detailed evaluation of environmental data described below.

The Tier 4 evaluation assumes that environmental degradation must be assessed for areas within a bay to determine priorities for source evaluations and remedial actions. This approach is most appropriate when few data on contaminant sources are available and sources cannot be easily prioritized based on other information (e.g., information on land use and industrial processes). The Tier 4 evaluation may also be warranted when a demonstration of environmental harm is required

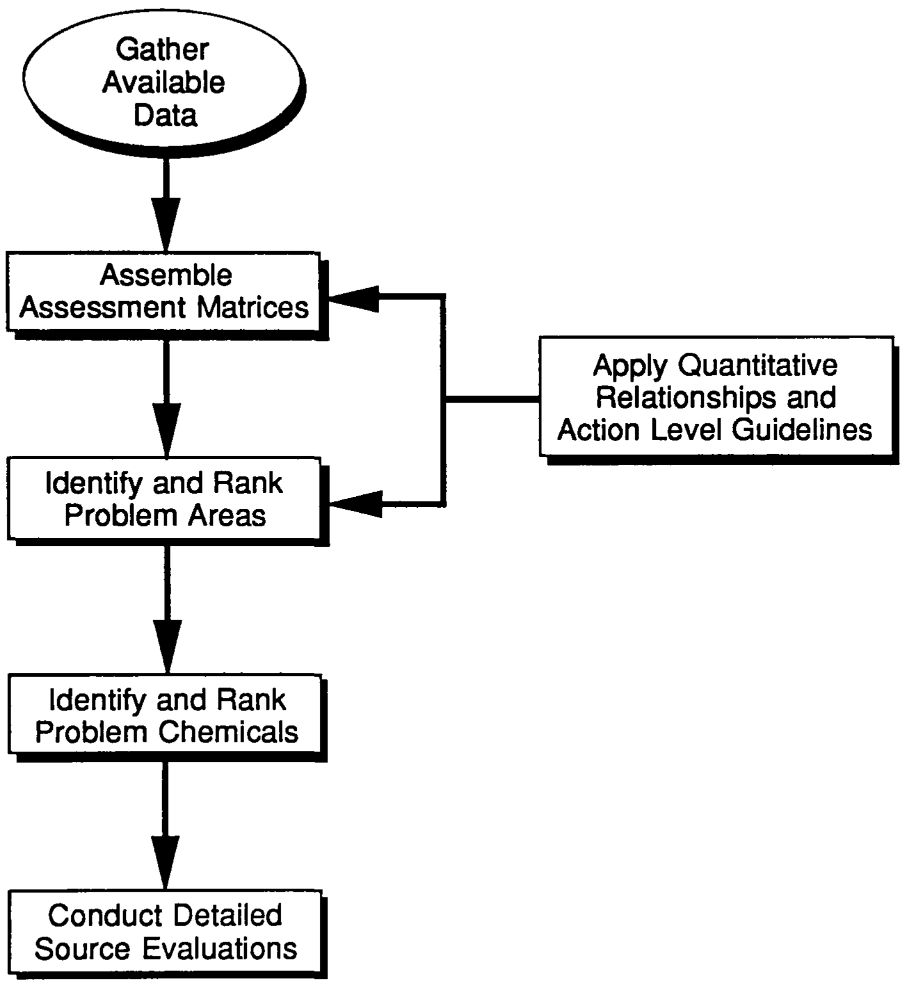

Figure 5. Decisionmaking approach for evaluation and ranking of problem areas and problem chemicals

to proceed with enforcement action or to elicit actions from responsible parties. Responsible parties could either be legally forced to do further sampling and analysis or to initiate immediate source control. In some cases, environmental data may not be needed to prioritize contaminant sources and to implement source controls (e.g., where the most important sources of contaminants are obvious and data on these sources are sufficient for regulatory controls).

Four major premises underlie the Tier 4 approach shown in Figure 5. First, recommendations for evaluation of contaminant sources and remedial actions are based on several measures of sediment contamination and biological effects. When results of these independent measures corroborate one another (i.e., there is a preponderance of evidence showing sediment contamination and biological effects), a problem area is defined. There may also be special circumstances where corroboration is not needed because a single environmental indicator (e.g., sediment contamination or adverse biological effect) provides an exceptionally strong basis for recommending source control or sediment remedial action.

Second, the decision to evaluate potential sources of contamination and the need for possible remedial alternatives applies only to those sites that exceed a minimum action level. An *action level* is a level of contamination or biological effects that defines a problem area. It is assumed that an area requires no action unless one of the indicators of contamination, toxicity, or biological effects is significantly elevated above reference levels. Action level guidelines provide a consistent and objective procedure for defining and ranking problem areas based on significant contamination and effects. One action level guideline used in Puget Sound is based on significant elevation above reference (EAR) levels for three or more environmental indicators (e.g., sediment toxicity, benthic community structure, and bioaccumulation). Additional examples of action level guidelines are provided by PTI and Tetra Tech (1988a,b). Specific guidelines developed for one urban bay action program may be adapted and applied to other bays. Action level guidelines should be developed in consultation with the interagency work group and the citizens advisory committee.

Third, it is assumed that adverse biological effects are linked to environmental conditions that result from toxic chemical releases from sources and that these links may be characterized empirically. Relationships between sources and biological effects should be quantified where possible (e.g., by correlations of specific contaminant concentrations and distributions with the occurrence of adverse biological effects). However, proof of specific causal agents is generally not obtained during an urban bay action program because laboratory studies of cause-effect relationships involving complex mixtures of contaminants are impractical in the context of short-term regulatory response. Nevertheless, analysis for a wide range of contaminants (e.g., in sediment) increases the probability of measuring either the causative substances or related covarying substances from the same source.

Finally, the recommended remedial actions may vary from location to location, depending on the nature of the water quality or sediment contamination problem. For example, removal or capping of contaminated sediments may be recommended where biological effects are apparent and contamination originated only from past sources (see Appendix B for information on evaluating sediment remedial action). In contrast, source control may be recommended where contamination originates from an ongoing source. In other cases, both sediment remediation and source control may be recommended. To prevent recontamination of newly cleaned areas, sediment remediation (if necessary) should usually be implemented only after major sources of contamination have been identified and controlled. Sources of information needed to support an urban bay action program are discussed in the next section. Because environmental data may not be needed to undertake source remedial actions, the following discussion addresses evaluation of contaminant sources before characterization of environmental contamination and biological effects.

SOURCES OF INFORMATION

Compilation of existing information on sediment and water quality, biological effects, and potential contaminant sources is the first step in evaluating contaminant sources and environmental problem areas. The needed information may be obtained through contacts with federal, state, and local agencies and should be collected into a project library. The following institutions, agencies, and agency programs can provide useful information:

- **State agencies** (e.g., departments of ecology or environmental quality, natural resources, and health)—Lists of hazardous waste generators; source information from inspections and investigations, including NPDES permits and monitoring results; surveys of contaminated sites
- **EPA**—Environmental quality surveys, STORET database, NPDES monitoring results
- **NOAA**—Information on chemical contamination in sediments and water, bioaccumulation, fish pathology, and bioassays; National Oceanographic Data Center database
- **U.S. Army Corps of Engineers**—Sediment data collected by dredging contractors and ports for dredging projects
- **Local health departments**—Surveys of storm drains and CSOs; studies that focus on health-related concerns (e.g., bioaccumulation, microbial contamination)
- **Chambers of commerce and city and county planning departments**—Land use information
- **Industries**—NPDES monitoring data, manufacturing and processing information, and maps of facilities and drainage systems
- **Local colleges and universities**—Studies that focus on or include urban bays.

IDENTIFICATION OF POTENTIAL CONTAMINANT SOURCES

Potential contaminant sources in urban bays include municipal wastewater treatment effluent, CSOs, surface runoff, contaminated groundwater infiltration, industrial discharges, boat and marina discharges, atmospheric deposition, and accidental spills. Actual and potential contaminant sources are identified based on existing information about past and present activities and information from site inspections and discharge permits. Data are most commonly available from files of state regulatory agencies for facilities with NPDES-permitted or known nonpermitted discharges, facilities contributing to contamination due to poor housekeeping practices, and sites with groundwater or soils contamination. Additional sources of information include consultant studies, university studies, U.S. Army Corps of Engineers permits for dredged projects, and U.S. Coast Guard files of oil spill occurrences.

Efforts to identify sources typically integrate a large database on potential contaminant sources, observed contaminant concentrations in water and sediment, and ancillary information.

- Spatial gradients of contamination in surface sediments and water column
- Vertical gradients of contamination in sediment cores and water column
- Maps of point source discharges, storm drain systems, landfills, hazardous waste sites, locations of relevant industries (e.g., shipyards, pulp mills, oil refineries, metal plating shops), marinas, and potential nonpoint sources
- Contaminant concentrations associated with point source effluent, storm drains (i.e., sediment or water within the storm drains), and nonpoint sources
- Contaminant concentrations from source tracing in CSO and storm drain networks
- Dredging history
- Data on environmental fate processes and circulation/transport
- Information on land use and industrial activities (e.g., use or production of a particular contaminant, handling and disposal practices).

Information used for evaluation of the contaminant source can be collected during shoreline surveys, inspections of industrial facilities, and other field investigations.

Because most persistent toxic chemicals adsorb to sediments, evaluation of spatial gradients of contaminants in surface sediments has proved to be one of the most important components in the source identification process for Puget Sound. However, overlap of the areas of influence of different source discharges may complicate the interpretation of contaminant data for surface sediments (see below for discussion of storm drain sampling as an alternative to surface sediment sampling). Evaluation of vertical gradients of contamination in sediment cores can be used to assess the chronology of contaminant accumulation. For example, a concentration maximum in the uppermost sediments of a depositional area probably indicates recent input or possible historical input exposed by dredging or ship scour. By contrast, a subsurface concentration maximum suggests that historical input was greater than current inputs and that recent burial with cleaner sediments has occurred.

To better characterize contaminant inputs from CSOs and storm drains, a screening-level survey may be conducted (e.g., Tetra Tech 1988b). One technique that appears promising for ranking contaminant sources is to collect settled sediment in CSOs and in storm drains that discharge directly into the waters of the project area (Meiggs 1980; Hubbard and Sample 1988). Sediments from the storm drains can be analyzed for the same contaminants measured in offshore sediments. These storm drains and other potential sources are evaluated for their contribution of contaminants to priority problem areas. Potential sources are identified based on the following elements:

- Proximity of the potential source to an offshore problem area
- Similarity of the kinds and relative concentrations of problem chemicals in sediments in storm drains and the receiving environment
- The spatial distribution of contaminants in offshore sediments
- Available information on past and ongoing practices that may contribute to observed contamination.

For example, in the Elliott Bay Action Program 10 priority storm drain systems were identified for source control activities based on information developed or compiled during the problem area analysis (PTI and Tetra Tech 1988a) and the evaluation of potential contaminant sources (Tetra Tech 1988a).

Information on land use and drainage patterns in the watershed of an urban bay can be used to identify likely sources of contamination. This information is typically summarized by mapping the location of potentially contaminated facilities and storm drain networks relative to locations of contaminated areas. If maps of storm drainage systems are not available, then obtaining the information to prepare drainage maps should be a high priority. Land use information should include both historic and current data. Geographic information systems provide the best format for organizing and evaluating the interrelationships among various types of information.

CHARACTERIZATION OF CHEMICAL CONTAMINATION AND BIOLOGICAL EFFECTS

Where environmental data are available or can be collected in a cost-effective manner, multiple indicators of sediment quality and water quality should be used to aid in prioritization of source evaluations and remedial actions. The preponderance-of-evidence approach requires the selection of several measurements that serve as indicators of contamination and biological effects in the urban bay. To minimize costs, the objective should be to select the minimum number of indicators that can adequately characterize the extent of contamination as well as enable a prioritization of problem areas. In Puget Sound, the urban bay approach has used five kinds of environmental indicators:

- **Sediment contamination**—Concentrations of chemicals and chemical groups
- **Sediment toxicity**—Acute mortality of amphipods, abnormalities in oyster larvae, and bacterial luminescence (Microtox®)
- **Benthic infauna**—Abundances of major taxa or species
- **Bioaccumulation**—Contaminant concentrations in English sole muscle tissue
- **Fish histopathology**—Prevalences of liver lesions in English sole.

The number and kinds of environmental indicators used to characterize problem areas depends on the amount of historical data available, the magnitude of a suspected problem, and data needs specified by regulatory enforcement agencies (including level of confidence desired for problem area identification). In the Puget Sound region, measurements of contaminant concentrations in sediments have been especially useful for characterizing the degree of contamination and for tracing pollutant sources. Measurements of contaminant concentrations in tissues of aquatic organisms have been used to identify large-scale problem areas and potential human health risks in populations of recreational anglers who consume seafood from contaminated areas. The basis for the use of bioaccumulation and histopathology was established by the earlier work of NMFS (e.g., Malins et al. 1980, 1982, 1984). Sediment bioassays and surveys of sediment-dwelling organisms are valuable for characterizing effects of contamination at specific sampling locations. Data on abundances of major taxa (e.g., Polychaeta, Gastropoda, Pelecypoda, Crustacea) are especially useful for screening surveys. Detailed assessments of species abundance are sometimes needed to discriminate effects of toxic substances from habitat influences (e.g., sediment grain size, organic carbon content) on benthic communities. Measurements of sediment chemistry, bioassays, and benthic community analyses form the triad of data used to characterize toxic problem areas in and benthic community analyses form the triad of data used to characterize toxic problem areas in Puget Sound (Long and Chapman 1985; Chapman et al. 1985; PTI and Tetra Tech 1988a,b) and San Francisco Bay (e.g., Chapman et al. 1987). A combination of chemical and biological measurements has also been used to define sediment quality values (i.e., guidelines for chemical concentrations expected to cause adverse biological effects; Barrick et al. 1988).

The scope of field surveys depends on funding level, amount and kind of available data, magnitude of contamination and biological effects, size of the urban bay, and complexity of contaminant sources. A comprehensive (baywide) field survey to identify problem areas and contaminant sources should be performed only when recent historical data are insufficient to conduct such an assessment. A baywide survey has several advantages. Consistent and reliable data may be obtained from suspected problem areas and relatively clean areas, new problem areas may be discovered, and problem areas can be ranked primarily on the basis of current data. However, a baywide survey may not be appropriate if there is little or no funding available from agencies participating in the interagency work group. Instead of a single comprehensive field survey, multiple field surveys may be performed in phases at selected locations. Opportunities for use of samples or data being collected as part of other programs should also be considered, although QA/QC requirements may limit the use of such "opportunistic samples." Funding for a comprehensive survey or a series of phased, smaller surveys can be solicited from participating agencies in the work group. If available data are sufficient for regulatory action, then parties responsible for contaminated sites may be required to perform further investigations to assess the extent of problems and select remedial alternatives.

If a field survey is necessary, documentation of the sampling and analysis design is essential. Cost-effective sampling and analysis strategies, with adequate QA/QC of both sampling and analytical laboratory performance, are required for an efficient and scientifically defensible project. Development of a sampling and analysis plan should involve evaluation of available data. Data on potential sources and drainage patterns are especially useful for deciding where to position sampling stations. Information on current and historical land uses should also be evaluated to identify potential problem areas. For major point sources, the most effective strategy is generally to sample discharge effluent and sediments in the immediate vicinity of the outfall. Where available environmental and land use data are sufficient to define a problem area, the sampling and analysis scheme may be almost exclusively devoted to characterization of contaminant sources. Where historical chemical and biological data indicate a problem area exists but sources are unknown, the emphasis of the sampling and analysis plan may focus initially on confirmation of adverse impacts before a major survey to identify sources is performed. Information on adverse impacts is valuable in ranking problem areas for further evaluation of sources, especially where source data are limited. Elements of sampling and analysis plan design are described in Appendix C.

Data validation is an essential element of any sampling program. Comprehensive validation of historical data is not always possible because QA information is not always available. Data quality review of historical data should focus on five primary data characteristics: sample collection, sample handling, QC samples (e.g., replicates, blanks), analytical methods, and detection limits. The data review procedures described in Appendices E and F of Tetra Tech (1988c) provide a good example of historical data review. Data validation of field studies conducted as part of an urban bay action program is subject to greater control. QA encompasses every aspect of a project, including planning, data collection, data quality review, and data use. Regional guidelines for data QA are summarized in PSEP (1986) and PTI (1989).

INTEGRATION OF MULTIPLE INDICATORS OF ENVIRONMENTAL QUALITY

Available chemical and biological data are used to calculate environmental quality indices. These indices are then used to rank or prioritize areas based on observed contamination and biological effects. The indices have the general form of a ratio between the average value of a variable at a contaminated site and the value of the same variable at a reference area. General objectives for reference areas and specific performance criteria for Puget Sound reference areas are provided by Pastorok et al. (1989). The ratios are structured so that the value of the index increases as the deviation from reference conditions increases. Thus, each ratio is termed an EAR index. For most variables, the measured average value at the study site is divided by the average value at the reference area to obtain the EAR index. A similar approach can be applied to water quality assessment. Where water quality standards exist, the EAR index is simply the ratio of the observed contaminant concentration in water to the water quality standard.

Information from multiple indicators can be integrated for an overall evaluation and prioritization of study areas. The environmental contamination and effects indices (i.e., EAR indices) are organized into an *action assessment matrix* that is used to compare study areas or sampling stations. A simplified hypothetical example of such a matrix is shown in Table 2. For this example, only general indices such as *sediment contamination* or *benthic macroinvertebrates* are shown. In the application of the approach to an actual case, multiple indices based on specific variables are used for each of the five data categories (e.g., specific chemicals for *sediment contamination* and various species for *benthic macroinvertebrates*).

QUANTIFICATION OF RELATIONSHIPS AMONG SEDIMENT CONTAMINATION AND BIOLOGICAL EFFECTS

In Puget Sound, sediment quality values based on the apparent effects threshold (AET) approach (Barrick et al. 1988) have also been used to characterize the severity of sediment contamination and to prioritize problem chemicals (PTI and Tetra Tech 1988a,b). AET values are developed from a large historical database of the observed (i.e., empirical) relationship between biological effects and chemical concentrations. An AET is defined as the concentration of a single chemical (or chemical class) in sediment above which a particular biological effect has always been observed (and thus is predicted to be observed in other areas with similar concentrations of that chemical).

AET values are particularly useful when biological effects data for particular sites are not available but sediment chemistry data are available, as is the case for many historical data sets. AET for Puget Sound values have been generated for individual chemicals or chemical groups in each of four biological effects categories: 1) benthic infauna depressions, 2) amphipod mortality bioassay, 3) oyster larvae abnormality bioassay, and 4) Microtox® bioassay. Ratios of chemical concentrations to their respective AET values provide useful indices of the relative severity of contamination. Details on the AET approach and its application to other programs in Puget Sound can be found in Barrick et al. (1988). AET should be applied only to data sets from the estuarine or coastal region where the AET values were developed. The EPA Science Advisory Board has recommended that AET be developed and applied on a site-specific basis only. Research is currently in progress to develop AET in United States coastal areas other than Puget Sound (e.g., San Francisco Bay and the Southern California Bight). In addition, the EPA Office of Water Criteria and Standards is investigating the use of the equilibrium partitioning theory to develop national sediment quality criteria (U.S. EPA 1988b). Sediment quality criteria values based on the

TABLE 2. THEORETICAL EXAMPLE OF ACTION ASSESSMENT MATRIX[a]

Indicator	EAR Values for Study Sites A	B	C	D	E	Reference Value
Sediment contamination	1,300	45	800	75	8	1,000 ppb
Toxicity	8.5	2.0	10.0	4.5	2.2	10% mortality
Bioaccumulation	900	20	1,100	200	13	10 ppb
Pathology	5.2	2.6	8.0	2.8	2.0	5% prevalence
Benthic macroinvertebrates	4.0	1.2	5.0	1.3	1.1	60 individuals/m^2

[a] EAR values for indicator variables are shown for Sites A-E. Benthic macroinvertebrate factors represent the reduction in numbers of individuals at the study site relative to the reference site. Factors for all of the other indices represent increases relative to the reference site values shown.

[ ] - Indicator value for the specified area is significantly different from reference value.

equilibrium partitioning theory should also be useful in evaluating sediment contamination and biological effects once they are fully developed.

IDENTIFICATION AND RANKING OF PROBLEM AREAS

Evaluation of information in the form of a matrix (e.g., Table 2) enables the decisionmaker to answer the following questions:

- Is there a significant increase in contamination, toxicity, or biological effects at any study site?
- What combination of indicators is significant?
- What are the relative magnitudes of the elevated indices (i.e., which represent the greatest relative hazard)?

The term *significant* as used in the urban bay approach generally indicates statistical significance at a selected confidence level (e.g., $\alpha = 0.05$). Significance of an EAR is generally based on statistical comparisons of variables between contaminated sites and an appropriate reference area.

The decision to evaluate potential sources of contamination and the need for possible remedial alternatives applies only to those sites that exceed a minimum action level. An *action level* is a level of contamination or biological effects that defines a problem. Individual stations that exceed action level guidelines are grouped into problem areas based on consideration of chemical distributions (including data from recent historical studies), the character and proximity of potential contaminant sources, and geographic and hydrographic boundaries. The need for remediation and the actions required to prevent further degradation should be decided on a case-by-case basis. Problem areas are ranked using a systematic method of assigning scores to sampling sites or areas based on the significance and severity (i.e., EAR index) of the various chemical and biological variables. The level of EAR values for metals and organic compounds percent bioassay response, number of marcroinvertebrate depressions, number of chemicals in fish muscle tissue, and number of lesion types in fish were all used in Puget Sound as criteria for ranking problem areas. Further information on the use of criteria for ranking problem areas for evaluation of sources and remedial actions is summarized by PTI and Tetra Tech (1988a).

Problem chemicals in sediments may be prioritized to focus efforts for evaluation of contaminant sources (e.g., Tetra Tech 1985). In Elliott Bay, chemicals within a given problem area were identified as potential problem chemicals if their concentrations exceeded the 90th percentile value for all observations within the bay. A contaminant was also identified as a problem chemical if its concentration exceeded the most sensitive (i.e., lowest) value of the four kinds of chemical-specific AET (i.e., benthic infauna depressions, amphipod mortality bioassay, oyster larvae abnormality bioassay, Microtox® bioassay).

ALTERNATIVE STRATEGIES FOR CHARACTERIZING PROBLEM AREAS

Because of the wide range of conditions represented in various urban bays, the basic approach described above may need to be modified to fit a particular situation. An example of one approach to streamlining the procedures for characterizing problem areas is presented in Appendix C. For example, this approach involves use of areawide indicators (e.g., bioaccumulation and histopathology in fish) to identify selected large-scale problem areas before use of site-specific indicators (e.g., sediment chemistry, toxicity, and benthic macroinvertebrates). The general approach, as applied in Puget Sound, could also be modified by including information that has not been assessed in the urban bay action programs conducted to date. Certain types of information may provide significant insight into environmental problems and their relative importance. For example, habitat sensitivity or economic value could be included in problem area ranking. In addition, for some areas it may be appropriate to conduct independent evaluations of potential human health hazards and environmental hazards. This approach would enhance flexibility in evaluating the relative importance of these two distinct types of hazards. For example, the ultimate ranking of contaminated areas in a protected, environmentally sensitive regime might emphasize the ecological hazard, while the ranking of contaminated areas that are heavily used by commercial and recreational fishermen might emphasize human health considerations.

SELECTION AND IMPLEMENTATION OF CORRECTIVE ACTIONS

The regulation of toxic contamination of the environment includes 1) the control of contaminated discharges and the cleanup of contaminated facilities; 2) natural sediment recovery through burial and mixing with clean, freshly deposited material; and 3) sediment remedial action in cases of highly concentrated or persistent contamination. Source control is addressed through various regulatory options. The rate of natural recovery may be characterized by using a mass balance model that links source loading, sediment contamination, benthic mixing, and sediment accumulation. Monitoring of the extent and severity of contamination may be included in an urban bay action program to ensure that source controls are sufficient, that sediment recovery is timely, and that recontamination does not occur. However, in some areas of severe and persistent contamination, sediment remediation may be required (i.e., where cost-benefit analysis shows a definite net benefit). The need for sediment remedial action may be determined by evaluating the balance between the rate of natural recovery after source control, the kinds and magnitudes of existing environmental impacts, and the cost of sediment remedial action (Appendix B). In areas with significant nonpoint sources of pollution (e.g., stormwater runoff), management strategies (U.S. EPA 1987a, 1988a; PSWQA 1989a; LIRPB 1984) emphasizing nonregulatory approaches may be necessary.

REGULATORY OPTIONS FOR SOURCE CONTROL

Cleanup and control strategies for sources vary widely, depending on the nature of the source. For example, source control actions applicable to industrial dischargers include in-line process modifications or effluent treatment. Strategies for controlling runoff from contaminated facilities include containment, collection, and treatment options. Alternative ways of controlling contaminated groundwater discharge range from pump-and-treat alternatives to confinement or diversion. Nonpoint sources such as runoff from urban areas are predominantly controlled by designing and implementing BMPs.

These diverse strategies for controlling sources are implemented through several regulatory and management processes. Point sources that are permitted can be controlled by modifying permit requirements. The following general types of regulatory actions are used to initiate source control action:

- Inspections
- Notification of permit violation
- Administrative order (e.g., to take a specified course of action within a specified schedule)
- Consent order or decree (e.g., a binding agreement between a regulatory agency and party under enforcement)
- Notice or demand letter (e.g., to accompany a consent order or decree and specify the timeframe and procedures for negotiations)

- Permit issuance or modification
- Penalties
- Court action.

For illegal dumping, criminal investigation and enforcement depend heavily on apprehending the violator in the act. Until a violator is identified, regulatory activity primarily involves monitoring an area where illegal activity is suspected. For control of nonpoint sources, working with local planning and utility agencies may provide effective solutions (e.g., specifications in local building and development permits to address stormwater/runoff issues).

INTEGRATING SOURCE CONTROL, NATURAL RECOVERY, AND SEDIMENT REMEDIAL ACTION

The selection of appropriate strategies for pollutant source control or sediment remedial action for the highest priority problem areas is a critical part of an urban bay action program. Because of typical budget limitations, it is unrealistic to assume that corrective actions can be implemented in all problem areas, at least in the short term. It is important that available resources initially be directed toward areas posing the greatest environmental hazard. Furthermore, it is important that decisions on sediment remedial action be based on evaluation of the environmental benefits that can be realized from the remedial costs incurred. A decisionmaking structure is needed that enables the appropriate direction of financial resources to areas where the greatest benefit will be realized.

In considering the need for pollutant source control and sediment remediation, it is important to distinguish between two key characteristics of these remedial activities:

- From a cost standpoint, the potential upper cost limit for sediment remediation (e.g., removal and treatment) is much greater than for some forms of source control (e.g., settling basins). The technologies for some forms of source control are also more feasible than sediment remediation techniques.
- Because sediments contaminated by historical pollutant sources or by recently controlled sources may have the potential for natural recovery, simply allowing natural processes to occur could substantially mitigate the environmental cleanup costs.

Because of these and other factors, the urban bay programs in Puget Sound have emphasized source control and natural recovery. Also, ongoing contaminant sources should be scheduled for control once they are identified. In contrast, contaminated sediments require further evaluation before sediment remediation is selected as an appropriate course of action. Also, the environmental benefits, impacts, and costs of sediment remedial action need to be evaluated relative to natural recovery and source control options. A general approach to evaluate the need for sediment remediation and to select preferred remedial alternatives is described in Appendix B.

MONITORING

Monitoring of sources and the receiving environment is critical to ensure that all necessary remedial actions have been undertaken in a problem area and to determine the success of individual remedial actions. The overall objective of monitoring is to document the level of source control achieved and the attainment of goals for environmental quality. With respect to sediments, the focus of source monitoring should be on determining the success of source contaminant reduction and control efforts. Contaminant loading data provide the most important information used in a comparative analysis of sources. Contaminant concentration data for nonpoint sources or wastewater discharges are important for determining if sediment and water quality goals will be attained (e.g., by modeling the relationship between source loading and environmental contamination). Monitoring of sediment and water contamination provides a basis for determining the ultimate effectiveness of source control, the rate of sediment recovery by natural processes, and the possibility of recontamination by new or existing sources. The recommended frequency of monitoring depends on the documented success of instituted source controls and natural sedimentation rates. In most cases, monitoring on an annual basis will be adequate for sediment variables. More frequent monitoring may be required for water column variables.

Guidance for the development of a monitoring program to determine the success of source control within drainage basins has been developed as part of the urban bay action program for Elliott Bay (Tetra Tech 1988c). The guidance incorporates the following decision points:

- Is it feasible to sample sediments from storm drains and CSOs?
- Is it feasible to sample sediment in the receiving environment?
- Is an effects-based monitoring approach preferred (e.g., use of biological indicators such as toxicity bioassay responses or community structure of benthic macroinvertebrates)?
- Are analyses of both sediment toxicity and benthic communities desired?

Appropriate monitoring locations and environmental indicators are selected based on the responses to these questions. Additional technical considerations included in the guidance document (Tetra Tech 1988c) include timing and frequency of sampling and siting of monitoring stations. Other sources of monitoring guidance are cited in Appendix C of this report.

PUBLIC PARTICIPATION

Public participation serves several important functions in the urban bay approach. Formal public participation allows the public to become part of the process and include their concerns in the priorities of the program. Participation by the public also serves as a method to increase awareness of urban bay problems among citizens and other interested parties. Continuing public participation promotes increased program effectiveness by putting pressure on interagency work group members, action teams, and specific dischargers to be accountable for implementation of the action plan. Additional, public involvement in the urban bay program can enhance or facilitate fiscal commitments by local, state, and federal programs. Citizen efforts to effect fiscal and programmatic commitments may help achieve urban bay program goals. It is important that the public understand why the program exists, the goals of the program, and the rationale and basic technical findings of any scientific investigations conducted in support of action plans.

Although the extent of public involvement may be different in different urban bays based on interest, timeliness, and current public involvement opportunities, the goals of public involvement in the urban bay approach are the same. The urban bay approach to public involvement includes the following objectives:

- Involve the public in program development and decisionmaking. Public involvement in urban bay programs is critical because the public can bring information, expertise, values, funding, and priorities to the decisionmaking process. Resource management programs that fail to educate and involve the public in a substantial and meaningful way are often met with resistance or animosity. A successful urban bay program needs to include participation both by organized citizen groups, which are designated as representatives of certain sectors or perspectives, and individuals who represent segments of the general public.

- Provide the public with clear and accurate information on program activities. This objective may be especially important early in the program, when public support may facilitate federal and state funding. A necessary element of this effort is to develop a public education plan or strategy to provide the mechanism(s) for allowing public access to the process and to information generated by the program.

- Obtain feedback from citizens during implementation of public participation programs. For instance, work group meetings should have time set aside to answer questions from citizen advisory committee members. A properly designed public involvement program will allow for feedback and should result in necessary changes in the mechanisms and information developed under the first objective. In addition, citizen feedback will provide important information to decisionmakers regarding the relative merit of cleanup programs and political accountability.

- Provide a forum for political or technical conflicts to arise and be resolved positively, in a manner that will not jeopardize the overall schedule. Often there is a tendency for minor conflicts between interest groups and agencies or among agencies to go unrecognized until a critical point is reached, resulting in project delays until the conflict is resolved. A public involvement program cannot ensure that there will be no unresolvable conflicts and resultant project delays. However, a well designed program minimizes this prospect by bringing potential opponents into a process that is open and responsive.

There are many available mechanisms to achieve an appropriate level of public involvement and information exchange (U.S. EPA 1980; Howell et al. 1987). For example, the public involvement program may include the following elements:

- Citizens advisory committee
- Public tours of the urban bay with an environmental scientist to explain environmental problems
- Press conferences, public service announcements, or public meetings at key junctures in the process, for example:
  - Foster public support for the program during the early planning phase of the process
  - Disseminate information about environmental conditions and priority problems after release of the initial data summary or significant sampling and analysis results
  - Obtain public and private sector responses on planned activities after release of the draft action plan
  - Disseminate information about program accomplishments after release of an annual program status report.
- Periodic memos, articles, or newsletters to disseminate technical information and record program successes
- Interpretive displays (e.g., posters showing the approach and results of an urban bay action program) at a local aquarium or at scientific conferences that are open to the public
- Mailing list of interested people who receive documents for comment or review.

CONCLUSIONS

As part of PSEP, the urban bay action programs have been effective in reducing releases of toxic chemicals to Puget Sound and associated adverse biological effects. The urban bay approach should be used in estuaries throughout the United States to reduce and ultimately eliminate contaminated discharges and runoff which cause unacceptable levels of chemical contamination and adverse biological effects. The success of the urban bay approach results primarily from achievement of the following objectives:

- Focus assessment and regulatory efforts on specific pollutant sources and contaminated sites
- Establish action teams to work in specific geographic areas
- Facilitate remedial actions (without excessive studies and delays) by use of available data and coordination among state and local agencies
- Define specific commitments of agencies or individuals for permitting, inspections, sampling, and other remedial activities
- Establish mechanisms for accountability of participating agencies (e.g., involve citizens, business-industrial organizations, public interest groups, and scientists in decisionmaking to maximize support and accountability for the program)
- Use field inspections and personal contacts with industries to encourage cooperation in finding innovative, cost-effective solutions to toxics problems
- Escalate regulatory and enforcement activities if warranted
- Transfer technologies and solutions to new urban bays with similar problems.

The decisionmaking framework for the urban bay approach enables regulatory efforts to be focused on contaminated areas posing the greatest environmental or public health risk. The central element of the urban bay approach is the formation of an action team with sufficient training, regulatory authority, and funding to effectively carry out field inspections, negotiate site cleanup, and enforce discharge permits. Source control plans should be based on input from federal, state, and local government agencies and from representatives of industry and citizen groups. A carefully implemented public relations effort is essential if regulatory actions are to be perceived as both necessary and fair, and if the program is to receive continuing support at state and local levels.

The long-term success of the urban bay action programs in Puget Sound and elsewhere requires expansion of source control to include specific effluent limitations and testing for toxicants, investigation and permitting of CSOs and storm drains, and continued interaction with other programs. For example, hazardous waste programs such as Superfund and RCRA are active in some urban bays of Puget Sound, and the urban bay programs can benefit from their sampling activities and source control actions. In the Puget Sound region, Ecology (the industrial permitting agency in Washington state), in cooperation with EPA, is requiring industrial permittees to monitor their storm drain systems for toxic chemicals and to conduct biomonitoring and environmental assessments (e.g., bioassays and sediment chemistry).

The benefits of an urban bay action program include the formation of an efficient environmental regulatory and management network; increased cooperation of industries, wastewater dischargers, and other responsible parties in controlling sources of contaminants; and rapid response by responsible parties to site-specific environmental problems. By providing a common forum for public agencies, private industries, and informed citizens to address toxic contamination problems, the urban bay approach enhances the effectiveness of existing regulatory programs. Cooperation among agencies and coordination of sampling and analysis programs reduce duplication of effort and maximize the efficiency with which funds are expended for environmental protection. This common focus also consolidates often duplicative and confusing regulatory efforts of several agencies with the result that responsible parties are often more responsive and more willing to voluntarily implement source control actions. The focus of the urban bay approach on site-specific problems encourages rapid response by agencies and responsible parties, because corrective actions can be designed for a defined discharge or runoff problem, and actions are focused on areas of highest priority (i.e., most severe environmental problems). In Puget Sound, the urban bay action programs are the only water quality programs other than EPA's 304(l) program to address observed *in situ* contamination problems. The site-specific focus of the urban bay action programs may also minimize the tendency of public agencies to be overcome by the inertia of areawide management plans that address multiple sites within a region simultaneously and require long-term, expensive outlays of public funds.

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APPENDIX A

The Urban Bay Toxics Control Program

Action Team Accomplishments - Executive Summary

(Ryan 1987)

EXECUTIVE SUMMARY

Puget Sound is an estuary of immense value and importance to the Pacific Northwest, but its water quality is threatened by contamination from a variety of toxic and conventional pollutants. Past pollution control efforts, while addressing some pollution sources, have lacked the system-wide approach needed to address current and anticipated problems.

In an effort to halt degradation of the estuary and improve the quality of water sediments, the U.S. Environmental Protection Agency and the Washington State Department of Ecology joined with other agencies and organizations in 1985 to develop and implement the Urban Bay Toxics Control Program. This program is designed to identify existing problems of toxic contamination; identify known and suspected pollutant sources; outline procedures to eliminate existing problems; and identify agencies responsible for implementing corrective actions. The Urban Bay Toxics Control Program was incorporated into the 1987 Puget Sound Water Quality Management Plan issued by the Puget Sound Water Quality Authority. An "action team" selected for each bay provides the link between problem identification and source control. Regulatory actions can include permitting, enforcement actions and negotiation with responsible parties.

Actions to date have focused on Elliott Bay, Commencement Bay, and Everett Harbor. More recently, some initial work has begun in Budd Inlet.

Since October of 1985, action teams have:

ELLIOTT BAY:

- Conducted more than 221 inspections of 124 sites and facilities
- Assessed 28 penalties amounting to $44,200
- Issued 36 Notices of Violation
- Issued 22 Administrative Orders
- Issued 2 NPDES permits with effluent limitation and monitoring requirement modifications
- Targeted 15 contaminated sites for action and achieved final cleanup at 2 sites
- Continued work on cleanup negotiations at 12 sites
- Continued work on permit actions at 8 sites.

COMMENCEMENT BAY:

- Conducted 134 site inspections
- Assessed 7 penalties amounting to $94,000
- Issued 2 Notices of Violation
- Issued 6 Administrative Orders
- Negotiated 1 Memorandum of Agreement
- Negotiated 7 Consent Orders
- Negotiated 2 Consent Decrees
- Targeted an additional 8 contaminated sites for enforcement action in Fiscal Year 1988
- Initiated permit actions at 9 sites.

EVERETT HARBOR:

- Conducted 23 site inspections
- Issued 2 Notices of Violation
- Issued 4 Orders
- Issued 2 permits
- Completed a pentachlorophenol spill cleanup.

APPENDIX B

Evaluation of Remedial Actions

EVALUATION OF REMEDIAL ACTIONS

Evaluation of potential source controls and sediment remedial actions to achieve an optimal approach to remediation is described in this section. The role of environmental modeling to support evaluation of alternative remedial actions is also discussed.

EVALUATION PROCESS

The process recommended for evaluation of potential remedial actions is shown in Figure B-1. The first step in this process is to evaluate the natural recovery of the sediments that would be expected to occur under various scenarios of source control (if ongoing sources are present). The SEDCAM model (Jacobs et al. 1988), a model recently developed for use in Puget Sound, is a simple tool that can be used to evaluate sediment recovery. Application of SEDCAM or other tools enables the assessment of changes in the magnitude and extent of contamination and effects under various recovery scenarios. In the example shown in Figure B-1, the area of greatest contamination (shaded area) was predicted to disappear over time and the total problem area to decrease considerably in overall spatial extent. The output of this first stage of the evaluation process is a comparison of the present magnitude and extent of problem areas with predictions of future sediment conditions.

The next step in the evaluation process is to quantify the environmental injury that has occurred or is predicted to occur under various sediment recovery scenarios. In this step, the relative value of degraded habitat must be evaluated. For example, the relative importance of a specific habitat or biological community type may be compared among various locations (e.g., the value of reduced crustacean abundances in an industrial waterway vs. the same effects in an area of shellfish harvesting or recreational fishing). The procedure also enables comparisons of the relative values of different biological effects such as benthic infauna depressions vs. elevated prevalences of fish tumors.

This information on resource value can then be integrated with the costs of various sediment remedial action alternatives in a cost-benefit analysis. The objective of this step is to compare the costs of sediment remediation with the environmental benefits resulting from the remediation. Many of the procedures developed for conducting natural resource damage assessments are appropriate for this task. These analyses can then be used in the final step to evaluate whether a candidate remedial alternative is justified. A specific procedure for cost-benefit analysis has not yet been developed for the urban bay action programs in Puget Sound. Implementation of this step will require the development of a decisionmaking framework with objective criteria for determining the justification for sediment remedial actions. The output of this step will be a decision to either proceed with sediment remedial action planning or to conduct only source control and monitor natural recovery of the contaminated sediments.

Techniques used in the urban bay approach for selecting and evaluating sediment remedial technologies were developed during the Commencement Bay nearshore/tideflats Superfund investigation. Potential sediment remedial technologies were identified in the early stages of this

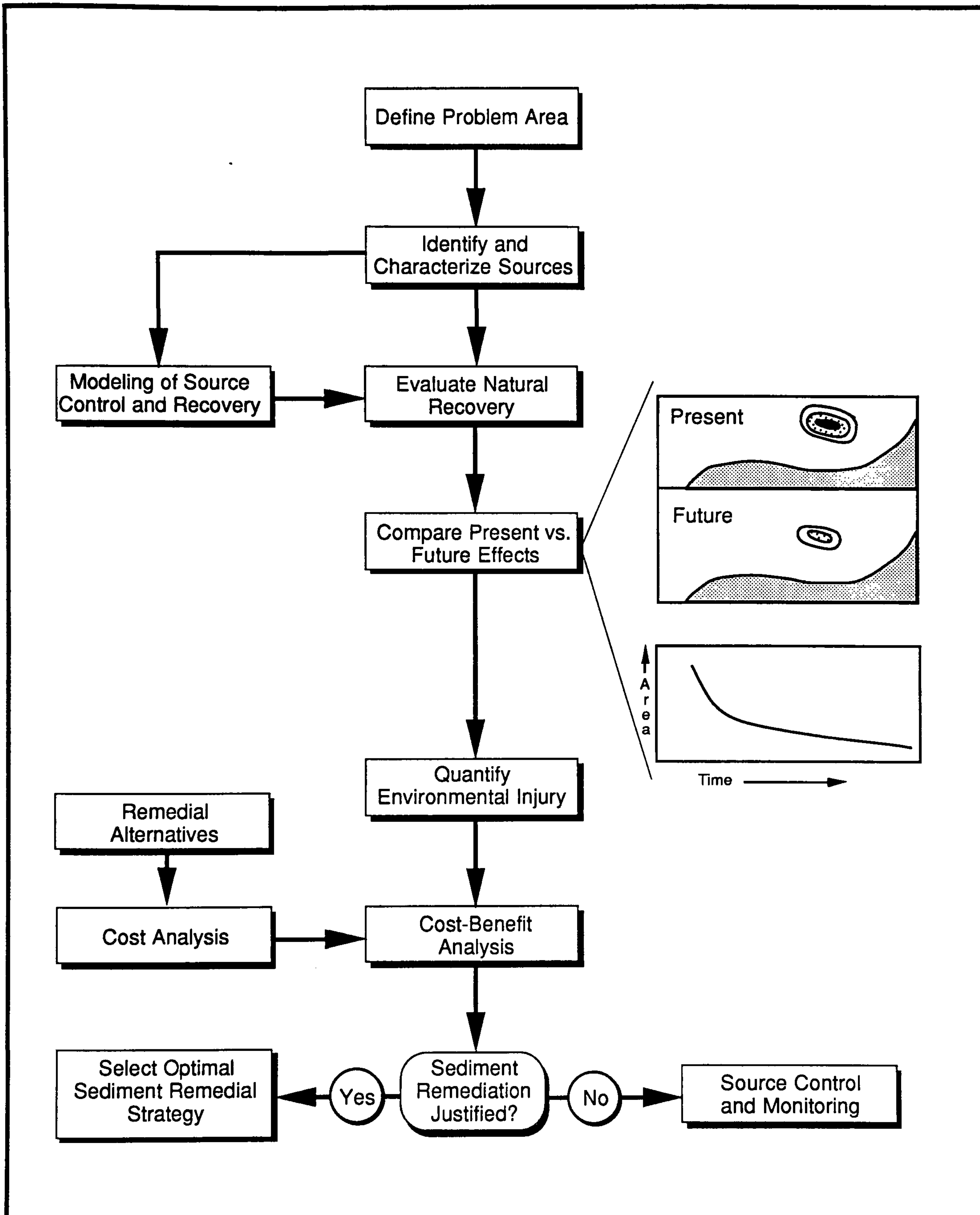

Figure B-1. Evaluation of the need for sediment cleanup investigation (U.S. COE 1984) and were later expanded and refined (Tetra Tech 1987). Techniques were also developed to organize information (by response option, technology type, and process option), to screen technologies based on site and contamination characteristics, and to evaluate candidate alternatives (Tetra Tech 1987; Tetra Tech 1989). The U.S. Army Corps of Engineers has developed general guidance on selection strategies for dredged material disposal options (U.S. COE 1985). Although these strategies have not yet been formally applied to any of the urban bay action programs in Puget Sound, the techniques have broad application to the remediation of contaminated sediments.

ROLE OF ENVIRONMENTAL MODELING

Evaluation and implementation of criteria for sediment quality, remediation, and evaluation of remedial actions may be facilitated by using database systems such as SEDQUAL (Nielsen 1989) or models like SEDCAM (Jacobs et al. 1988). SEDQUAL is a database system for storing, manipulating, and analyzing environmental data such as chemical concentrations in sediments, toxicity bioassay results, and biological effects on indigenous populations. Models can provide key links between potential causative agents and effects such as:

- **Source mass emission rate vs. extent and magnitude of sediment contamination**—A model of this relationship would enable evaluation of the environmental implications of source control scenarios [e.g., DECAL (Farley 1987)].

- **Contaminant levels in surficial sediments following source control or natural recovery**—This model would be important in evaluating optimal combinations of source control and sediment remedial actions (e.g., SEDCAM).

- **Relationship between sediment contamination and biological effects**—These empirical or theoretical models are important for predicting the occurrence of problem sediments, defining cleanup levels, and determining management options [e.g., apparent effects threshold (AET), equilibrium partitioning].

- **Relationship between nonpoint source control measures and toxics discharges**—These models would be used to evaluate the relative importance of various nonpoint sources and alternative control strategies for limiting nonpoint sources of pollutants (e.g., various models in U.S. Environmental Protection Agency National Urban Runoff Program studies).

- **Localized fate of pollutants associated with water quality or biological effects**—Such models can be applied to specific embayments to evaluate localized transport and water quality conditions [e.g., Budd Inlet Model (URS 1986)].

These models and others are candidate tools for assessing the two key links (pollutant source to environmental contamination, and environmental contamination to biological effects) that are required for making water quality management decisions in Puget Sound. Sediment quality values developed using SEDQUAL (e.g., AET) may be used to define the boundaries of problem areas designated for remediation. SEDQUAL may also be useful for evaluating costs of alternative remedial actions following development of a cost analysis module for SEDQUAL (scheduled for funding by the Washington Department of Ecology). SEDCAM may then be used to modify priorities for remediation based on evaluation of the effects of alternative remedial actions and the need for remediation given predicted rates of natural recovery.

APPENDIX C

Design of Sampling and Analysis Plans to Support Urban Bay Action Programs

DESIGN OF SAMPLING AND ANALYSIS PLANS TO SUPPORT URBAN BAY ACTION PROGRAMS

Collection of data to support an urban bay action program may involve sampling and analysis of sediments, sediment dwelling organisms, and contaminant sources. Data may be collected as part of reconnaissance surveys to identify contaminant sources or toxic problem areas, detailed investigations to characterize sources or environmental conditions, or monitoring to evaluate source controls and sediment remedial action. The term *investigation* will be used in the text below to denote sampling and analysis for any of the purposes just described. Sampling and analysis may be conducted by the lead state agency as part of ongoing regulatory programs, by individual wastewater dischargers and parties responsible for contaminated sites, or by an U.S. Environmental Protection Agency (EPA) regional office or other environmental management agency (e.g., state resource agencies, National Oceanic and Atmospheric Administration). Design of cost-effective sampling and analysis plans, including specification of quality assurance/quality control (QA/QC) measures, is a prerequisite to the collection of high quality data for characterization of toxic sediment problem areas or contaminant sources. Guidance on design of sampling and analysis plans is provided below.

The first step in developing a sampling and analysis plan is to define the technical objectives and their relationship to management goals and data needs. Because the cost of a program is related to sample replication and level of analysis (e.g., screening vs. full analysis), definition of precise data needs and data quality objectives helps to achieve cost-effective designs. Relevant data should be reviewed to define data gaps so that redundant information is not collected.

The following should be specified in a sampling and analysis plan:

- Technical objectives
- Variables to be measured
- Locations of sampling stations
- Timing and frequency of sampling
- Sampling and analysis methods
- Data to be recorded by laboratories
- Data analysis approach and statistical design
- Data management system and procedures.

A QA/QC plan should be developed for each sampling and analysis design. Available information that can be used directly or adapted for sampling and analysis protocols and QA/QC plans includes the EPA toxicity-based approach to water quality controls [U.S. EPA 1985c (especially relevant to assessment of contaminant sources)], Puget Sound protocols (PSEP 1986), documents of the federal Clean Water Act 301(h) program (Tetra Tech 1986b), and the urban bay action programs (e.g., storm drain assessment approaches developed for EPA Region 10; Tetra Tech 1988b).

CHARACTERIZATION OF CONTAMINANT SOURCES

Evaluation of contaminant sources involves defining kinds and quantities of contaminants released to the environment. Municipal sewage treatment plant discharges, direct industrial discharges, industrial nonpoint sources, and other nonpoint sources that eventually discharge to waterways via well-defined channels or pipes may be included in a point source investigation. The term *effluent* refers to the discharge from any point source, including storm drains.

Investigations of point sources may include collection of data on effluent chemical concentrations and effluent toxicity. These data can be used for the following objectives:

- Estimate mass loading of contaminants
- Determine effectiveness of source control
- Determine compliance with discharge permit specifications.

Elements of a point source investigation may include one or more of the following:

- Influent chemistry and flow (where applicable)
- Effluent chemistry and flow (including storm drain discharges)
- Freshwater effluent bioassays
    - Acute (U.S. EPA 1985a)
        a. Juvenile salmonid mortality
        b. *Daphnia* spp. mortality
        c. Fathead minnow (*Pimephales promelas*) mortality
    - Chronic (U.S. EPA 1985b)
        a. *Ceriodaphnia dubia*
        b. *Selenastrum capricornutum*
        c. Fathead minnow
- Saltwater effluent bioassays
    - Acute (U.S. EPA 1985a)
        a. Microtox®
        b. Mysid (e.g., *Mysidopsis bahia*) mortality
        c. Bivalve (e.g., *Mytilus edulis*, *Crassostrea gigas*) larvae abnormality
        d. Echinoderm (e.g., *Dendraster excentricus*) sperm abnormality
    - Chronic (U.S. EPA 1988c)
        a. Mysid life cycle
- Additional National Pollutant Discharge Elimination System (NPDES) requirements and inspections (U.S. EPA 1987b,c).

Effluent quality measurements combined with toxicity tests provide the basis for evaluation of contaminant mass loading, source controls, and potential toxicity (U.S. EPA 1985c). Measurements of influent quality and flow (where applicable) will provide additional information for evaluation of treatment efficiency.

Strategies for tiered testing of point sources are discussed by U.S. EPA (1985c). Application of screening approaches is recommended in reconnaissance surveys and in the initial phases of designing a long-term monitoring program to determine the appropriate approach (i.e., balance of chemical monitoring and kinds of biological tests). If screening of storm drains is needed to determine priorities for source control, chemical measurements on sediment samples collected from within outfall pipes or drains (above tidal influence) are provisionally recommended. In Puget Sound, the value of this technique has been assessed by EPA and the Washington Department of Ecology (Ecology) as part of the Elliott Bay Action Program (Tetra Tech 1988b). Further validation of this technique is warranted. For example, the degree to which grain size sorting influences the results, and the correlation between concentration of contaminants in sediments and those in the stormwater discharge has not been well studied.

In the Puget Sound region, EPA and Ecology are designing monitoring programs for point sources (including some storm drains and combined sewer overflows) to ensure compliance of NPDES dischargers with permit conditions. The NPDES process now includes restructuring of permits to incorporate specific limits on toxic substances and increased monitoring, especially biomonitoring of effluents. Guidance on sampling and analysis of contaminant sources presented in this section is generally consistent with planned elements of the NPDES program. However, it should be recognized that the elements of NPDES monitoring, especially the specific biomonitoring tests, are in a process of development.

Because the characteristics of different discharges can vary substantially, a single sampling scheme will not be applicable to all discharges. It is likely that sampling and analysis programs will include a range of techniques. One major difference among discharges is whether the effluent is fresh or saline water. As indicated in the list of chemical and biological tests above, the salinity of the effluent affects the choice of biological tests. Aside from potential differences in effluent composition, the major distinction between storm drains and other kinds of discharges is the high variability of both effluent flow and chemical composition of stormwater discharges compared with other point sources. Differences in recommended sampling and analysis designs for various kinds of discharges are discussed by U.S. EPA (1985c), Bergman et al. (1986), and PTI (1988).

Groundwater investigations may be conducted at facilities where groundwater infiltration transports contaminants offsite. Characterization of contaminant transport by groundwater is a complex task, and requires a great deal of preliminary characterization of site geology and the flow regime to adequately describe the physical factors controlling contaminant transport. Superimposed on the physical flow regime are additional processes that may influence transport of a chemical such as sorption, precipitation, or in the case of volatile chemicals, outgassing to the soil atmosphere. Monitoring provides a means of documenting changes in contaminant loading to the waterway. Guidance on sampling and analysis designs for groundwater investigations is provided in the *RCRA Groundwater Monitoring Technical Enforcement Guidance Document* (U.S. EPA 1986).

CHARACTERIZATION OF TOXIC SEDIMENT CONTAMINATION AND BIOLOGICAL EFFECTS

At least five types of environmental indicators can be used to characterize sediment contamination and biological effects:

- **Sediment Chemistry**

    - Contaminant concentrations for toxic chemicals and ancillary variables (e.g., sediment grain size, sulfides, and total organic carbon)

- **Bioaccumulation**

    - Pesticide, polychlorinated biphenyl, mercury or other chemical concentrations in muscle tissue of bottomfish or commonly harvested species

- **Sediment Bioassays**

    - Amphipod (e.g., *Rhepoxynius abronius*) mortality
    - Oyster larvae (e.g., *Crassostrea gigas*) abnormality
    - Bacterial luminescence (Microtox®)
    - Polychaete (*Neanthes arenaceodentata*) growth/mortality

- **Benthic Macroinvertebrate Abundances**

    - Major taxa abundances (e.g., polychaetes, crustaceans, pelecypods, gastropods)
    - Species abundances

- **Fish Pathology**

    - Lesion (e.g., tumor) prevalence in livers of bottomfish.

Although many other variables may be evaluated throughout the decisionmaking process, the indicators listed above are recommended for problem area identification and priority ranking. The rationale for using the five kinds of environmental indicators is provided by Tetra Tech (1985) and PTI and Tetra Tech (1988a,b). As described in the next section, various combinations of selected indicators can be used for different purposes (e.g., reconnaissance survey vs. detailed investigation) or in different phases of an urban bay action program.

OPTIONAL SAMPLING AND ANALYSIS STRATEGIES TO ENHANCE COST EFFECTIVENESS

Tiered strategies of sampling and analysis should be evaluated to increase the cost effectiveness of investigations of sources and sediments. For example, tiered strategies should be evaluated at the following three levels in the study design process for environmental sampling:

- **Selection of sampling station locations and density**—The first tier of an investigation may use widely spaced sampling locations over the whole project area, whereas the second tier may use dense sampling within smaller selected areas identified as high priority during the first tier.

- **Selection of variables**—The first tier may involve analysis of an inexpensive screening variable [e.g., total polycyclic aromatic hydrocarbons (PAH) screen] using all samples, whereas the second tier may involve more expensive analyses to develop more specific information (e.g., individual PAH compounds) on selected samples identified as the highest priority during the first tier.

- **Selection of number of replicate samples**—This strategy involves sequential laboratory analysis of replicate samples and corresponding data analysis to provide feedback on information gained with each successive analysis. The potential benefit is realized when the amount of information is judged adequate before all sample replicates have been analyzed.

Cost effectiveness of a design should be analyzed to ensure that the final design meets data quality objectives and budget constraints. Some statistical approaches to support cost-benefit analyses of sampling designs are available from the Clean Water Act 301(h) program (Tetra Tech 1986a).

An example of one approach to streamlining the procedures for characterizing problem areas is presented in Figure C-1. This approach relies primarily upon the areawide indicators (fish histopathology and bioaccumulation) in an initial (Phase I) assessment of the study area. In special cases, the site-specific variables of sediment contamination, sediment toxicity, and benthic macroinvertebrate effects may be applied at a very few high priority stations (e.g., in depositional areas, near major pollutant sources) to document the expected worst-case conditions in each study area. The objective would be to define those general areas with the greatest environmental hazard by using the relatively inexpensive areawide indicators (especially compositing of fish tissue) in conjunction with minimal use of the relatively expensive site-specific variables as part of Phase I studies. As previous investigations have shown, the areawide indicators correlate well with the general locations of problem sediments (Malins et al. 1984; Tetra Tech 1985; PTI and Tetra Tech 1988a,b).

The results of these Phase I studies can be processed relatively quickly and can be used to focus the more detailed assessments using more intensive application of the site-specific variables. The Phase II studies could then be designed based on the Phase I results, in conjunction with historical information on the area. The relatively expensive Phase II variables (i.e., chemistry, bioassays, and benthic macroinvertebrate variables) should be focused only on the high priority areas, potentially resulting in a substantial cost savings. In the final step, the areawide variables, site-specific variables, and historical data could be integrated to prioritize problem areas.

The Phase II site-specific variables could be applied using a tiered approach. The approach involves an increasing level of analysis that provides the lead agency with increased degrees of confidence in the identification of problem areas. The level of analysis can be adjusted to match specific agency objectives and cost constraints. At each station, an adequate amount of sediment should be collected to allow potential evaluation of all Phase II indicators. The screening level analyses should proceed immediately after field sampling. Subsequent analyses can be conducted later (if necessary) on previously frozen subsamples for chemical analyses and preserved samples for benthic macroinvertebrate analyses.

In the first tier, samples should be analyzed for screening chemical variables (e.g., total PAH) and inexpensive bioassays (e.g., Microtox®, amphipod mortality). If any of the screening chemical or biological variables indicate a problem, then full chemical analyses may be recommended. In Puget Sound, the results of these detailed chemical analyses could be compared with benthic apparent effects threshold (AET) to determine whether effects on indigenous biota are likely. If one or more AET are exceeded, then benthic macroinvertebrate analyses at the major taxonomic level may be recommended to verify the predicted effects. If major taxa are found to be depressed, then species-level benthic analyses may be desired in special cases to provide additional information on the adverse effects to indigenous biota. (e.g., Are pollution-sensitive species depressed and pollution-tolerant species enhanced, or are important prey species of fishes depressed?) The strength of the tiered Phase II approach is its flexibility to allow a variable combination of analyses to be conducted from a single field sampling effort.

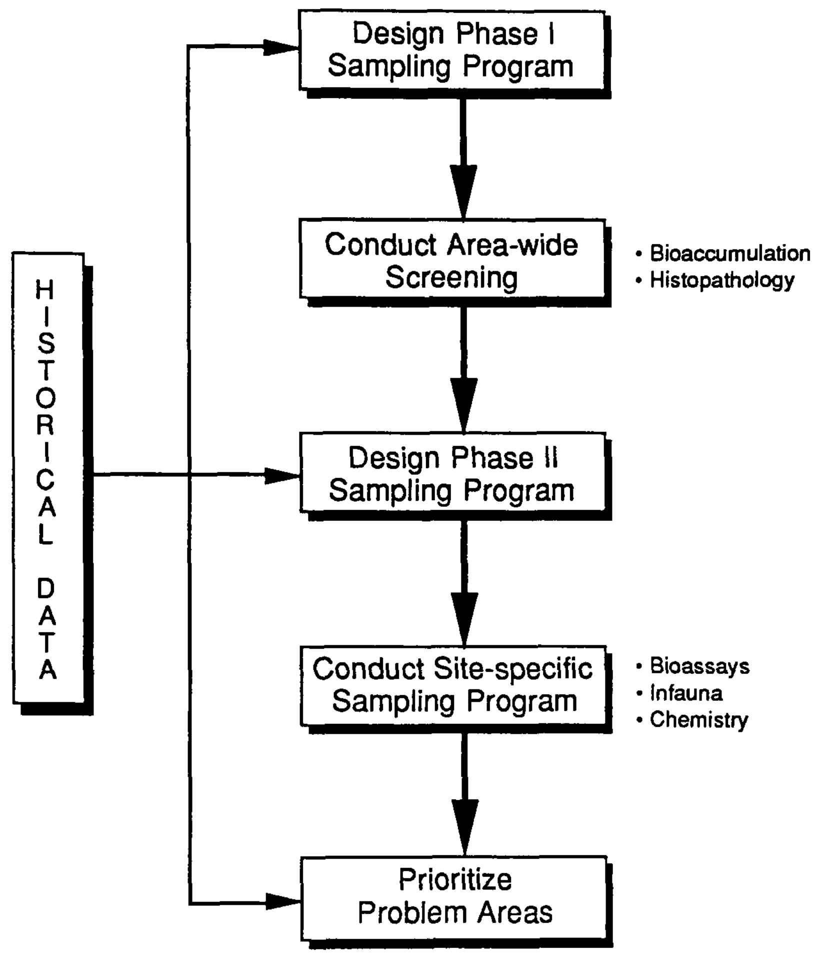

Figure C-1. Phased approach to characterizing problem areas