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Combined Sewer Overflows

Guidance For Long-Term Control Plan

EPA/832-B-95-002
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Guidance for Long-Term Control Plan

U.S. Environmental Protection Agency
Office of Wastewater Management
Washington, DC 20460

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

AUG 31 1995

OFFICE OF
WATER

MEMORANDUM

SUBJECT: Guidance for Long Term Control Plan

FROM: Michael B. Cook,
Office of Wastewater Management (4201)

TO: Interested Parties

I am pleased to provide you with the Environmental Protection Agency's (EPA's) guidance document on the development and implementation of a long-term control plan for combined sewer overflows (CSOs). This document is one of several being prepared to foster implementation of EPA's CSO Control Policy. The CSO Control Policy, issued on April 11, 1994, establishes a national approach under the National Pollutant Discharge Elimination System (NPDES) permit program for controlling discharges into the nation's waters from combined sewer systems.

To facilitate implementation of the CSO Control Policy, EPA is preparing guidance documents that can be used by NPDES permitting authorities, affected municipalities, and their consulting engineers in planning and implementing CSO controls that will ultimately comply with the requirements of the Clean Water Act.

This document has been prepared to provide guidance to municipalities on how to develop a comprehensive long-term control plan that recognizes the site specific nature of CSOs and their impacts on receiving water bodies. The final plan should include water quality based control measures that are technically feasible, affordable, and consistent with the CSO Control Policy.

This guidance has been reviewed extensively within the Agency as well as by municipal groups, environmental groups, and other CSO stakeholders. I am grateful to all who participated in its preparation and review, and believe that it will further the implementation of the CSO Control Policy.

If you have any questions regarding the manual or its distribution, please call Joseph Mauro in the Office of Wastewater Management, at (202) 260-1140.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Combined sewer systems (CSSs) are wastewater collection systems designed to carry sanitary sewage (consisting of domestic, commercial, and industrial wastewater) and storm water (surface drainage from rainfall or snowmelt) in a single pipe to a treatment facility. CSSs serve about 43 million people in approximately 1,100 communities nationwide. Most of these communities are located in the Northeast and Great Lakes regions. During dry weather, CSSs convey domestic, commercial, and industrial wastewater. In periods of rainfall or snowmelt, total wastewater flows can exceed the capacity of the CSS and/or treatment facilities. When this occurs, the CSS is designed to overflow directly to surface water bodies, such as lakes, rivers, estuaries, or coastal waters. These overflows—called combined sewer overflows (CSOs)—can be a major source of water pollution in communities served by CSSs.

Because CSOs contain untreated domestic, commercial, and industrial wastes, as well as surface runoff, many different types of contaminants can be present. Contaminants may include pathogens, oxygen-demanding pollutants, suspended solids, nutrients, toxics, and floatable matter. Because of these contaminants and the volume of the flows, CSOs can cause a variety of adverse impacts on the physical characteristics of surface water, impair the viability of aquatic habitats, and pose a potential threat to drinking water supplies. CSOs have been shown to be a major contributor to use impairment and aesthetic degradation of many receiving waters and have contributed to shellfish harvesting restrictions, beach closures, and even occasional fish kills.

1.2 HISTORY OF THE CSO CONTROL POLICY

Historically, the control of CSOs has proven to be extremely complex. This complexity stems partly from the difficulty in quantifying CSO impacts on receiving water quality and the site-specific variability in the volume, frequency, and characteristics of CSOs. In addition, the financial considerations for communities with CSOs can be significant. The U.S. Environmental

Protection Agency (EPA) estimates the CSO abatement costs for the 1,100 communities served by CSSs to be approximately $41.2 billion.

To address these challenges, EPA's Office of Water issued a National Combined Sewer Overflow Control Strategy on August 10, 1989 (54 *Federal Register* 37370). This Strategy reaffirmed that CSOs are point source discharges subject to National Pollutant Discharge Elimination System (NPDES) permit requirements and to Clean Water Act (CWA) requirements. The CSO Strategy recommended that all CSOs be identified and categorized according to their status of compliance with these requirements. It also set forth three objectives:

- Ensure that if CSOs occur, they are only as a result of wet weather
- Bring all wet weather CSO discharge points into compliance with the technology-based and water quality-based requirements of the CWA
- Minimize the impacts of CSOs on water quality, aquatic biota, and human health.

In addition, the CSO Strategy charged all States with developing state-wide permitting strategies designed to reduce, eliminate, or control CSOs.

Although the CSO Strategy was successful in focusing increased attention on CSOs, it fell short in resolving many fundamental issues. In mid-1991, EPA initiated a process to accelerate implementation of the Strategy. The process included negotiations with representatives of the regulated community, State regulatory agencies, and environmental groups. These negotiations were conducted through the Office of Water Management Advisory Group. The initiative resulted in the development of a CSO Control Policy, which was published in the *Federal Register* on April 19, 1994 (59 *Federal Register* 18688). The intent of the CSO Control Policy is to:

- Provide guidance to permittees with CSOs, NPDES permitting and enforcement authorities, and State water quality standards (WQS) authorities

- Ensure coordination among the appropriate parties in planning, selecting, designing, and implementing CSO management practices and controls to meet the requirements of the CWA

- Ensure public involvement during the decision-making process.

The CSO Control Policy contains provisions for developing appropriate, site-specific NPDES permit requirements for all CSSs that overflow due to wet weather events. It also announces an enforcement initiative that requires the immediate elimination of overflows that occur during dry weather and ensures that the remaining CWA requirements are complied with as soon as possible.

1.3 KEY ELEMENTS OF THE CSO CONTROL POLICY

The CSO Control Policy contains four key principles to ensure that CSO controls are cost-effective and meet the requirements of the CWA:

- Provide clear levels of control that would be presumed to meet appropriate health and environmental objectives

- Provide sufficient flexibility to municipalities, especially those that are financially disadvantaged, to consider the site-specific nature of CSOs and to determine the most cost-effective means of reducing pollutants and meeting CWA objectives and requirements

- Allow a phased approach for implementation of CSO controls considering a community's financial capability

- Review and revise, as appropriate, WQS and their implementation procedures when developing long-term CSO control plans to reflect the site-specific wet weather impacts of CSOs.

In addition, the CSO Control Policy clearly defines expectations for permittees, State WQS authorities, and NPDES permitting and enforcement authorities. These expectations include the following:

- Permittees should immediately implement the nine minimum controls (NMC), which are technology-based actions or measures designed to reduce CSOs and their effects on receiving water quality, as soon as practicable but no later than January 1, 1997.
- Permittees should give priority to environmentally sensitive areas.
- Permittees should develop long-term control plans (LTCPs) for controlling CSOs. A permittee may use one of two approaches: 1) demonstrate that its plan is adequate to meet the water quality-based requirements of the CWA ("demonstration approach"), or 2) implement a minimum level of treatment (e.g., primary clarification of at least 85 percent of the collected combined sewage flows) that is presumed to meet the water quality-based requirements of the CWA, unless data indicate otherwise ("presumption approach").
- WQS authorities should review and revise, as appropriate, State WQS during the CSO long-term planning process.
- NPDES permitting authorities should consider the financial capability of permittees when reviewing CSO control plans.

Exhibit 1-1 illustrates the roles and responsibilities of permittees, NPDES permitting and enforcement authorities, and State WQS authorities.

In addition to these key elements and expectations, the CSO Control Policy also addresses important issues such as ongoing or completed CSO control projects, public participation, small communities, and watershed planning.

Exhibit 1-1. Roles and Responsibilities

Permittee	NPDES Permitting Authority	NPDES Enforcement Authority	State WQS Authorities
• Evaluate and implement NMC • Submit documentation of NMC implementation by January 1, 1997 • Develop LTCP and submit for review to NPDES permitting authority • Support the review of WQS in CSO-impacted receiving water bodies • Comply with permit conditions based on narrative WQS • Implement selected CSO controls from LTCP • Perform post-construction compliance monitoring • Reassess overflows to sensitive areas • Coordinate all activities with NPDES permitting authority, State WQS authority, and State watershed personnel	• Reassess/revise CSO permitting strategy • Incorporate into Phase I permits CSO-related conditions (e.g., NMC implementation and documentation and LTCP development) • Review documentation of NMC implementation • Coordinate review of LTCP components throughout the LTCP development process and accept/approve permittee's LTCP • Coordinate the review and revision of WQS as appropriate • Incorporate into Phase II permits CSO-related conditions (e.g., continued NMC implementation and LTCP implementation) • Incorporate implementation schedule into an appropriate enforceable mechanism • Review implementation activity reports (e.g., compliance schedule progress reports)	• Ensure that CSO requirements and schedules for compliance are incorporated into appropriate enforceable mechanisms • Monitor adherence to January 1, 1997, deadline for NMC implementation and documentation • Take appropriate enforcement action against dry weather overflows • Monitor compliance with Phase I, Phase II, and post-Phase II permits and take enforcement action as appropriate	• Review WQS in CSO-impacted receiving water bodies • Coordinate review with LTCP development • Revise WQS as appropriate: Development of site-specific criteria Modification of designated use to - Create partial use reflecting specific situations - Define use more explicitly Temporary variance from WQS

1.4 GUIDANCE TO SUPPORT IMPLEMENTATION OF THE CSO CONTROL POLICY

To help permittees and NPDES permitting and WQS authorities implement the provisions of the CSO Control Policy, EPA is developing the following guidance documents:

- *Combined Sewer Overflows—Guidance for Long-Term Control Plan* (EPA, 1995a)
- *Combined Sewer Overflows—Guidance for Nine Minimum Controls* (EPA, 1995b)
- *Combined Sewer Overflows—Guidance for Screening and Ranking* (EPA, 1995c)
- *Combined Sewer Overflows—Guidance for Monitoring and Modeling* (EPA, 1995d)
- *Combined Sewer Overflows—Guidance for Financial Capability Assessment* (EPA, 1995e)
- *Combined Sewer Overflows—Guidance for Funding Options* (EPA, 1995f)
- *Combined Sewer Overflows—Guidance for Permit Writers* (EPA, 1995g)
- *Combined Sewer Overflows—Questions and Answers on Water Quality Standards and the CSO Program* (EPA, 1995h).

1.5 GOAL OF THIS GUIDANCE DOCUMENT

The main goal of this document is to provide technical support to assist municipalities in the development of technically feasible, affordable, and comprehensive LTCPs consistent with the objectives of the CSO Control Policy.

1.5.1 Target Audience

The primary audience of this document is municipal officials who are developing LTCPs. This document might be of particular benefit to small and medium-sized municipalities, which might not have access to the resources and expertise available to larger municipalities. A secondary audience is EPA and State officials, as well as NPDES permit writers, who can refer to this document when reviewing and evaluating LTCPs. Although the document presents the engineering concepts required for the preparation of certain aspects of the LTCPs, it has been written for the non-engineer.

Certain aspects of EPA's CSO Control Policy are explained in more detail in other guidance documents. This LTCP guidance document summarizes information from those documents, where appropriate. It emphasizes the role of public participation and agency interaction, the use of monitoring and modeling data to develop and evaluate CSO control strategies, and the role of financial capability in the selection and implementation of CSO controls.

1.5.2 Document Organization

Chapter 2 describes the characterization of the CSS, including the analysis of existing data and system monitoring and modeling, establishment of the existing baseline conditions, and integration of the NMC with the LTCP. Chapter 2 also includes a case study that documents how a CSO community characterized its system. Chapter 3 presents methodologies for the development and evaluation of CSO control alternatives. It discusses the role of public participation, the "presumption" and "demonstration" approaches to developing alternatives, identification of CSO control goals and alternatives to achieve those goals, and other aspects of alternatives development, such as preliminary sizing, cost/performance considerations, siting issues, and operating strategies. The chapter concludes with two case studies describing the development and evaluation of CSO control alternatives. Chapter 4 discusses the final step of the LTCP: the selection and implementation of the long-term controls. This step includes development of an operational plan, identification of financing options and funding sources, development of the implementation schedule and post-construction compliance monitoring program, and re-evaluation and update of the final plan.

1.6 LONG-TERM PLANNING APPROACH SUMMARY

The overall planning approach consists of three major steps: system characterization, development and evaluation of alternatives, and selection and implementation of the controls. Each of these steps is discussed separately and in detail in subsequent chapters. The remainder of this section provides general guidance on developing the program structure, which municipalities usually need to proceed with the various aspects of the LTCP. Section 1.6 also introduces several key topics that EPA feels are critical in developing an LTCP consistent with the CSO Control Policy.

The CSO Control Policy lists nine elements that should be addressed as appropriate in either one, or all three steps of the overall planning approach. Public participation should be addressed in all three steps, for example, while an implementation schedule might be addressed in two of the steps.

As listed in the Policy, the nine elements of the LTCP are:

1. **Characterization, monitoring, and modeling** activities as the basis for selection and design of effective CSO controls
2. **A public participation** process that actively involves the affected public in the decision-making to select long-term CSO controls
3. Consideration of **sensitive areas** as the highest priority for controlling overflows
4. **Evaluation of alternatives** that will enable the permittee, in consultation with the NPDES permitting authority, WQS authority, and the public, to select CSO controls that will meet CWA requirements
5. **Cost/performance considerations** to demonstrate the relationships among a comprehensive set of reasonable control alternatives
6. **Operational plan** revisions to include agreed-upon long-term CSO controls
7. **Maximization of treatment at the existing POTW treatment plant** for wet weather flows
8. **An implementation schedule** for CSO controls
9. **A post-construction compliance monitoring program** adequate to verify compliance with water quality-based CWA requirements and ascertain the effectiveness of CSO controls.

Exhibit 1-2 presents the recommended planning approach described in this document, along with cross-references to the appropriate chapters of this document and sections of the CSO Control Policy. The planning approach is generally intended to be followed sequentially;

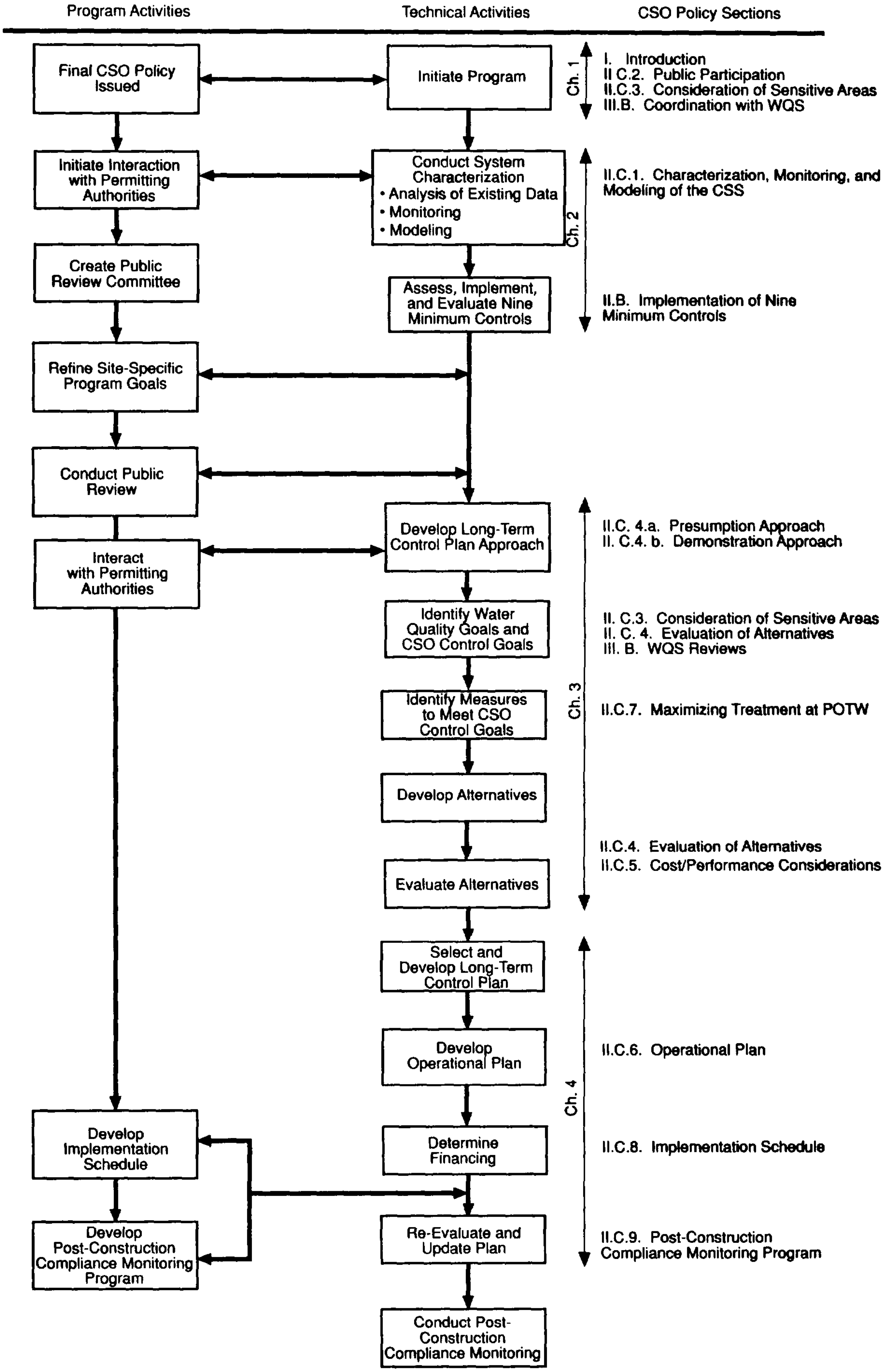


Exhibit 1-2. Long-Term CSO Control Planning Approach

however, it can be altered depending on specific circumstances (e.g., municipalities with limited combined systems or municipalities that have already conducted efforts to control CSOs may select a different approach). Exhibit 1-2 distinguishes program activities from technical activities. Program activities are tasks that will provide overall program structure, coordination, and management; technical activities are the specific engineering tasks necessary to develop the LTCP. Although the planning approach described in this document is intended to address CSOs, it might also include information needed to address other pollution sources, such as storm water and nonpoint sources.

The CSO Control Policy encourages municipalities to develop, and permit writers to evaluate, LTCPs on a watershed management basis (see Section 1.6.5). Municipalities should try to evaluate all sources of pollution (e.g., point sources, CSOs, storm water, CSOs) during system characterization (Chapter 2) and, wherever possible, develop control strategies on a watershed basis in coordination with the NPDES permitting authority.

Exhibit 1-3 provides an example of a typical CSO Control Policy implementation timeline. As noted in the CSO Control Policy, municipalities should develop and submit their LTCPs "*...as soon as practicable, but generally within two years after the date of the NPDES permit provision, Section 308 information request, or enforcement action requiring the permittee to develop the plan*" (II.C). As illustrated in Exhibit 1-3, however, "*NPDES authorities may establish a longer timetable for completion of the long-term CSO control plan on a case-by-case basis to account for site-specific factors which may influence the complexity of the planning process*" (II.C).

1.6.1 Initial Activities

An important first step is development of an administrative structure for CSO control planning. This involves organizing a CSO program team; establishing communication, coordination, and control procedures for team members and other participants; identifying tasks and associated resource needs; and scheduling tasks.

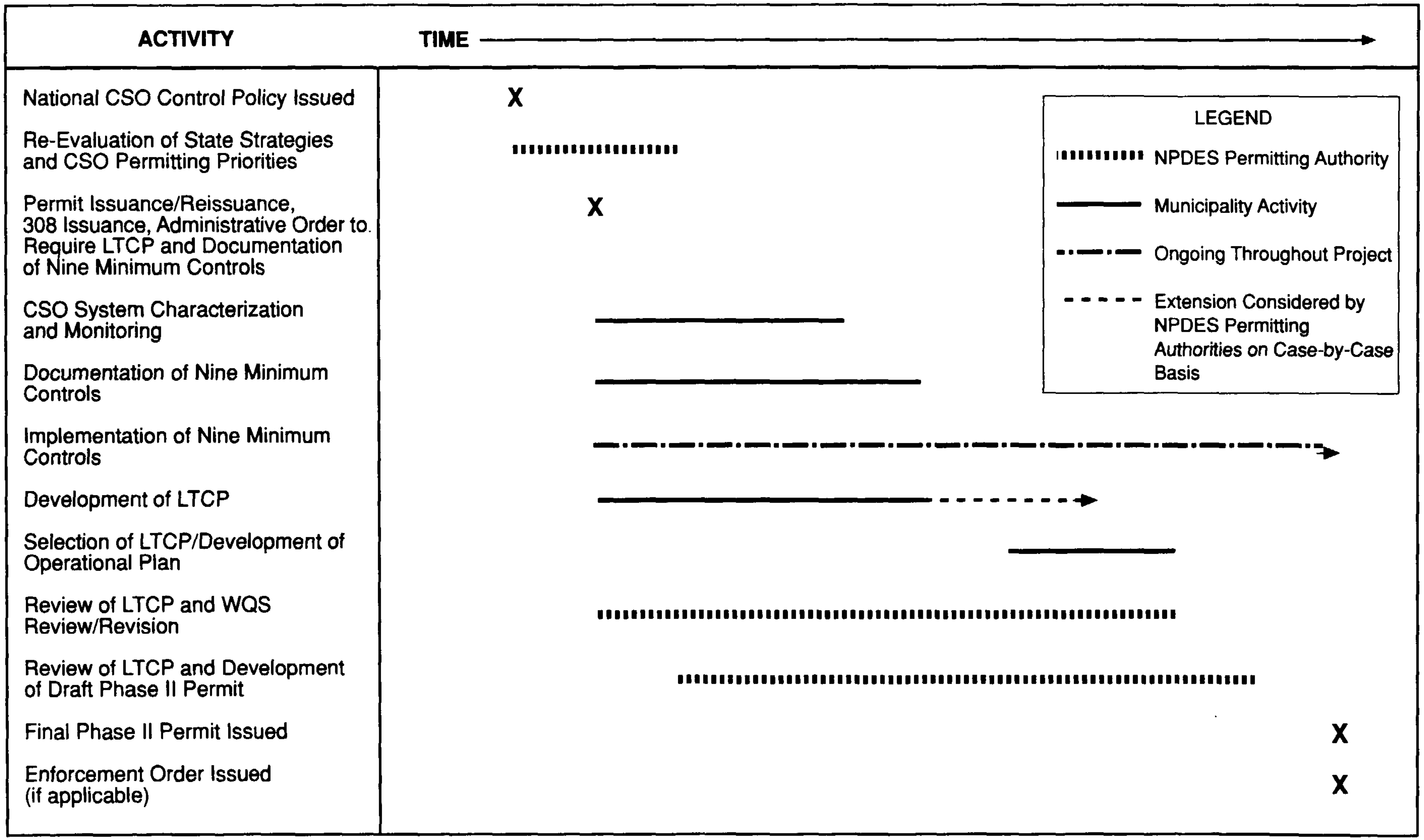


Exhibit 1-3. Example of a CSO Control Policy Implementation Timeline

The program team should include all entities who have a stake in the program outcome, and it should be sufficiently multidisciplinary to address the myriad of engineering, economic, environmental, and institutional issues that will be raised during the development of the LTCP. The team generally will have to prepare a plan for funding the program and will develop a program for public information, education, and involvement.

The team should contain municipal personnel such as public works, wastewater treatment plant operations, and engineering personnel, as well as parks, conservation, and other officials involved in such issues as utilities, land use and zoning, development review, and environmental issues. It should include Federal and State regulatory officials, local political officials, and the general public, including rate payers and environmental interests. Depending on the size and complexity of the program, private consulting resources might also be necessary.

The municipality also should establish management tasks such as estimating, forecasting, budgeting, and controlling costs; planning, estimating, and scheduling program activities; developing and evaluating quality control practices; and developing and controlling the program scope. Some municipalities already have project management and control procedures in place; in other cases, particularly where several agencies are involved, it is appropriate to develop management tasks specifically for the CSO control program.

1.6.2 Public Participation and Agency Interaction

Establishing early communication with both the public and regulatory agencies is an important first step in the long-term planning approach and crucial to the success of a CSO control program. The importance of public participation is stressed in the CSO Control Policy: "*In developing its long-term CSO control plan, the permittee will employ a public participation process that actively involves the affected public in the decision-making to select the long-term CSO controls*" (II.C.2). Given the potential for significant expenditures of public funds for CSO control, public support is key to CSO program success. By informing the public early in the planning process about the scope and goals of the program and continuing public involvement during development, evaluation, and selection of the control strategy, issues and potential conflicts can be identified and addressed more expeditiously, minimizing the potential for prolonged delay or additional cost.

Citizen Advisory Committees (CACs) can serve as liaisons among municipal officials, NPDES permitting agencies, and the general public. Public meetings and public hearings can provide an effective forum to present technical information and obtain input from interested individuals and organizations. It is worthwhile to gage public acceptance of potential CSO alternatives before completing the engineering evaluation of each alternative and to incorporate input from the public meetings into the selection of a recommended plan. Impacts on user fees and tax rates are also important to communicate as early as possible in the LTCP development. After the municipality has selected a recommended plan, public involvement will continue to be useful. Particular attention should be given to informing residents and businesses that would be affected by any construction associated with project implementation.

If Federal or State funding is involved, the municipality might be required to submit a work plan to the regulatory agency. The work plan should include an approach for public participation. Public participation requirements for Federal- or State-funded projects are given in 40 CFR Part 25.

The CSO Control Policy emphasizes that "*State WQS authorities, NPDES authorities, EPA regional offices and permittees should meet early and frequently throughout the long-term planning process*" (III.A). It also describes several issues involving regulatory agencies that could affect the development of the LTCP, including the review and appropriate revision of water quality standards (WQS) and agreement on the data, analyses, monitoring, and modeling necessary to support the development of the LTCP.

1.6.3 Coordination with State Water Quality Standards Authority

A primary objective of the LTCP is to develop and evaluate a range of CSO control alternatives sufficient to meet WQS, including attainment and protection of designated uses on CSO-impacted receiving waters. To ensure that the LTCP meets this objective, State WQS authorities should be involved early in the LTCP development process. This will give participants an opportunity to review the proposed nature and extent of data and information to be collected during LTCP development. Such data and information can be used in assessing the attainability of the designated uses (through a use attainability analysis) and possibly revisiting designated use classifications for the CSO-impacted waters (e.g., by defining uses more precisely).

The CSO Control Policy recognizes that the review and appropriate revision of WQS is an integral part of LTCP development, and describes the options available to States ". . . *to adapt their WQS, and implementation procedures to reflect site-specific conditions including those related to CSOs*" (III.B). Such options include:

- Adopting partial uses to reflect situations where a significant storm event precludes the use from occurring
- Adopting seasonal uses to reflect that certain uses do not occur during certain seasons (e.g., swimming does not occur in winter)
- Defining a use with greater specificity (e.g., warm-water fishery in place of aquatic life protection); or
- Granting a temporary variance to a specific discharger in cases where maintaining existing standards for other dischargers is preferable to downgrading WQS.

Whenever such changes are proposed, the State must ensure downstream uses are protected, and other uses not affected by the storm or season are protected. The State must also ensure that the quality of the water is improved or protected.

EPA encourages States with CSOs to work within their current regulatory framework, using existing flexibility to consider wet weather conditions in reviewing their WQS.

Early in the process, the municipality should identify data needs, monitoring protocols, and models for system characterization, as well as develop a compliance monitoring program. The water quality impacts of the existing CSOs can then be evaluated to establish the existing baseline condition against which the effectiveness of the selected CSO controls can be measured, and to predict whether or not WQS will be attained after LTCP implementation. If this information indicates that WQS are not likely to be attained after LTCP implementation, it can be used to identify additional CSO control alternatives necessary to attain WQS or to determine whether non-CSO sources of pollution are contributing to nonattainment. A TMDL could be used to evaluate more stringent controls on non-CSO dischargers for the receiving water and pollutant(s) of concern.

Municipalities and States should share and coordinate information with other municipalities within the same watershed. This information, along with storm water and other point and nonpoint source data, provides an opportunity for NPDES permitting authorities and permittees to implement a comprehensive watershed management approach, including TMDLs. This same information also provides an opportunity for municipalities to coordinate the development and implementation of their individual LTCPs with one another.

1.6.4 Integration of Current CSO Control Efforts

Some municipalities have already begun, and perhaps completed, CSO abatement activities. In these cases, "*...portions of* [the] *Policy may not apply, as determined on a case by case basis...*" (I.C). The CSO Control Policy outlines three such scenarios: (1) municipalities that have completed or substantially completed construction of CSO facilities, (2) municipalities that have developed or are implementing a CSO control program pursuant to an existing permit or enforcement order, and (3) municipalities that have constructed CSO facilities but have failed to meet applicable WQS. Municipalities that fall under these scenarios should coordinate with their NPDES permitting authorities to determine the scope of the required long-term planning activities.

In cases where significant work has been conducted, municipalities would present an overview of their programs to illustrate the impact of CSO improvements on a system-wide basis. Exhibit 1-4 presents an example of an assessment of existing and future CSO controls. In this example, system characterization was completed in 1989 and the system improvements

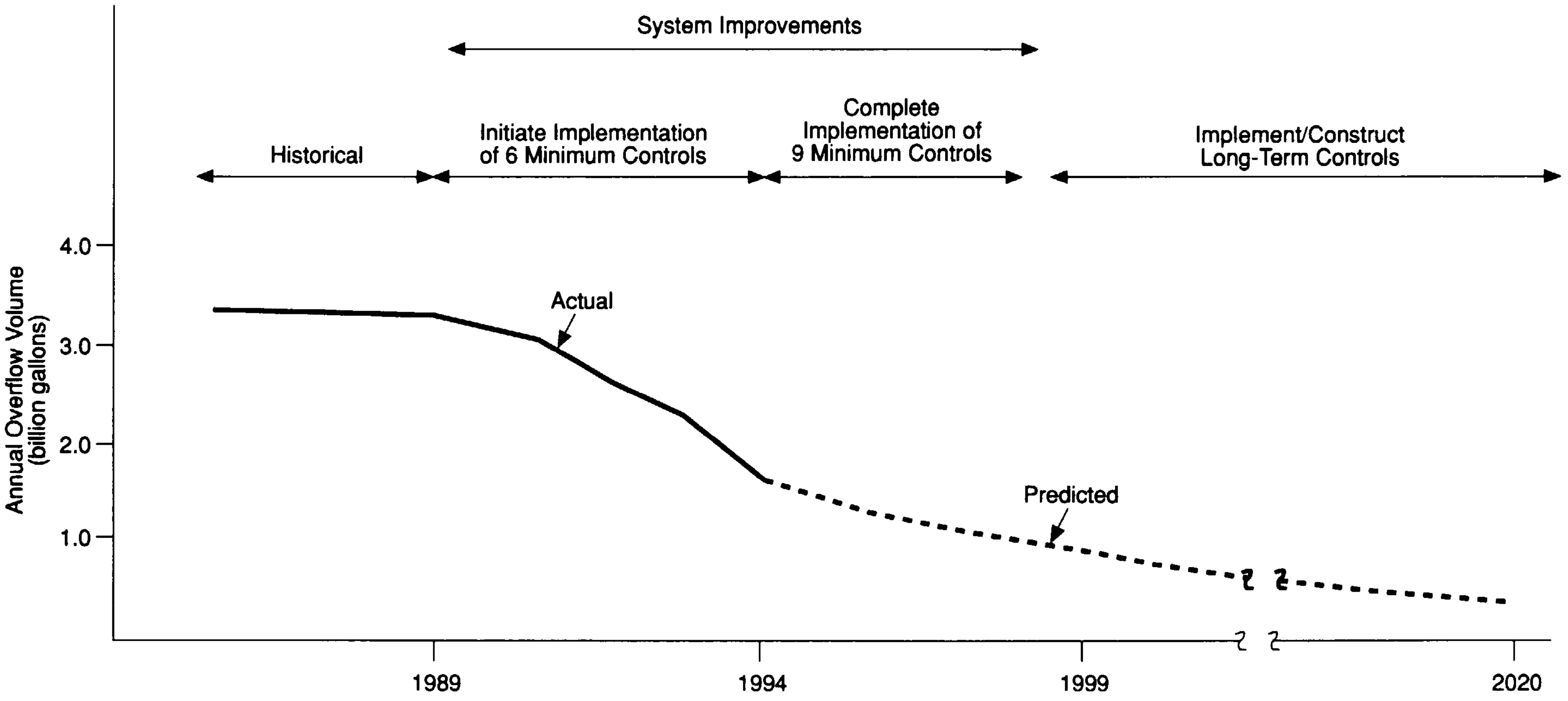


Exhibit 1-4. Impact of CSO Program Improvements on System-Wide CSOs

shown as taking place between 1989 and 1999 include both minimum controls and other actions, such as collection system and POTW improvements and upgrades, that will result in CSO control.

1.6.5 Watershed Approach to CSO Control Planning

The CSO Control Policy acknowledges the importance of watershed planning in the long-term control of CSOs by encouraging the permit writer "*...to evaluate water pollution control needs on a watershed management basis and coordinate CSO control efforts with other point and nonpoint source control activities*" (I.B). The watershed approach is also discussed in the section of the CSO Control Policy addressing the demonstration approach to CSO control (II.B.4.b; see also Chapter 3 of this document), which, in recommending that NPDES permitting authorities allow a demonstration of attainment of WQS, provides for consideration of natural background conditions and pollution sources other than CSOs, promoting the development of total maximum daily loads (TMDLs).

EPA's Office of Water is committed to supporting States that want to implement a comprehensive statewide watershed management approach. EPA has convened a Watershed Management Policy Committee, consisting of senior managers, to oversee the reorientation of all EPA water programs to support watershed approaches.

Of particular importance to CSO control planning and management is the *NPDES Watershed Strategy* (EPA, 1994b). This strategy outlines national objectives and implementation activities to integrate the NPDES program into the broader watershed protection approach. The Strategy also supports the development of statewide basin management as part of an overall watershed management approach. Statewide basin management is an overall framework for integrating and coordinating water resource management efforts basin-by-basin throughout an entire State. This will result in development and implementation of basin management plans that meet stated environmental goals.

The sources of watershed pollution and impairment, in addition to CSOs, are varied and include other point source discharges; discharges from storm drains; overland runoff; habitat destruction; land use activities, such as agriculture and construction; erosion; and septic systems and landfills. The benefits to implementing a watershed approach are significant and include:

- Consideration of all important sources of pollution or impairment
- Closer ties to receiving water benefits
- Greater flexibility
- Greater cost effectiveness (through coordination of monitoring programs, for example)
- Fostering of prevention as well as control
- Fairer allocation of resources and responsibilities.

The major advantage in using a watershed-based approach to develop an LTCP is that it allows the site-specific determination of the relative impacts of CSOs and non-CSO sources of pollution on water quality. For some receiving water reaches within a watershed, CSOs could well be less significant contributors to nonattainment than storm water or upstream sources. In such cases, a large expenditure on CSO control could result in negligible improvement in water quality.

Exhibit 1-5 outlines a conceptual framework for conducting CSO planning in a watershed context. This approach can be used to identify CSO controls for each receiving water segment based on the concepts of watershed management and use attainability.

The first activity in the process is to define baseline conditions, including WQS and receiving water quality, and to delineate the watershed. The receiving water assessment includes consideration of the major sources of pollutant loads in the watershed: CSOs, storm water discharges, agricultural loads, and other point sources. Using information from an assessment of baseline receiving water conditions, a range of water quality goals for each receiving water

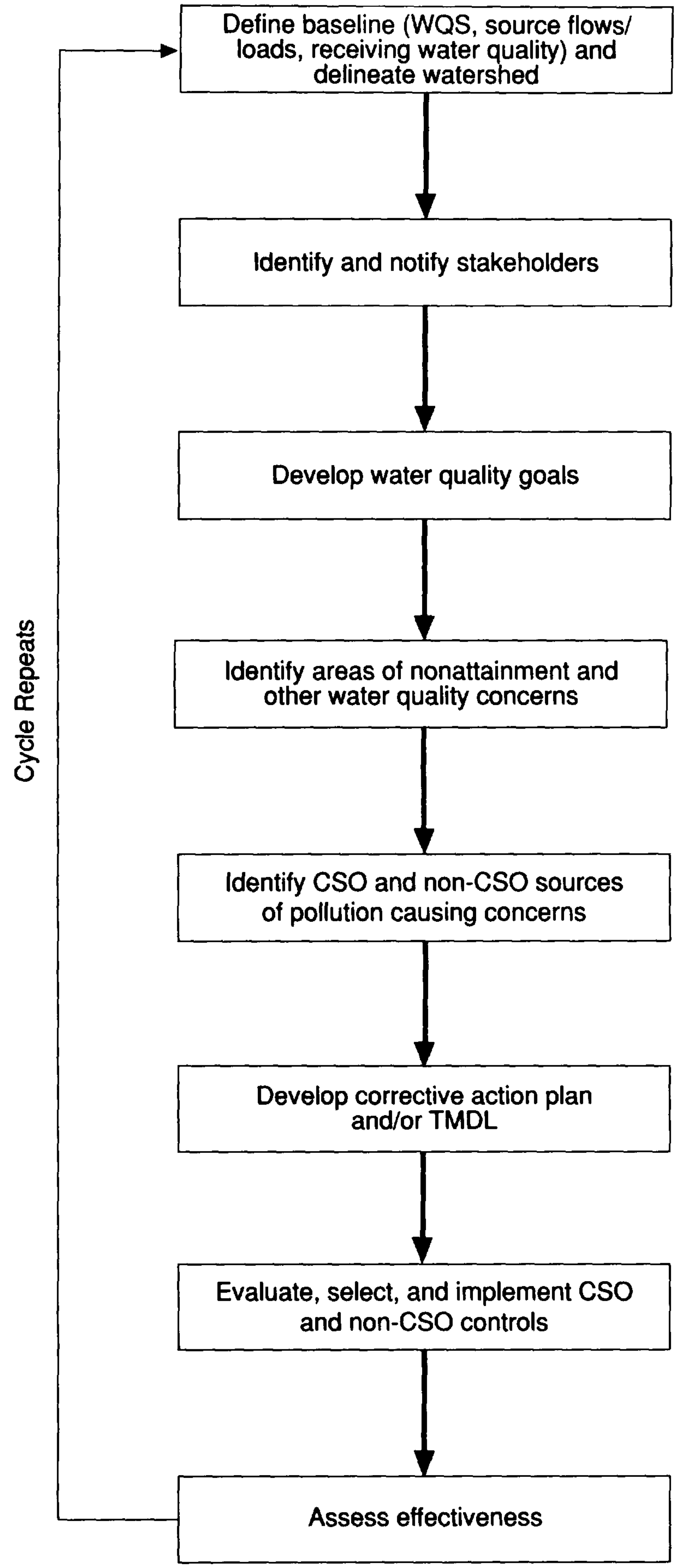


Exhibit 1-5. Watershed-Based CSO Control Planning Approach for a Receiving Water Segment

segment is established. At this stage of the planning approach, all affected stakeholders should be notified.

The next step in this approach is to first identify the overall watershed concerns, and then prioritize the cause or causes for each specific problem. The flows and loads from the pollutant sources are estimated from modeled flows generated for various hydrologic conditions and from pollutant concentrations generated from statistical analyses of available site-specific data. In the approach illustrated in Exhibit 1-5, a receiving water model would be used to assess the impact of CSOs and storm water on selected receiving water segments and to quantify the impacts of CSO sources only, storm water and upstream sources only, and a combination of CSO, storm water, and upstream sources on the attainment of WQS for each segment. It is possible that in several receiving water segments, pollution contributed by CSOs will be only a fraction of the total pollutant loads from other sources. In these segments, even complete elimination of CSOs would not achieve the water quality goals because the other sources prevent the attainment of beneficial uses. The CSO control goals are developed under the assumption that if the other sources were remediated by the appropriate responsible parties, then the CSO control goals would be stringent enough for water quality goals to be met.

Once CSO control goals to achieve the water quality goals in each receiving water segment are established, engineering and hydraulic analyses are conducted to develop, evaluate, and select a corrective action plan. Following the implementation of the CSO and non-CSO controls, their effectiveness must be assessed. In some cases, implementation of CSO and non-CSO controls might require a phased approach, whereby the process illustrated in Exhibit 1-5 could repeat itself over several cycles.

1.6.6 Small System Considerations

As EPA acknowledged in the CSO Control Policy, compliance with the scope of the LTCP may be difficult for some small combined sewer systems. For this reason, "*At the discretion of the NPDES Authority, jurisdictions with populations under 75,000 may not need to complete each of the formal steps outlined in Section II.C. of the Policy....*" (I.D). At a minimum, however, all small municipalities should be required to develop LTCPs that will provide for the attainment of WQS and that include the following elements:

- Implementation of the NMC (II.B)
- Public participation (II.C.2)
- Consideration of sensitive areas (II.C.3)
- Post-construction compliance monitoring program (II.C.9).

A municipality with a population less than 75,000 should consult with both the NPDES permitting and WQS authorities to ensure that its LTCP addresses the elements noted above and can show that the CSO control program will meet the objectives of the CWA.

1.6.7 Sensitive Areas

In accordance with the CSO Control Policy, municipalities should give highest priority to controlling overflows to receiving waters considered sensitive. As part of developing the LTCP, municipalities should be required to identify all sensitive water bodies and the CSO outfalls that discharge to them. The designated beneficial uses of the receiving water bodies will help identify sensitive areas (EPA, 1995g). Sensitive areas are identified by the NPDES authority, in coordination with other State and Federal agencies as appropriate. According to the CSO Control Policy, sensitive areas include:

- Outstanding National Resource Waters
- National Marine Sanctuaries
- Waters with threatened or endangered species or their designated critical habitat
- Primary contact recreation waters, such as bathing beaches
- Public drinking water intakes or their designated protection areas
- Shellfish beds.

In accordance with the CSO Control Policy, the LTCP should give highest priority to the prohibition of new or significantly increased overflows (whether treated or untreated) to designated sensitive areas. If physically possible and economically achievable, existing overflows to sensitive areas should be eliminated or relocated unless elimination or relocation creates more environmental impact than continued discharge (with additional treatment necessary to meet WQS) to the sensitive area.

1.6.8 Measures of Success

As municipalities, NPDES permitting authorities, and the public embark on a coordinated effort to address CSOs, serious consideration should be given to "measures of success." For purposes of this discussion, measures of success are objective, measurable, and quantifiable indicators that illustrate trends and results over time. Measures of success generally fall into four categories:

- Administrative measures that track programmatic activities;
- End-of-pipe measures that show trends in the discharge of CSS flows to the receiving water body, such as reduction of pollutant loadings, the frequency of CSOs, and the duration of CSOs;
- Receiving water body measures that show trends of the conditions in the water body to which the CSO occurs, such as trends in dissolved oxygen levels and sediment oxygen demand; and
- Ecological, human health, and use measures that show trends in conditions relating to the use of the water body, its effect on the health of the population that uses the water body, and the health of the organisms that reside in the water body, including beach closures, attainment of designated uses, habitat improvements, and fish consumption advisories. Such measures would be coordinated on a watershed basis as appropriate.

EPA's experience has shown that measures of success should include a balanced mix of measures from each of the four categories.

As municipalities begin to collect data and information on CSOs and CSO impacts, they have an important opportunity to establish a solid understanding of the "baseline" conditions and to consider what information and data are necessary to evaluate and demonstrate the results of

CSO control. Municipalities and NPDES permitting authorities should agree early in the planning stages on the data and information that will be used to measure success.

The following list presents examples of potential measures of success for CSO control, organized by the four categories discussed above:

- **Administrative measures:**
    - Number of NPDES permits or other enforceable mechanisms requiring implementation of the NMC
    - Number of NPDES permits or other enforceable mechanisms issued requiring development of LTCPs
    - Number of municipalities meeting technology-based requirements in permits
    - Number of municipalities meeting water quality-based requirements in permits
    - Compliance rates with CSO requirements in permits
    - Dollars spent/committed for CSO control measures
    - Nature and extent of CSO controls constructed/implemented.
- **End-of-pipe measures:**
    - Number of dry weather overflows eliminated
    - Number of CSO outfalls eliminated
    - Reduction in frequency of CSOs
    - Reduction in volume of CSOs
    - Reduction in pollutant loadings (conventional and toxics) in CSOs.
- **Receiving water body measures:**
    - Reduced in-stream concentrations of pollutants
    - Attainment of narrative or numeric water quality criteria.
- **Ecological, human health, and use measures:**
    - Improved access to water resources
    - Reduced flooding and drainage problems
    - Reduced costs and treatment of drinking water
    - Economic benefits (e.g., value of increased tourism, value of shellfish harvested from beds previously closed)
    - Restored habitat
    - Improved biodiversity indices
    - Reduction in beach closures
    - Reduction in fish consumption advisories.

(Note: These measures are included as examples only; EPA is supporting the development of national measures of success for CSOs through a cooperative agreement with the Association of Metropolitan Sewerage Agencies (AMSA). The results of AMSA's efforts are expected to be available in late 1995.)

When establishing CSO measures of success, municipalities and NPDES permitting authorities should consider a number of important factors:

- **Data quality and reproducibility**—Can consistent and comparable data be collected that allow for comparison over time (e.g., trend analysis) and from different sources (e.g., watershed analysis)? Do standard data collection procedures exist?
- **Costs**—What is the cost of collecting and analyzing the information?
- **Comprehensibility to the public**—Will the public understand and agree with the measures?
- **Availability**—Is it reasonably feasible for the data to be collected?
- **Objectivity**—Would different individuals evaluate the data or information similarly, free from bias or subjectivity?
- **Other uses in wet-weather and watershed planning and management**—Can the data be used by State agencies as support for other CSO and watershed planning efforts?

Careful selection, collection, analysis, and presentation of information related to measures of success should allow municipalities, States, and EPA to demonstrate the benefits and long-term successes of CSO control efforts. Notwithstanding the effort to develop national measures of success, municipalities should identify measures, document baseline conditions, and collect appropriate information that demonstrates the cause and effect of CSO impacts and the benefits and success of CSO control. It is likely that measures of success will vary from municipality to municipality and will be determined by the environmental impacts of CSOs on site-specific basis.

CHAPTER 2
SYSTEM CHARACTERIZATION

Once the administrative structure for long-term combined sewer overflow (CSO) control planning has been established, characterization of the combined sewer system (CSS) and receiving water should begin. System characterization includes analysis of existing data and monitoring and modeling of the CSS and receiving water.

Chapter 2 focuses on the establishment of existing baseline conditions. The objective of this chapter is to provide an overview of how the components of the system characterization contribute to LTCP development. As a prelude to the description of the technical activities that make up the system characterization, this chapter discusses the importance of input from the public and the appropriate regulatory agencies during LTCP development and integration of the nine minimum controls (NMC) with the LTCP. The chapter includes a case study documenting the watershed approach to system characterization used by a small CSO municipality. *Combined Sewer Overflows—Guidance for Monitoring and Modeling* (EPA, 1995d) contains a more comprehensive description of these components.

2.1 PUBLIC PARTICIPATION AND AGENCY INTERACTION

Public participation and agency interaction facilitate system characterization. The public participation effort might involve public meetings at key points during the system characterization phase of the control plan development process. For example, meetings could be held to discuss the scope of the various technical activities that make up the system characterization, identification and consideration of the different watershed systems in the analysis of existing data and development of the monitoring and modeling programs, identification and status of implementation of the NMC, and the process for evaluating alternative CSO controls. The municipality could present the following information to the public as it is developed during system characterization:

- Scope of monitoring and assessment programs for system characterization

- The watershed approach to CSO control planning
- Identification of watersheds in the CSO area
- Identification and quantification of non-CSO sources
- Existing sewer system conditions and problems (e.g., flooding, basement backups)
- Quantification of CSO flows and loads and impacts of CSOs on receiving waters
- Results of CSS and receiving water monitoring programs
- Development and calibration of the CSS and receiving water models
- Identification and implementation status of the NMC
- Process for evaluating alternatives.

Input from the public, obtained during the early phases of the planning process, will enable a municipality to better develop an outreach program that reaches a broad base of citizens. In addition to public meetings, municipalities can obtain input in a number of ways, including telephone surveys, community leader interviews, and workshops. Each of these activities can give the municipality a better understanding of the public perspective on local water quality issues and sewer system problems, the amount of public concern about CSOs in particular, and public willingness to participate in efforts to eliminate CSOs.

As noted in Exhibit 1-2 (Chapter 1), interaction between the municipality and the regulatory agencies, including State WQS and National Pollutant Discharge Elimination System (NPDES) permitting authorities, should be initiated in the early stages of CSO control planning and continue through the development of the LTCP and the CSO plan re-evaluation and update. An important outcome of this interaction during system characterization should be agreement between all parties "*...on the data, information and analysis needed to support the development of the long-term CSO control plan and the review of applicable WQS, and implementation procedures, if appropriate*" (III.A).

2.2 OBJECTIVE OF SYSTEM CHARACTERIZATION

The primary objective of system characterization is to develop a detailed understanding of the current conditions of the CSS and receiving waters. This assessment, a crucial component of the planning process, establishes the existing baseline conditions and provides the basis for determining receiving water goals and priorities and identifying specific CSO controls in the LTCP. In the context of the CSO Control Policy: "*The purpose of the system characterization, monitoring and modeling program initially is to assist the permittee in developing appropriate measures to implement the nine minimum controls and, if necessary, to support development of the long-term CSO control plan. The monitoring and modeling data also will be used to evaluate the expected effectiveness of both the nine minimum controls and, if necessary, the long-term CSO controls, to meet WQS*" (II.C.1).

As discussed in Section 1.6.6, the municipality should characterize the system in the context of entire watersheds. By characterizing both CSO and non-CSO sources of pollution within each watershed, the causes of WQS nonattainment can be addressed more effectively, and receiving water body goals can be established. Coordination of data collection and analysis efforts throughout each watershed will also provide greater consistency with the LTCP objectives.

System characterization and implementation of the NMC, described in this chapter, can follow the sequential order shown in Exhibit 1-2. In practice, however, this sequential approach might not always be possible or necessary, and the CSO Control Policy recognizes the need for flexibility. In some cases, municipalities will not need to include every step in this process. For example, some systems are already well understood by system engineers and planners through ongoing monitoring, O&M, or other efforts and, therefore, need not revisit their current approaches to monitoring and modeling. In other cases, because of time constraints, some municipalities might be characterizing their combined systems and receiving waters, implementing the NMC, and conducting monitoring programs concurrently.

2.3 IMPLEMENTATION OF THE NINE MINIMUM CONTROLS

One of the goals of the CSO Control Policy is to achieve an early level of CSO control, even as the municipality is involved in developing the LTCP. Although the CSO Control Policy recommends flexibility for municipalities to plan and implement the LTCP on a phased, iterative basis, it recommends that the NMC be implemented no later than January 1, 1997. Following an assessment of NMC effectiveness, municipalities should ultimately integrate the NMC into their LTCPs (EPA, 1995g).

2.3.1 Existing Baseline Conditions

The validated CSS and receiving water models can be used to predict the existing baseline conditions, which are used to evaluate the effectiveness of the NMC and the performance of the long-term CSO controls.

2.3.2 Summary of Minimum Controls

Exhibit 2-1 summarizes the NMC, based on the detailed discussion presented in *Combined Sewer Overflows—Guidance for Nine Minimum Controls* (EPA, 1995b). The NMC were developed to provide low-cost technology-based controls that can be implemented by January 1, 1997, to reduce the magnitude, frequency, and duration of CSOs.

In practice, the implementation of NMC and their integration with the LTCP will be an iterative process. For example, several of these minimum controls might already be ongoing as part of regular operation and maintenance procedures. In some cases, others could be implemented early in the process, before completion of system characterization. However, to effectively maximize the use of the collection system for storage and maximize flow to the POTW for treatment, an adequate understanding of the conveyance system and its hydraulic characteristics is essential.

Although the NMC will generally not significantly reduce runoff entering the CSS, the overflow volume to be addressed by the LTCP can be reduced by maximizing NMC effectiveness, thus reducing potential program costs for the municipality.

2.4 COMPILATION AND ANALYSIS OF EXISTING DATA

As indicated in Exhibit 1-2, one of the first technical activities within system characterization is the compilation and analysis of existing data. This section discusses

Exhibit 2-1. Summary of the Nine Minimum Controls

Minimum Control	Examples of Control Measures
Proper Operation and Maintenance	• Maintain/repair regulators • Maintain/repair tidegates • Remove sediment/debris • Repair pump stations • Develop inspection program • Inspect collection system
Maximum Use of Collection System for Storage	• Maintain/repair tidegates • Adjust regulators • Remove small system bottlenecks • Prevent surface runoff • Remove flow obstructions • Upgrade/adjust pumping operations
Review and Modify Pretreatment Requirements	Volume Control • Diversion storage • Flow restrictions • Reduced runoff • Curbs/dikes Pollutant Control • Process modifications • Storm water treatment • Improved housekeeping • BMP Plan
Maximum Flow to the POTW for Treatment	• Analyze flows • Analyze unit processes • Analyze headloss • Evaluate design capacity • Modify internal piping • Use abandoned facilities • Analyze sewer system
Eliminate Dry Weather Overflows	• Perform routine inspections • Remove illicit connections • Adjust/repair regulators • Repair tidegates • Clean/repair CSS • Eliminate bottlenecks
Control of Solid and Floatable Materials in CSOs	• Screening – Baffles, trash racks, screens (static and mechanical), netting, catch basin modifications • Skimming – booms, skimmer boats, flow balancing • Source controls - street cleaning, anti-litter, public education, solid waste collection, recycling
Pollution Prevention	• Source controls (see above) • Water conservation
Public Notification	• Posting (at outfalls, use areas, public places) • TV/newspaper notification • Direct mail notification
Monitoring	• Identify all CSO outfalls • Record total number of CSO events and frequency and duration of CSOs for a representative number of events • Summarize locations and designated uses of receiving waters • Summarize water quality data for receiving waters • Summarize CSO impacts/incidents

watershed mapping, analysis of existing collection system information, CSO and non-CSO source characterization, field inspections, and receiving water characterization. It concludes with a case study.

Data collection activities are often the most expensive aspect of the CSO planning process; therefore, it is important to maximize the use of available data, as well as to coordinate efforts with other Federal, State, and local water quality agencies. By using existing information, data gaps can be identified and efforts to collect new data can be more focused.

Investigating and describing existing conditions is generally a prerequisite to monitoring and modeling, problem assessment, and evaluation of controls. Extensive applicable information can usually be obtained from municipal government departments, State and Federal agencies, and searches of maps, files, and data bases of environmental data. An investigation of existing data should include gathering, reviewing, analyzing, and summarizing hydrological, water quality, and other environmental data, as well as maps and municipal planning information for the watershed. A description of existing conditions has two major components:

- Watershed characterization, which describes the sources of runoff and the causes of water quality problems. The watershed characterization defines the watershed area and its subwatersheds and further identifies relevant geographic and environmental features (e.g., land use, geology, topography, wetlands), infrastructure features (e.g., sewerage and drainage systems), municipal data (e.g., population, zoning, regulations, ordinances), and potential pollution source data (e.g., landfills, underground tanks, point source discharges). This description can also include historic, social, and cultural characterizations.

- A receiving water body characterization, which describes the receptors of the pollutant sources within the watershed and the effects of those sources. The receiving water body characterization provides water quality and flow information for water bodies (e.g., rivers, streams, lakes, estuaries and their sediment and biota) in the watershed.

These data collection efforts will provide support for future phases of CSO control planning by:

- Providing a basis for establishing and reassessing water quality goals

- Identifying pollutants of concern and their effects on water resources
- Identifying sensitive areas where pollutant loadings pose a high environmental or public health risk and where control efforts should be focused
- Providing watershed base maps for locating pollution sources and controls.

2.4.1 Watershed Mapping

A watershed includes a water body and the entire land area that drains into that water body. A single study area might include several watersheds because many wet weather and CSO control programs are based upon political rather than watershed boundaries.

The first step is to delineate the watershed and its subwatersheds, using base maps or digital mapping resources (if available) or topographic maps. The map should include the municipalities and other entities with jurisdiction, as well as land use categories that could contribute significantly to receiving water impacts. Additional information should then be added as necessary to aid in CSO control planning; this includes topography, soils, infrastructure, natural resources, recreational areas, special fish and habitat areas, and existing pollution control structures. If this information is several years old, field validation might be necessary. Exhibit 2-2 summarizes the types of data typically used in CSO planning.

Watershed maps can be generated by computer. One way of organizing and analyzing data is in a Geographic Information System (GIS). The data in a GIS are organized into thematic layers, such as infrastructure, land use, water bodies, watersheds, topography, or transportation, which can be overlaid and plotted in any combination. In addition, a GIS includes a data management system that can organize and store text and numerical descriptive information. A well-developed GIS can contain most of the data needed. This descriptive information can be very basic, such as land use type (e.g., residential or industrial), or very sophisticated with multiple tables of related data, such as land ownership records, sewer system physical configuration, discharge monitoring report data, soils information, and water quality data.

Exhibit 2-2. Data Types For CSO Planning

Watershed Data	Source Input/Receiving Water Data
Environmental	**Source Inputs (Flow and Quality)**
Land use	CSO
Recreational and open areas	Storm water
Soil and surface/bedrock geology	Other point source and nonpoint source
Natural resources	**Receiving Water**
Temperature	Physiographic and bathymetric data
Precipitation	Flow characteristics
Hydrology	Sediment data
Infrastructure	Water quality data
Roads and highways	Fisheries data
Storm drainage system	Benthos data
Sanitary sewer (and combined sewer) system	Biomonitoring results
Treatment facilities	Federal standards and criteria
Municipal	State standards and criteria
Population	
Zoning	
Land ownership	
Regulations and ordinances	
Potential Sources/BMPs	
Municipal source controls	
Direct (NPDES) and indirect dischargers	
Pollution control facilities	
Storm water control structures	

Source: EPA, 1993b

The use of a GIS might not be feasible for all municipalities undertaking CSO control programs, because of the technical expertise required and the capital expenditures for computer hardware (e.g., an appropriate personal or mainframe computer and a graphics plotter) and software. Although full GIS capabilities can require expensive hardware and advanced training, recently developed software, such as PC-based GIS and "view" systems, are making many GIS functions more accessible to average PC users.

2.4.2 Collection System Understanding

Understanding the physical and hydraulic characteristics of the existing collection system is crucial to any CSO control program. The CSO Control Policy recommends that the municipality "...*evaluate the nature and extent of its combined sewer system through evaluation of available sewer system records, field inspections and other activities necessary to understand the number, location and frequency of overflows and their location relative to sensitive areas and to pollution sources in the collection system, such as indirect significant industrial users*" (II.C.1.b).

The municipality should compile existing information on the collection system. Drawings and records are usually kept by the local public works department, city and county planning offices, and municipal archives. Available information can provide an understanding of the existing system and can also be used to identify areas where plans need to be verified or updated during field inspections. Information should be compiled for sewers, regulators, diversion chambers, pump stations, interceptors, outfalls, and any other key hydraulic control points. Separate sewers, industrial connections, and other related information can be added as appropriate. The municipality will need to know which drainage areas are combined and which are separate or the location of partially separated or combined sewers. The CSO program team can use these data for subsequent monitoring, modeling, and LTCP development.

2.4.3 CSO and Non-CSO Source Characterization

As noted in Section 1.6.6, an advantage in developing an LTCP using a watershed-based approach is that it allows the site-specific determination of the relative impacts of CSOs and non-CSO sources of pollution on water quality. The municipality should identify areas that contain probable sources of significant loadings, such as industrial areas with significant indirect industrial users (i.e., industrial users discharging to the POTW rather than directly to the receiving water body). For many of these sources, the municipality can use existing data collected through the pretreatment program. If the monitoring data are not available, the municipality should consider the collection of such data in the monitoring plan.

2.4.4 Field Inspections

The most effective method for accurately determining the operational status and condition of a CSS is to conduct field investigations. Whereas watershed mapping and review of the collection system information verify a system's design, field inspections help to determine actual operation. Municipalities should inspect their CSSs for many reasons, including the following:

- To characterize areas of the watershed not adequately described by available information
- To identify locations to conduct water quality sampling and install flow measurement equipment
- To determine the structural integrity of the system
- To assess the mechanical condition and operational performance of the system components
- To check for problems, including illegal connections, dry weather overflows, or sediment buildup.

Field inspections can also provide the information necessary to begin assessing and implementing the NMC. The complete implementation of certain minimum controls, such as maximizing the use of the collection system for storage and maximizing flow to the POTW for treatment, will be enhanced greatly by the hydraulic analysis conducted during system characterization. This analysis must proceed from a correct and current understanding of the system.

The extent of the inspection effort necessary will be a function of the adequacy of the municipality's current records and inspection activities. In some cases, the CSS will be large and available funds will dictate the investigation schedule. The municipality should develop a list of inspection priorities related to the project objectives. A first priority might be to inspect elements of the collection system where conflicting information exists, field modifications have been made, or information is missing. A review of the existing drawings, maintenance crew inspection reports, public complaint files, infiltration/inflow (I/I) reports, a sewer system evaluation survey (SSES), or treatment plant upgrade studies might reveal areas of inconsistency or undocumented modifications.

2.4.5 Receiving Water

The main impetus for CSO control is attainment of WQS, including designated uses. To this end, the review of existing information should include characterizing the receptors of CSOs and other watershed pollutant sources and their effects as completely as possible. In many cases, multiple receiving waters will exist, such as tributaries, larger rivers, estuaries, or lakes.

Identification and use of existing receiving water data can shorten the LTCP schedule and reduce cost, particularly sampling and analysis cost. The municipality should review the types of historical receiving water data and information summarized in Exhibit 2-2. These data should be gathered to assist in developing a profile of the conditions in the CSO-impacted receiving water. Often, pollutant source discharge, hydraulic, chemical, sediment, and biological data will exist because of past studies conducted in the watershed. By gathering this information, the municipality can describe existing conditions, as well as data gaps that need to be addressed with the monitoring program. In addition, this effort is important to LTCP development because it provides a basis for:

- Establishing and reassessing priorities for improvements to receiving water quality by water body
- Documenting the type and extent of receiving water impacts caused by CSOs and other point and nonpoint sources
- Identifying sensitive areas
- Quantifying pollutant loads
- Documenting impairment or loss of beneficial uses and water quality criteria exceedances
- Identifying areas with good water quality that might be threatened or that should be protected.

Various agencies at the local, State, and Federal levels might have receiving water data. The municipality should contact each agency that might have been involved in the study area, obtain any existing data, and inquire about other potential data sources. The following list provides possible sources at each level:

- **Local**—Municipal departments, including water, health, and public works, can be useful sources of data and information generated as part of previous studies, wetland or other permit applications, or routine receiving water monitoring. Data will be available from NPDES monitoring records. Municipal departments responsible for reviewing construction and wetlands permit applications can track local water quality conditions as part of local water resource regulations designed to prevent cumulative degradation of sensitive resources. Local permit applications can contain recent and historical water quality, source discharge, and hydrologic data used to demonstrate compliance with local or State wetlands and water quality regulations. Data might also be available for water bodies in special drinking water or flood control districts.
- **State**—Most States have several agencies that deal directly or indirectly with water quality issues: water resources, pollution control, clean lakes, transportation, fisheries, environmental review, wetlands, and coastal zone management. States periodically monitor important water resources and record affected receiving water segments as part of CWA Section 305(b) requirements.
- **Federal**—The Federal Government is an excellent source of hydrology and water resources data through a number of agencies, including EPA, Soil Conservation Service (SCS), U.S. Geological Survey (USGS), and U.S. Fish and Wildlife Service. A number of major Government agencies have water data, including water quality, hydrology, meteorology, biomonitoring, and sediment quality data. In some cases, information can be obtained through the mail; in other cases, such as the USGS National Water Data Exchange and the National Weather Service, the information can be accessed using a computer modem. Many of these agencies also have regional or field offices that are additional sources of data.

An important objective of the initial receiving water investigation is the identification and classification of areas potentially affected by CSOs. A more complete description of the possible impacts to these receiving waters can be developed during monitoring, which is conducted as part of the LTCP. When defining the wet weather receiving water impacts, the municipality should consider the applicable WQS, as well as the existing and desired uses of the receiving water. In developing the LTCP, a "use attainability" approach (40 CFR 131.10) can be an effective method to ensure that recommended improvements in receiving water quality result in the attainment of actual desired uses and that these desired uses are reasonably related to costs. Chapter 3 addresses this issue under the discussion of the demonstration approach.

CASE STUDY: LEWISTON-AUBURN, MAINE—CSO PLANNING

Lewiston and Auburn are located on opposite sides of the Androscoggin River in southwestern Maine. Together, the communities serve as the industrial, commercial, and service center for the south-central-western region of Maine. Lewiston, with a population of approximately 40,000, occupies about 35 square miles of land along the east bank of the Androscoggin River. The city of Auburn has a population of 20,000 and occupies about 65 square miles on the west bank. Combined wastewater flows from both cities are conveyed to the Lewiston-Auburn Water Pollution Control Facility (LAWPCF), located in Lewiston. The LAWPCF provides secondary treatment (conventional activated sludge) with effluent wastewater discharged to the Androscoggin River.

During wet weather conditions, excess flows within the Lewiston CSS and Auburn Sewer District (ASD) CSS discharge directly to the Androscoggin River and its tributaries. On the east side of the river, CSOs from the Lewiston CSS occur along the bank of the Androscoggin River and along drainage courses tributary to the river, including Gully Brook, Jepson Brook, Stetson Brook, and Goff Brook. As indicated in Exhibit 2-3, CSOs from the ASD sewer system on the west side occur along the banks of the Androscoggin and Little Androscoggin Rivers.

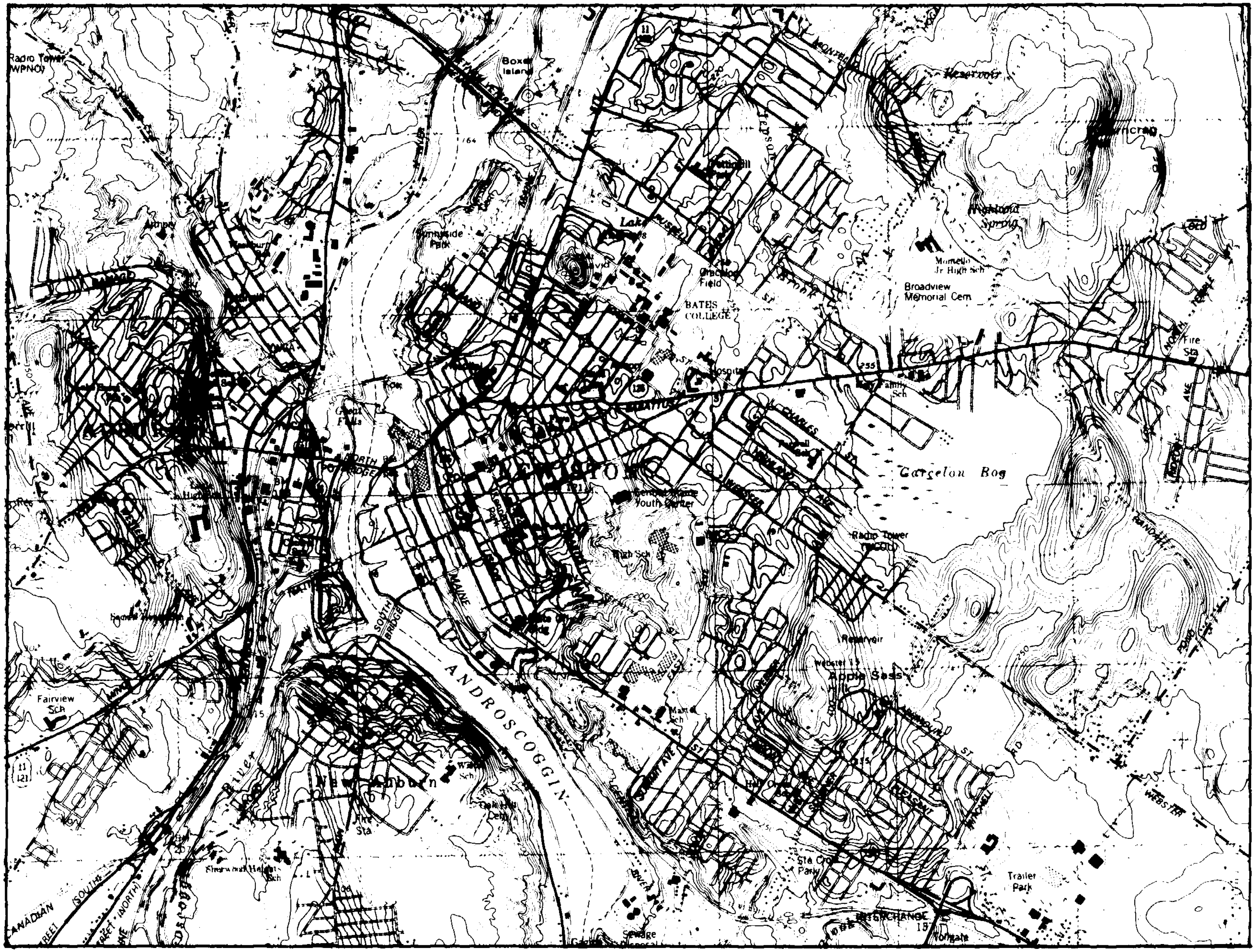
In 1991, the cities embarked on a planning program to address a number of issues, including CSO impacts, storm water management, and nonpoint source control. They decided to incorporate these considerations into an overall planning effort. This case study, which is divided into three separate sections within Chapter 2, outlines CSO planning efforts in Lewiston and Auburn. The first portion of the case study focuses on Lewiston for the early steps in the planning process. The second section describes the CSO and receiving water monitoring efforts, and the third section summarizes the CSO and receiving water modeling.

PUBLIC PARTICIPATION AND AGENCY INTERACTION

The Department of Public Works (DPW) assumed responsibility for the program in Lewiston. The DPW formed a team of representatives from the planning department, LAWPCF, highway department, and the general public who would meet periodically and guide and provide input to the planning process. In addition, the DPW secured funding (100 percent from city funds), developed a scope of services, and hired an engineering consultant to perform technical tasks beyond the capability or available resources of the city.

One of the first tasks undertaken by the program team was to compile information on current Federal and State regulations that were potentially pertinent to the planning effort. The team made a series of contacts, especially with the State regulatory personnel, to determine the status of regulatory activities. They gathered information on Federal and State policies and programs for CSO control, storm water NPDES permitting, Safe Drinking Water Act compliance, nonpoint source pollution control, coastal zone nonpoint source pollution control, and agricultural nonpoint source controls. Changes were occurring in several areas, especially in CSOs and storm water, that needed to be monitored and incorporated into the program.

The team developed initial goals for the program in conjunction with an assessment of existing conditions using available data. Initially, the overall area was divided into watersheds representing the land draining to each of the water bodies in the city, and goals were set for each of these watersheds and receiving water bodies. Exhibit 2-4 lists the characteristics of the watersheds in the city of Lewiston. Because the program was initiated prior to the release of the CSO Control Policy, the team established a basic goal that the program should result in an understanding of and compliance with current and upcoming regulations related to CSO, storm water, and nonpoint source (NPS) control.



Source: USGS Topographic Maps
Lewiston, Maine 1979
Minot, Maine 1981
Lake Auburn East, Maine 1979
Lake Auburn West, Maine 1981

Exhibit 2-3. Lewiston-Auburn Location Plan

Exhibit 2-4. Watershed Characteristics in the City of Lewiston

Watershed Name	Size (acres)	Land Use Description
No Name Pond	750	Rural/residential - shore line cottages
No Name Brook	10,000	Mainly undeveloped - some residential
Stetson Brook	3,000	Ranges from rural to residential to commercial/industrial
Hart and Goff Brooks	1,600	Residential, commercial, and industrial
Salmon/Moody Brooks	1,900	Primarily undeveloped, minor agriculture
Jepson Brook	1,500	Residential and institutional
Androscoggin River	2,300	Urban in central core, undeveloped or industrial in outlying area

The program team held a workshop to facilitate discussion and obtain input on the city's water resources and initial goals for the program. The workshop included discussion of each watershed and the water quality classifications, current uses, known problems, desired uses, and goals completed. A qualitative assessment or "ranking" of the individual watersheds was included to indicate the relative importance of the water resources to the city. The results indicated that CSOs exist mostly in water resources used primarily for non-contact recreation, as shown in Exhibit 2-5.

In some cases, the desired uses of the water resource were being met. For these, maintaining and protecting the uses was set as an initial goal. For some of the brooks, aesthetics was the only use of concern, even though the Class B standard allows fishing and swimming. For these, the initial goal of meeting Class B standards was set. For Jepson Brook, which is a channelized drainage ditch, there was no desire to meet Class B standards. For No Name Brook, there was a desire to upgrade the standard from Class C to Class B. The range of initial goals reflects the variety of watersheds and water resources being addressed.

ANALYSIS OF EXISTING DATA

The program team assessed existing information and data and made the following conclusions pertaining to the initial goals of the planning program:

- The city has an aggressive and extensive regulatory control system that addresses many NPS and storm water control issues. With minor improvements, this system could fulfill the goals of maintaining and protecting existing uses.
- There were virtually no water quality data or information on any of the brooks in the city. More information is needed to better assess the existing conditions and establish goals for these systems.
- There are extensive data on the Androscoggin River, which does not meet the Class C standards. Most pollution appears to be from upstream sources, but the contribution of CSOs needs to be defined better.

Exhibit 2-5. Initial Water Resource Goals for Lewiston

Watershed Name	Water Quality Class	Current Uses	Known Problems	Qualitative Assessment of Importance	Desired Uses	Goals
No Name Pond	GPA	Aesthetics Recreation—fishing, boating	Algal blooms Septic tank discharges	Most important town water resource	Same as current	Maintain and protect existing uses
No Name Brook	C	Aesthetics	Erosion from use of all terrain vehicles Debris	Second most important town water resource	Same as current	Maintain and protect existing uses Upgrade to Class B
Stetson Brook	B	Aesthetics	Erosion CSOs	Third most important town water resource	Same as current plus fishing	Meet Class B
Hart and Goff Brooks	B	Aesthetics	Erosion Industrial areas Interceptor sewer surcharging	Fourth most important town water resource	Same as current	Meet Class B
Salmon/Moody Brooks	B	Aesthetics	Agriculture	Small watercourses of minor importance	Same as current	Meet Class B
Jepson Brook	B	Drainage	CSOs (no visual/odor) Debris	Channelized drainage ditch	Same as current	Maintain current use
Androscoggin River	C	Aesthetics Recreation—fishing, boating	Point sources (paper mills) Erosion (gravel pits) CSOs	Large regional water resource	Same as current	Meet Class C
Groundwater	GWA	Drinking water supply (for town of Lisbon)	None	Of limited current importance to town	Same as current	Maintain and protect existing uses

Proceeding from these conclusions, the program team made numerous contacts and held meetings with individuals who might have pertinent data. Exhibit 2-6 lists the data compiled.

Potential Pollution Sources

In addition to CSOs, a number of possible pollution sources existed within the city's watersheds; however, these had never been mapped. The city compiled extensive information on underground and above-ground storage tanks, landfills, vehicle maintenance areas, salt storage and snow dumping areas, CSOs, and storm drain cross-connections. These were plotted on a base map, along with watershed boundaries, receiving waters, and other important features, such as gaging stations, recreational areas, and flood control structures, to provide a convenient way of reviewing watersheds and potential pollution sources within them, possible threats to receiving waters, and the underlying zoning districts.

The mapping showed that most of the potential pollution sources exist within the Jepson Brook, Hart Brook, and Androscoggin River watershed areas, because these are the most developed watersheds. Stetson Brook watershed has several potential sources, and Salmon/Moody Brook has almost none. The No Name Brook and No Name Pond watersheds did not have many source areas. One area of medium density residential development on Sabattus Street with a concentration of underground tanks was noted. This area is of concern because it is located in the downstream portion of No Name Brook near No Name Pond.

Nonstructural Controls

Nonstructural controls include regulatory controls that prevent pollution problems by controlling land development and land use. They also include source controls that reduce pollutant buildup or lessen its availability for washoff during rainfall. The program team reviewed the city's land use and zoning code and other development guides to determine the status of nonstructural controls. It was determined that the city has a comprehensive set of nonstructural controls. These were analyzed and presented in a series of matrices, which were used to assess the strengths and weaknesses of the regulations. The major areas of existing regulatory authority included conservation districts, performance standards, and development review standards. These controls provide pollution control by reducing the amount of storm water runoff and improving the runoff quality as new development and redevelopment occurs.

Municipal Source Controls

The team also conducted interviews to summarize the city's current source control activities. Most of the activities appeared to correspond to standard practices of similar size municipalities. Areas that appeared to need further consideration included sewer cross-connection removal, road salting, and household hazardous waste pickup. The city identified some cross-connections and plans to implement a removal program. Many communities are involved in household hazardous waste pickup programs. Such a program could prove beneficial, and it would be consistent with the other aggressive solid waste programs of the city. Such programs also can be expensive, however. The team plans further evaluation of municipal BMP/source control activities after collection of data and evaluation of various possible BMP programs.

Receiving Water Data

The program team located limited data on receiving waters and on the major pollution sources to the receiving waters, as listed in Exhibit 2-7. Data were available for the Androscoggin and Little Androscoggin (which feeds into the Androscoggin River in Lewiston) Rivers only. The USGS maintains monitoring stations on both rivers, and published data on dissolved oxygen, temperature, pH, and conductivity are available. Maine DEP collected grab samples on a weekly basis during summer months,

Exhibit 2-6. Lewiston Watershed Data

Description	Source
Environmental	
Topography	USGS topographical maps; city's 100 and 200 scale maps
Land Use	"Zoning Map Lewiston, Maine" revised 11-7-91; Comprehensive Land Use Plan (1987)
Recreational Areas	Parks Department inventory
Soil and Surface/Bedrock Geology	USDA Soil Conservation Service soil survey
Vegetation	USGS quadrangle sheets & Maine DOT aerial photos
Natural Resources	Comprehensive Land Use Plan (1987)
Temperature	NOAA
Precipitation	National Climatic Data Center; four rainfall gages owned and operated by Lewiston
Hydrology	FEMA flood mapping
Infrastructure	
Roads and Highways	Various maps of the city exist
Storm Drainage System	Record drawings provided by the city
Sanitary Sewer and Combined Sewer System	Record drawings provided by the city
Treatment Facilities	Record drawings provided by the city
Other Utilities	Gas, New England Telephone maps
Municipal	
Population	U.S. Census data; Maine Department of Data Research and Vital Statistics; Comprehensive Land Use Plan (1987)
Zoning	Zoning regulations; city zoning map; Comprehensive Land Use Plan (1987)
Land Ownership	City Assessor's maps
Regulations and Ordinances	"Draft. Development Permit" provided by the city; Comprehensive Land Use Plan (1987)
Municipal Source Control BMPs	Interviews with various city departments and staff
Potential Sources/BMPs	
Landfills	Locations developed by city
Waste Handling Areas	Locations developed by city
Salt Storage Facilities	Locations developed by city
Vehicle Maintenance Facilities	Locations developed by city
Underground Tanks	Maine DEP list supplemented by the city
NPDES Discharges	Locations developed by city
Pollution Control Facilities	Lewiston Area Water Pollution Control Authority
Retention/Detention Ponds	Public Works Department inventory
Flood Control Structures	Public Works Department inventory

Exhibit 2-7. Lewiston Source Input and Receiving Water Data

Description	Source
Source Inputs (Flow and Quality)	
CSO	None
Storm Water	None
Other NPS	None
Receiving Water	
Physiographic and Bathymetric Data	Some available - see water quality data below
Flow Characteristics	USGS flow data
Sediment Data	International Paper - Androscoggin River
Water Quality Data	Maine DEP, USGS, CMP, Union Water Power Co. (Note: all water quality data in Androscoggin River only)
Fisheries Data	International Paper - Androscoggin River
Benthos Data	International Paper - Androscoggin River
Biomonitoring Results	None
Federal Standards and Criteria	EPA
State Standards and Criteria	Maine DEP

and data on dissolved oxygen, *E. coli* or fecal coliform bacteria, phosphorus, TKN, NO_3, NH_3, and conductivity are available for several years. The most comprehensive set of data available was collected by International Paper Company relative to its wastewater discharge upstream of Lewiston. Although the available data do not cover the entire reach of the Androscoggin River in Lewiston, significant data on fisheries and sediment exist. None of the existing data were oriented toward definition of wet weather impacts in the receiving water. Some of the Maine DEP grab samples were taken during or after storm events, and the bacteria data indicate elevated bacteria levels during these periods.

Due to the limitations in the available data, the program team identified two major areas for new data collection: (1) CSO flows, loads, and impacts, which were required as part of CSO planning efforts by the State and (2) water resources where no data currently exist. These programs are described in the next section of the case study, following Section 2.5.3.6.

2.5 COMBINED SEWER SYSTEM AND RECEIVING WATER MONITORING

In many cases, existing data will not be sufficient to establish existing baseline dry weather or wet weather conditions. Thus, the next step in the long-term planning process generally will be to develop and conduct a monitoring program to adequately characterize existing conditions, as well as provide the necessary calibration and verification data for system modeling. As stated in the CSO Control Policy, "*The permittee should develop a comprehensive, representative monitoring program that measures the frequency, duration, flow rate, volume and pollutant concentration of CSO discharges and assesses the impact of the CSOs on the receiving waters. The monitoring program should include necessary CSO effluent and ambient in-stream monitoring and, where appropriate, other monitoring protocols such as biological assessment, toxicity testing and sediment sampling*" (II.C.1.c).

This section summarizes the main considerations in the development of a monitoring program and the elements that make up the CSS and receiving water monitoring plans. Because CSO data collection programs are site-specific and varied, providing detailed guidance on "typical" activities is a difficult task. EPA's guidance on monitoring and modeling (EPA, 1995d) addresses these issues in greater detail and provides additional references.

2.5.1 Monitoring Plan Development

The monitoring plan plays a significant role in the CSO planning process. Because CSO control decisions are based largely on system characterization (a major element of which is monitoring data), the data obtained must represent the conditions throughout the CSS and receiving water accurately. A well-developed monitoring plan is essential whether the collection of monitoring data is for NMC implementation, LTCP development and implementation, or post-construction monitoring. The municipality should continue to coordinate its efforts with the regulatory authorities (State WQS and watershed personnel, and EPA Regional staff), as well as with other municipalities in the same watershed, throughout the development of the monitoring plan.

The primary goal of any CSO control program is to implement the most cost-effective controls to reduce water quality impacts from CSOs. The monitoring plan will generate data to support decisions for selecting appropriate CSO controls. The monitoring plan might have numerous data collection objectives, depending on local site-specific conditions, some of which are given below:

- Define the CSS's hydraulic response to rainfall.
- Determine CSO flows and pollutant concentrations/loadings.
- Evaluate the impacts of CSOs on receiving water quality.
- Support the review and revision of WQS.
- Support implementation and documentation of the NMC.
- Support the evaluation and selection of long-term CSO controls.

Monitoring is expensive. By tailoring the monitoring program to the CSS, water quality problems and priorities, pollutants of concern, and needs and resources of a community, a balance can be achieved between obtaining sufficient data for system understanding and keeping data collection costs under control. This balance can be achieved and maintained provided that activities between the data collectors and model developers are well coordinated.

To meet the objectives listed above, the data collection program should identify sampling stations, frequency of data collection, and parameters to be monitored. Section 2.5.2 briefly discusses these components for CSS monitoring, as well as techniques and equipment for obtaining rainfall, flow, and pollutant data. Section 2.5.3 follows the same approach for receiving water monitoring.

2.5.2 Combined Sewer System Monitoring

The CSO Control Policy outlines several possible objectives of a CSS monitoring plan:

- Gain a thorough understanding of the CSS

- Adequately characterize the CSS response to wet weather events, such as the number, location, and frequency of the CSOs and the volume, concentration, and mass of pollutants discharged
- Support a mathematical model to characterize the CSS
- Support the development of appropriate measures to implement the NMC
- Support LTCP development
- Evaluate the expected effectiveness of the NMCs and, if necessary, the long-term CSO controls.

The CSS monitoring program should be conducted to satisfy the above objectives as appropriate. For example, the CSO Control Policy specifies that permittees should immediately begin characterizing their CSS and CSOs, demonstrating implementation of the NMC and developing an LTCP. Implementation of the NMC is affected directly by the results of the CSS monitoring program. Monitoring can be performed to support various aspects of the NMC, including maximizing use of the collection system for storage, maximizing flow to the POTW for treatment, and control of solids and floatable materials in CSOs.

2.5.2.1 Selection of Monitoring Stations

An accurate determination of CSO flow, pollutant loadings, and resulting water quality impacts depends on the appropriate and efficient selection of sampling stations. The municipality should select sampling stations strategically so that data collected from a limited number of stations can be used to satisfy multiple monitoring objectives. As mentioned earlier, a thorough examination of the available information on the CSS, its overflow points, field investigation reports, and flow measurements will help in this exercise.

Wet weather discharges can contribute large pulses of pollutant load and might constitute a significant percentage of long-term pollutant loads from combined sewer areas. Wet weather sampling can be used to characterize runoff from these discharges, determine individual pollutant source and total watershed loadings, and assess the impact to receiving waters. The municipality should consider the following criteria when selecting the actual location for CSO sampling (EPA, 1993b):

- **Discharge Volume**—Select sites that constitute a significant portion of the flow from a watershed.
- **Hydraulic Stations**—Spread stations out in interceptors and sewers to define flows; locate at key hydraulic control points, such as pump stations and diversions. Storm water or other source flow data might be required; I/I in the system and entering upstream might need to be defined.
- **Pollutant Stations**—Either based on historical information or deduced from an analysis of land use or population density, select sampling sites to quantify representative or varying pollutant loads (dry versus wet weather quality), sources that affect sensitive areas, and, possibly, non-CSO sources.
- **Geographic Location**—Select sites that permit sampling of flows from major subwatersheds or tributaries to permit isolation of pollutant sources.
- **Accessibility**—Select sites that allow safe access and sample collection.

If possible, the monitoring plan should include some type of flow and pollutant concentration information at every CSO location. Municipalities with small systems and a limited number of overflow points might be able to monitor all locations for each storm event studied. Other municipalities, however, might have budget constraints or a large number of discharge points that make this approach impossible. In such cases, an approach that includes monitoring high priority or critical sites (e.g., the possible criteria outlined previously) with techniques, such as continuous depth and velocity flow monitoring and the use of sampling for chemical analyses, might be appropriate. According to the CSO Control Policy, a "*...representative sample of overflow points can be selected that is sufficient to allow characterization of CSO discharges and their water quality impacts and to facilitate evaluation of control plan alternatives*" (II.C.1). Both the case study, presented after Section 2.5.3.6, and EPA's guidance on monitoring and modeling (EPA, 1995d) present approaches for selecting CSO monitoring sites.

2.5.2.2 Frequency of Monitoring

Municipalities should monitor a sufficient number of storms to support development of hydraulic models or prediction of the CSS response to rainfall events and CSO impacts. The frequency of monitoring should be based on the need to collect data for the development of models or predictions. The data to be collected should be based on model parameters and site-specific considerations, such as the overflow rate, which depends on the rainfall pattern, antecedent dry period, ambient tide or stage of river or stream, and base flow (wastewater and infiltration) to the treatment plant. Monitoring frequency can reflect:

- A certain size precipitation event (e.g., 3-month, 24-hour storm)
- Precipitation events that result in overflows (e.g., more than 0.4 inches of rainfall)
- A certain number of precipitation events (e.g., monitor until five storms are collected of a certain minimum size).

When determining the monitoring frequency, municipalities should consider the following criteria:

- **Frequency of Rainfall/Discharge**—Facilities located in areas where rainfall is more frequent might have more frequent CSOs.
- **Sensitivity of Receiving Waters**—If facilities discharge to sensitive areas or high quality waters, more frequent monitoring might be desirable or warranted. For example, in an area where human contact occurs through swimming, boating, and other recreational activities or where there are intakes for drinking water, more accurate estimates might be needed.
- **Variability of Discharge**—CSOs with variable characteristics should be monitored more frequently than CSOs with relatively consistent characteristics.

The frequency of monitoring should change when the data are used for model verification and later during the post-construction monitoring phase. Information on determining appropriate sampling frequencies can be found in EPA, 1995d, and EPA, 1983.

2.5.2.3 Pollutant Parameters

Chemical analyses generate information about the concentration of pollutants carried in the combined sewage and the variability of these concentrations from outfall to outfall and from storm to storm. Chemical analysis data are used with flow data to compute pollutant loadings to receiving waters. In some cases, such data can also be used to detect the sources of pollutants in the system.

The selection of parameters to be measured during the sampling program should be based on problems identified during the review of existing conditions; the overall goals of the program; the specific objectives of the data collection program; and the requirements of local, State, and Federal regulations. For example, most State WQS have numeric limits for indicator bacteria levels in waters intended for swimming and boating. If local beaches are threatened by bacterial contamination from CSOs or storm water, the program needs to include bacteria sampling.

CSSs need to be monitored for the identified parameters of concern. Parameters of concern should include the pollutants with water quality criteria for the specific designated use(s) of the receiving water and pollutants key to the attainment of the designated water use(s). The CSO Control Policy states: "*Monitoring parameters should include, for example, oxygen demanding pollutants, nutrients, toxic pollutants, sediment contaminants, pathogens, bacteriological indicators (e.g.*, Enterococcus, E. coli), and *toxicity*" (II.C.1.c).

The monitoring plan should also include any other pollutants for which water quality criteria are being exceeded, as well as pollutants suspected to be present in the combined sewage. CSS monitoring should include identified pollutants of concern that are known or thought to be discharged by industrial users in amounts that could affect CSO pollutant concentrations and/or the receiving water. If the water quality criterion for zinc is being exceeded, for example, CSS monitoring for zinc should be conducted in the portions of the CSS associated with significant industrial users that discharge zinc. POTW monitoring data and industrial pretreatment program data on nondomestic discharges can help identify other pollutants expected to be present. In coastal systems, measurements of sodium, chloride, TDS, or conductivity can be used to detect the presence of sea water in the CSS, which can occur because of intrusion through failed tide gates (EPA, 1995d).

2.5.2.4 Rainfall Monitoring and Analysis

Rainfall data are necessary to estimate the amount of runoff generated during a single wet weather event or long-term series of events and for successful hydraulic modeling of the CSS. CSS performance can be predicted by entering rainfall data into a hydrologic/hydraulic model, observing the resulting simulated overflows, and correlating these predicted overflows with measured overflow volumes. There are two general types of rainfall data: (1) continuous rainfall records, obtained either from existing weather stations (often maintained at airports) or from stations set up within the CSS watershed of interest and (2) rainfall frequency data (depth-duration-intensity-frequency analyses of historic rainfall).

For rainfall data collection, the variability in the possible distribution of rainfall over a relatively small area might necessitate a network of rain gages. The number of gages necessary depends on the size of the program, the area, topography, season, and typical characteristics of local rainfall events. EPA has provided guidance for determining rain-gage network density (EPA, 1976a). In addition, the sampling interval is important. The 1-hour data commonly gathered at NOAA gages might underestimate CSO flows by averaging larger peak intensities that occur over shorter time intervals (5- or 15-minute rainfall data might be more appropriate).

Rainfall data can be analyzed using the EPA SYNOP program to develop long-term rainfall statistics, such as depth, intensity, duration, and number of storms. In addition, it might be necessary to develop synthetic rainfall hyetographs for particular design conditions of interest to the program. (Hyetographs are graphs of rainfall intensity versus time, and standard hydrology textbooks contain methods for developing them.) More discussion of rainfall monitoring and analysis can be found in *Combined Sewer Overflows—Guidance for Monitoring and Modeling* (EPA, 1995d).

2.5.2.5 CSO Flow Monitoring and Analysis

Accurate flow monitoring is needed to confirm the hydraulic characteristics of the CSS, provide the necessary calibration and verification data for characterizing rainfall runoff and conveyance, and predict CSO volumes. Selecting the most appropriate monitoring technique often depends on a combination of site characteristics, budgetary constraints, and personnel availability.

Flow measurements are generally made using automatic devices that can be installed in channels, storm drains, or CSO structures. These devices use a variety of sensor types, including pressure/depth sensors and acoustic measurements of stage height or Doppler effects from flow velocity. Data are stored in a computer chip that can be accessed and downloaded by portable computer. Data are processed based on the appropriate pipe, flume, or weir hydraulic equations. Field calibration of data using such equations is important because these types of data can be influenced by surcharging, backwater, tidal flows, and other complex hydraulic conditions typical of wet weather flows. EPA's guidance on CSO monitoring and modeling (EPA, 1995d) provides a matrix and description of the various CSO monitoring methods, including manual methods, primary flow, depth sensing, and velocity meters, as well as advantages and disadvantages of their use in CSS monitoring.

The CSS flow monitoring data can be evaluated to develop an understanding of the hydraulic response of the system. Using this evaluation, the following questions can be answered for the monitored outfalls based on the monitored storms (EPA, 1995d):

- Which CSOs contribute the majority of the flow volume?
- What size storm can be contained by the regulator serving each outfall?
- Does this capacity vary from storm to storm?
- Approximately how many overflows would occur and what would be their volume, based on a rainfall record from a different year? How many occur per year, on average, based on the long-term rainfall record?

Extrapolating from the monitored period to other periods, such as a rainfall record for a year with more storms or larger volumes, requires professional judgment and familiarity with the data. In addition to analyzing total overflow volumes for the CSOs, flow data can be used to develop various graphical and tabular presentations. These could include plots of flow and/or head for a selected conduit during a storm event, as well as tables comparing the relative volumes and activation frequencies from different monitoring sites in the CSS.

2.5.2.6 CSO Quality Sampling and Analysis

Characterization of the CSS requires information on the quality, as well as the quantity, of the overflows. The objective of CSO pollution abatement is to prevent the degradation of receiving water quality from short- and long-term effects of pollutant discharges during wet weather events. It is necessary, therefore, to know the constituents of the overflows and their pollutant loadings.

In general, water sampling methods fall into three categories: grab sampling, flow-weighted sampling, and automated sampling. Grab samples are collected by hand using a container to collect water from the sewer. This method requires minimal equipment and allows field personnel to record additional observations while collecting the sample. Because of their special characteristics, oil and grease, volatile compounds, and bacteria, *must* be analyzed from a sample collected by manual methods according to standard procedures (APHA, 1992).

Data can be obtained by combining multiple grab samples collected throughout a storm event to create a flow-weighted or composite sample. These samples provide data that are representative of the overall quality of combined sewage averaged throughout a storm event. Typically, samples are combined in relation to the amount of flow observed in the period between the samples.

Automated samplers have features that are useful for CSS sampling, such as the ability to collect multiple discrete samples, as well as single or multiple composited samples. They can collect samples on a timed basis or in proportion to flow measurement signals from a flow meter. Although these samplers require a large investment, they can decrease the labor required in a sampling program and increase the reliability of flow-weighted compositing.

In addition, toxicity testing can be used to directly measure, prior to discharge, the acute and chronic impacts of combined sewage on aquatic life. Procedures for toxicity testing are described in *Technical Support Document for Water Quality-based Toxics Control* (EPA, 1991); these procedures can also be used, with caution, for wet weather discharges.

Other important components of any CSO quality sampling effort include sample preservation, handling, and shipping; chain of custody documentation; and quality assurance and quality control (QA/QC) procedures. The QA/QC procedures are essential to ensure that data collected in environmental monitoring programs are useful and reliable. QA refers to program-related efforts to ensure the quality of monitoring and measurement data. QC, which is a subset of QA, refers to the routine application of procedures designed to obtain prescribed standards of performance in monitoring and measurement.

Because data collection programs generate large amounts of information, management and analysis of the data are critical to a successful program. Even small-scale programs, such as those involving only a few CSO and receiving water monitoring locations, can generate an extensive amount of data. EPA's guidance on CSO monitoring and modeling provides examples of data analysis methods (EPA, 1995d).

2.5.3 Receiving Water Monitoring

The objectives of receiving water monitoring generally include the following:

- Assess the attainment of WQS, including designated uses
- Establish the baseline conditions in the receiving water
- Evaluate the impacts of CSOs
- Gain sufficient understanding of the receiving water to support evaluation of proposed CSO control alternatives, including any receiving water modeling that may be needed

- Support the review and revision of WQS.

2.5.3.1 Selection of Monitoring Stations

Municipalities should select monitoring stations for receiving water quality sampling considering the following factors (WPCF, 1989; EPA, 1993b):

- Proximity to discharge sampling locations
- Accessibility
- Safety of personnel and equipment
- Proper location upstream or downstream of incoming sources or tributaries
- Adequate mixing of sources or tributaries at the sampling site.

In addition, municipalities should coordinate the locations with sites that might already have an existing monitoring data base.

To identify sampling locations as part of a receiving water monitoring program, some knowledge of the dynamics of the receiving water is important. In addition to the general criteria listed above, the selection of appropriate locations depends on the characteristics of the receiving water, the pollutants of concern (e.g., bacteria, dissolved oxygen, toxic material), and the location of sensitive areas. The number and placement of sampling locations also depends on the size of the water body, the horizontal and vertical variability in the water body, and the degree of resolution necessary to assess attainment of WQS.

Individual monitoring stations can be located to characterize:

- Pollutant concentrations and loadings from an individual source
- Concentrations and impacts at specific locations, including sensitive areas such as shellfishing beds
- Variations in concentrations between upstream and downstream sampling sites for rivers or between inflow and outflows for lakes, reservoirs, or estuaries

- Changing conditions through time at individual sampling stations
- Differing water bodies or segments that receive CSOs, such as lakes, ponds, rivers, tributaries, bays, or channels
- Effects of other pollution sources within the watershed.

2.5.3.2 Extent of Monitoring

Monitoring studies for receiving water characterization should target seasons, flow regimes, and other critical environmental conditions where CSOs have the greatest potential for impacts, as identified in the data investigation (Section 2.4). Based on initial sampling results, the number of stations may be able to be reduced. For example, if initial sampling results show that one of a series of streams within a watershed is of high quality, sampling coverage of this stream could be reduced. Conversely, additional monitoring might be necessary to fill data needs and to support receiving water modeling or to distinguish the relative contribution of other sources to the water quality impairment.

In assessing or demonstrating compliance with WQS, monitoring should provide data designed to answer relevant questions. For instance, to establish a maximum or geometric mean coliform concentration at the point of discharge into a river (or mixing zone boundary, if allowed), grab samples should be taken during and immediately after discharge events in sufficient number (usually specified in the standards) to obtain a reasonable approximation of actual in-stream conditions. On the other hand, assessing attainment of narrative standards to control nutrient load to prevent eutrophication might require the collection of samples through the water body and timed to examine long-term average conditions over the growing seasons. Finally, assessing attainment of narrative standards for the support of aquatic life might require biological assessment in potentially impacted locations and a comparison of the data to reference sites. EPA's guidance on monitoring and modeling describes several examples of receiving water sampling designs, including point-in-time, short-term, long-term, reference site, near-field, and far-field designs (EPA, 1995d).

2.5.3.3 Pollutant Parameters

To assess the impact of wet weather runoff, the water quality of receiving waters during normal dry weather periods should be known. Water quality data collected during dry weather conditions provide a basis of comparison to data collected during wet weather conditions. Sampling several events with varying antecedent dry periods will help define the variations in pollutant loading for the system.

Receiving water monitoring should include identified parameters of concern. These parameters typically include those previously identified for combined sewage and CSO monitoring.

- pH
- BOD
- TDS
- TSS
- Nutrients
- Metals
- Indicator bacteria.

Knowledge of the site-specific water quality concerns could expand the list to include dissolved oxygen, toxics, biological assessment, and sediment.

2.5.3.4 Hydraulic Monitoring and Analysis

Establishing the hydraulic characteristics of the receiving water is an important first step in a receiving water study, since the physical dynamics of the receiving water determine the dilution of pollutants contained in CSOs. Large-scale water movement largely determines the overall transport and transformation of pollutants. Small-scale hydraulics, such as water movement near a discharge point (often called near-field), determine the initial dilution and mixing of the discharge. For example, a discharge into a wide, fast-flowing river might not mix across the river for a long distance. This information can help identify sampling locations in the river to determine CSO effects (EPA, 1995d).

Hydraulic monitoring in receiving waters consists of assessment of transport characteristics (water depth and velocity) and physical characteristics (elevation, bathymetry, cross-section) of the receiving water body. Hydraulic monitoring methods are determined in part based on the type of receiving water being assessed. Generally, gages can be installed on a temporary or long-term basis to determine depth and velocity variations during wet weather.

Analysis of hydraulic data in receiving waters can consist of developing stage-discharge or other rating curves for specific monitoring locations, plotting and reviewing the hydraulic data, pre-processing the data for input into hydraulic models, and evaluating the data to define hydraulic characteristics, such as initial dilution, mixing, travel time, and residence time. Methods for developing rating curves for various types of flow monitoring stations are presented in *Measurement and Computation of Streamflow* (USGS, 1982) and *Water Measurement Manual* (USDI, 1984). The general purpose of these analyses is to allow estimation of the flow rate based on a depth measurement. Calibration of the stage-discharge relationship using measured velocities is necessary.

2.5.3.5 Receiving Water Quality Monitoring and Analysis

The collection and analysis of receiving water quality data are necessary when available data are not sufficient to describe water quality impacts that result from the CSOs. The initial steps in conducting a receiving water sampling program involve selecting sampling locations and determining sampling frequency and parameters (Sections 2.5.3.1 - 2.5.3.3).

Sampling receiving waters to provide background water quality data and to assess CSO impacts can range from manual collection of bacterial samples from a stream to a full-scale oceanographic investigation of a harbor using a sizable vessel and requiring considerable logistics (EPA, 1993b). The use of proper sampling techniques is crucial (USDI, 1984; EPA, 1982; Plumb, 1981; APHA, 1992).

Chemical receiving water quality data are analyzed by plotting and reviewing the raw data to define water quality characteristics and by processing the data for input to water quality models. Data can be analyzed and displayed using various types of spreadsheets, graphics software, and statistical packages. One basic analysis is to compare the receiving water quality data with applicable water quality criteria to determine whether criteria are being exceeded in the receiving water body. Sampling before, during, and after a wet weather event can indicate whether water quality problems occur during dry and/or wet weather and if they are likely due to CSOs or other sources. Sampling data in areas thought to be affected by CSOs can be compared with data from areas upstream of or away from CSO outfalls to try to distinguish CSO impacts. In addition, water quality data are used to calibrate receiving water models usually by plotting the data versus time and/or distance to compare with model simulations (Section 2.6.2). In some cases, special studies might be necessary to identify rate constants, such as bacteria die-off rates or suspended solids settling rates.

2.5.3.6 Sediment and Biological Monitoring and Analysis

It is often difficult and expensive to identify CSO impacts during wet weather using hydraulic and water quality sampling (EPA, 1995d). In some cases, sediment and biological monitoring can serve as cost-effective supplements or even as alternatives to water quality sampling. For example, the long-term effect of CSOs can be represented by comparing grab samples of bottom sediments or biota to data from reference sampling points.

Sediment Sampling

Receiving water sediments serve as sinks for a wide variety of materials. Nutrients, metals, and organic compounds bind to suspended solids and settle to the bottom of a water body when flow velocity is insufficient to keep them in suspension. However, it should be noted that sediments affected by wet weather runoff usually exhibit the long-term effects of both dry and wet weather discharges because of their relative immobility. Grab samples can be taken to indicate historical accumulation patterns. Sampling sites can be located at points of impact, upstream (or downstream) reference sites, areas of future expected changes, or other areas of particular interest, based on an awareness of possible impact sites, accessibility, and hydraulic conditions.

Sediment sampling results are useful for assessment of physical characteristics (grain size, distribution, type of sediment) of the deposited sediments, chemical analysis of sediments deposited by CSOs, and examination of benthic communities that might be affected. Sediments from upstream reference stations, and possibly from areas affected by non-CSO sources, should be sampled for comparison with sediments near the CSO. (It should be noted that sediments affected by CSOs and other wet weather sources may be considerably downstream of the sources, particularly in waters whose velocities increase greatly during rainfall. In general, sediments tend not to settle in streams with velocities greater than 0.5 feet/second.)

Biological Sampling

Evaluating aquatic populations and communities can provide information not available through water and sediment testing. Because resident populations and communities of aquatic organisms integrate over time all the environmental changes that affect them, the biological community can reveal the cumulative impact of pollutant sources or short-term toxic discharges not represented in discrete water and sediment samples. EPA's guidance on monitoring and modeling provides a comprehensive summary of biological collection methods, as well as the information potentially available through the monitoring of aquatic organisms (EPA, 1995d).

Benthic (bottom-dwelling) organisms are affected by contaminants in the water column and through contact with or ingestion of contaminated sediments. Therefore, the type, abundance, and diversity of benthic organisms can be used to investigate the presence, nature, and extent of pollution problems. Comparing areas upstream and downstream of a suspected pollution source requires sampling locations with similar bottom types, because physical characteristics affect the habitat requirements of organisms.

Community structure, described in terms of species diversity, richness, and species evenness, is commonly used to evaluate the environment. The use of biological organisms as indicators of aquatic environmental health is based on the understanding that a natural environment is normally characterized by a balanced biological community comprised of a large number of species with no one species dominating. The presence of certain species that are known to be intolerant of polluted or disturbed conditions may also be used as an indicator of an unstressed environment, and conversely, other species may serve as indicators of environmental stress. Species diversity is affected by such factors as colonization rates, extinction rates, competition, predation, physical disturbance, and pollution, and it is often difficult to determine which factors have caused measured variation in species diversity (i.e., pollution or other conditions). A qualitative data assessment whereby the benthic species collected and their relative population sizes are compared with their known sensitivities to contaminants present, can help with this determination. Various documents describe these assessment techniques (EPA, 1995d; Plafkin et al., 1989).

CASE STUDY: LEWISTON-AUBURN, MAINE—CSO AND RECEIVING WATER MONITORING

Because of the limited CSO and receiving water data available, a full monitoring program was undertaken. The objective of the monitoring program was to collect dry weather (baseline condition) and wet weather data on CSOs, sanitary and separate storm sewer flows, and the rivers and brooks receiving CSOs. These data were then used to quantify pollutant loadings to receiving waters and to assess impacts of those loadings on receiving water quality. The sampling and monitoring data were also used to calibrate and verify computer models of the CSSs in both Lewiston and Auburn (see the case study following Section 2.6.2.3). The different elements of the sampling and monitoring program are summarized below:

- Wastewater flows within each sewer system were measured, sampled, and analyzed for various water quality parameters during dry weather, high ground water (spring time) conditions to determine base wastewater flows, infiltration rates, and baseline pollutant loadings.

- CSOs from four storm events at selected CSO regulators within each CSS were measured, sampled, and analyzed for various water quality parameters during two 6-week periods to determine CSO flows and loads to receiving waters.

- Storm water runoff from four storm events at selected locations within the separate storm drain systems of each city were measured, sampled, and analyzed for various water quality parameters during two 6-week periods to determine pollutant loadings in storm water runoff to receiving waters.

- Receiving waters were sampled and analyzed during dry weather and during two storm events. The collected samples were analyzed for various water quality parameters and priority pollutants to define baseline receiving water quality and to determine the impacts of CSOs on receiving water quality.

- Continuous release dye studies were conducted to assess the rate of mixing and dispersion of CSOs from each city in the receiving waters.

Each of these sampling activities occurred during the same storm events to ensure consistency among the data. The discussions in this case study focus only on the CSO and receiving water sampling.

SELECTION OF CSO MONITORING STATIONS

A review of existing information coupled with a field inspection of the CSSs in Lewiston and Auburn identified a total of 29 CSO regulators and 17 cross-connections between the combined sewer and separate storm drain systems. Because it was not economically feasible to sample and monitor each CSO outfall, site-selection criteria for CSO sampling and monitoring stations were used to select representative CSOs in the study area that were significant contributors of CSO flows to receiving waters.

Initially, the location of each CSO regulator and cross connection in Lewiston was ranked as having a low, moderate, or high frequency of activity. The ranking was determined as follows:

- Low frequency of activity, rainfall greater than 0.75 inches
- Moderate frequency of activity, rainfall between 0.25 and 0.75 inches
- High frequency of activity, rainfall less than 0.25 inches.

Because the CSOs in Auburn were not inspected during all storm events, the data were limited. As a result, a ranking of the frequency of activity during specific rainfall volumes (similar to ranking performed for Lewiston) was not possible. Instead, the frequency of activity between the CSOs for the period that data were available was compared. The criteria used to rank the frequency were as follows:

- Low frequency of activity, 0 to 3 overflows recorded
- Moderate frequency of activity, 4 to 7 overflows recorded
- High frequency of activity, 8 to 10 overflows recorded.

The following final monitoring station selection criteria were developed:

- **Land Use**—The tributary area land uses must be representative of the study area in order to define meaningful rainfall/runoff relationships and pollutant loadings for use in analyzing other tributary areas in the study area.

- **Tributary Area**—An important selection criterion for monitoring CSOs is the ability to define the tributary area boundaries. Tributary areas free of external diversions or transfers were sought to ensure that the flows and pollutants measured at the monitoring site were actually produced within the subbasin being monitored rather than being imported from adjacent service areas or exported out of the subbasin. The tributary areas were identified through detailed study of the sewer systems and topographical maps of the study areas.

- **Hydraulic Compatibility**—The hydraulic control sections at the monitoring stations must be stable and compatible with the proposed monitoring equipment.

- **Accessibility**—The sites should be readily accessible from public rights-of-way and during adverse weather conditions and should be located away from high traffic areas.

- **Receiving Water**—The ecological, social, scenic, or recreational importance of the receiving water where the discharge occurs was considered.

Based on field inspection of CSO regulators and cross-connections, a preliminary screening of potential sampling and monitoring stations was performed using the site-selection criteria. Preliminary screening identified a total of 12 potential locations: 9 in Lewiston and 3 in Auburn (see Exhibits 2-8 and 2-9, respectively).

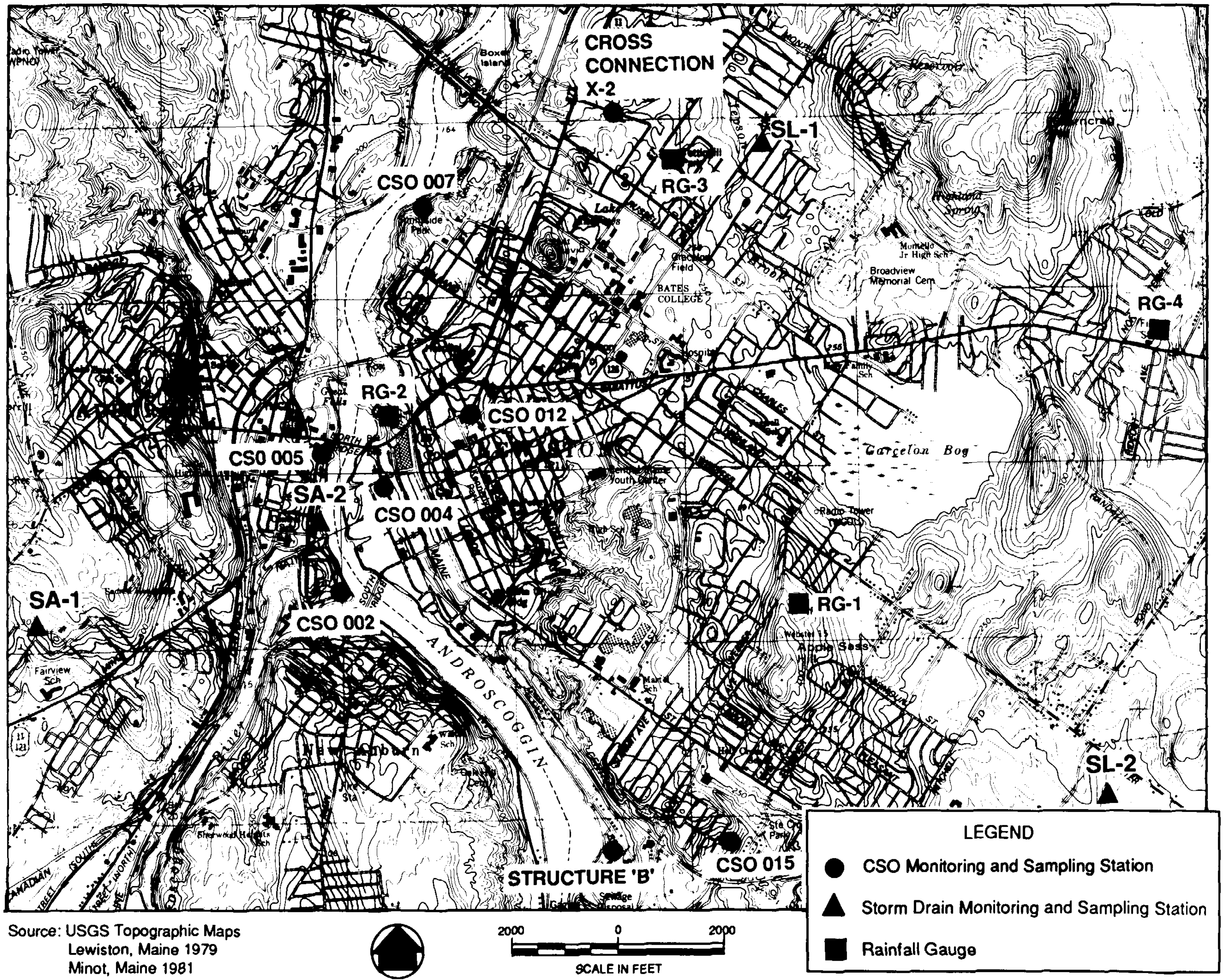
Subsequent to this preliminary screening, field inspections of the potential sampling and monitoring stations were conducted. The purpose of these inspections was to ensure that each location was easily accessible, hydraulically compatible with the equipment to be used, and had a clearly defined tributary area. The eight most advantageous locations were then selected as the final sampling and monitoring stations for CSOs. Exhibit 2-10 shows the locations of the monitoring and sampling locations. As indicated in Exhibit 2-10, these included six CSO regulators in Lewiston (30 percent of the total) and two in Auburn (25 percent of the total). This approach yielded sufficient wet weather data to quantify CSOs in the study area at a reasonable cost.

Exhibit 2-8. Screening of Final CSO Sampling and Monitoring Stations for the City of Lewiston

CSO or Cross-Connection	Advantages	Disadvantages	Selected	Not Selected	Reason Not Selected
003	Overflows frequently, easy accessibility.	Represents mixed land use, small tributary area.		X	Represents small tributary area.
004	Overflows frequently, one of few that serves predominantly commercial/industrial area.	Moderate accessibility due to traffic and ventilation concerns.	X		
005	Overflows to small, stagnant receiving water, potentially large volume of overflow, overflows frequently.	Difficult to monitor CSO flows accurately due to configuration of regulator, potential recreational use of Gully Brook is very limited.		X	Not hydraulically compatible to monitor because it would require at least three flow metering locations.
007	Moderate frequency of overflows, serves predominantly residential area, easy accessibility, medium size service area.	Regulator manhole is shallow making it difficult to install sampling and monitoring equipment.	X		
012	Moderate frequency of overflows.	Represents mixed land use, limited record information on CSO regulator.	X		
013	Overflows frequently.	Represents mixed land use, difficult to monitor CSO flows accurately due to having two tributary regulators.		X	Two flow meters would be required to determine flows and pollutant loads tributary to each regulator.
015	Overflows frequently, represents only CSO discharging directly to Goff Brook, serves predominantly residential neighborhood.	Dry weather flow in Goff Brook is nearly nonexistent, no potential for recreational use.	X		
Structure 'B' @ LAWPCF	Easy accessibility, potentially large volume of bypassed flows, can bypass flow during some plant maintenance procedures.	Represents mixed land use, all CSO regulators in the system are tributary, bypassed flows controlled manually.	X		
X-2	Moderate frequency of overflows, serves predominantly residential neighborhood, discharges to Jepson Brook.	Difficult to monitor CSO flows due to configuration of regulator.	X		

Exhibit 2-9. Screening of Final CSO Sampling and Monitoring Stations for the Auburn Sewerage District

CSO or Cross-Connection	Advantages	Disadvantages	Selected	Not Selected	Reason Not Selected
002	Easy accessibility, discharges to Little Androscoggin River, high frequency of overflows.	Represents mixed land use.	X		
003	Representative of large land area, easy accessibility, discharges to Little Androscoggin River. Moderate frequency of overflow due to plugging of siphon.	Represents mixed land use, overflows infrequently when both siphons operating.		X	Infrequent overflows, difficult to access remote location during off-hours.
005	Easy accessibility, high frequency of overflows.	Represents mixed land use.	X		



Source: USGS Topographic Maps
Lewiston, Maine 1979
Minot, Maine 1981
Lake Auburn East, Maine 1979
Lake Auburn West, Maine 1981

Exhibit 2-10. Lewiston-Auburn CSO and Separate Storm Drain Monitoring and Sampling Locations

EXTENT OF CSO MONITORING AND PARAMETERS ANALYZED

The elements of the CSO monitoring program in each community are summarized below:

- Conducted flow metering for two 6-week periods at six CSOs in Lewiston and two CSOs in Auburn.

- Sampled the CSO monitoring locations during four significant storm events (at least 0.5 inches of rainfall with high rainfall intensity). For each storm event, a maximum of 12 discrete samples were collected during first flush and sustained flow. Initially, samples were taken at 15-minute intervals. Samples for sustained flow were collected in progressively longer time intervals (e.g., 15-, 30-, 60-, 90-minutes) depending on the anticipated duration of the overflow event. Each discrete sample was analyzed for BOD_5, suspended solids, pH, and *E. coli* bacteria. A single flow-weighted composite, prepared from the discrete samples collected with an automatic sampler for one storm event, was analyzed for lead, chromium, zinc, copper, nickel, mercury, silver, cadmium, arsenic, and TKN.

- Collected a grab sample at the CSO monitoring locations during the first flush for one storm event and was analyzed for hydrocarbons, polyaromatic hydrocarbons, PCBs, and herbicides. Specific toxic pollutants, herbicides, and hydrocarbons were selected for analyses based on available analysis methods, experience on other previous similar projects, the probability of their existence within the geographic region, and on water quality analysis industry standards.

- Conducted block testing for all CSO regulators and cross-connections in each community during the two 6-week periods that temporary flow metering was conducted to identify the frequency of CSOs to study area receiving waters.

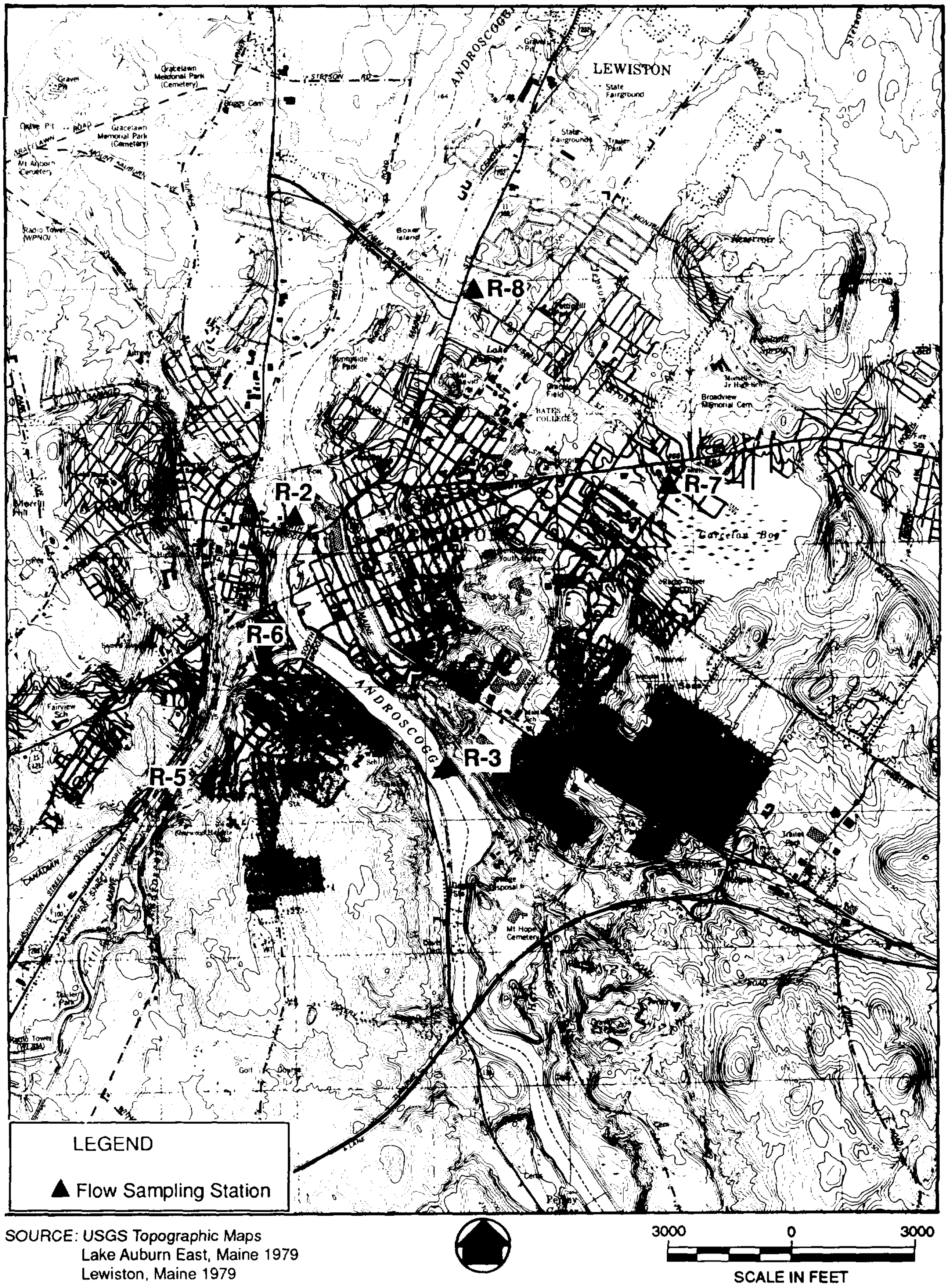
- Conducted coordinated sampling of Lewiston's and Auburn's influent flow at the treatment plant during the four monitored events. Plant personnel collected and analyzed influent samples for BOD_5, suspended solids, and *E. coli* bacteria.

The CSS was monitored using a combination of automatic samplers and hand-operated manual samplers. Continuous flow and velocity measurements in the collection system were also recorded.

SELECTION OF RECEIVING WATER MONITORING STATIONS

To assess the impacts of CSOs on the receiving waters in the study area, water quality data were collected during wet weather periods. CSOs originating from the Lewiston and Auburn sewer systems occur along the banks of the Androscoggin River and the Little Androscoggin River, as well as along drainage brooks tributary to the Androscoggin River, including Goff Brook, Gully Brook, Jepson Brook, and Stetson Brook. Sampling and monitoring were conducted at eight stations to obtain data on CSO-related water quality impacts. The receiving water sampling and monitoring stations were selected based on an examination of the receiving water use, location, importance, and the number, frequency, and relative size of the CSOs compared to that of the receiving water. Field inspections of the area receiving waters were conducted in conjunction with the field inspections of CSO regulators and cross-connections within the Lewiston and Auburn sewer systems. The purpose of these inspections was to determine the locations for sampling and monitoring of receiving waters to assess CSO-related water quality impacts.

Exhibit 2-11 shows the locations of the eight final sampling and monitoring stations for receiving waters in the study area. Four sampling and monitoring stations were selected for the Androscoggin River (stations numbered R-1 through R-4) to assess water quality impacts resulting from CSOs by both Lewiston and



SOURCE: *USGS Topographic Maps*
Lake Auburn East, Maine 1979
Lewiston, Maine 1979

Exhibit 2-11. Lewiston-Auburn Receiving Water Sampling Stations

Auburn. Two sampling and monitoring stations were selected for the Little Androscoggin River (stations numbered R-5 and R-6) to assess water quality impacts resulting from Auburn's CSOs to the river. Two sampling and monitoring stations were selected for Jepson Brook (stations numbered R-7 and R-8) to assess water quality impacts resulting from Lewiston's CSOs to the brook.

RECEIVING WATER MONITORING FREQUENCY AND PARAMETERS

The elements of the monitoring program for receiving waters are summarized below:

- A dry weather sampling survey was conducted, with samples collected at three lateral locations at each of the stations in the Androscoggin and Little Androscoggin Rivers. Samples were collected at only one location at each of the stations along Jepson Brook because it is relatively narrow. Samples were analyzed for *E. coli* bacteria. In-situ measurements were made of pH, dissolved oxygen (DO), and temperature. In-situ measurements for pH, DO, and temperature in the Androscoggin River and Little Androscoggin River were collected in 1-meter vertical profiles at each location. The sample for *E. coli* bacteria was collected near the water surface. In-situ measurements in Jepson Brook were not taken in 1-meter vertical profiles because the channel is relatively shallow.

- Two wet weather receiving water surveys were conducted during the same storm events that CSO sampling and monitoring were performed. Samples were collected during the two storm events at the eight stations in 4- to 6-hour intervals over a 2-day period. pH, DO, and temperature were measured in-situ. The collected samples were analyzed for *E. coli* bacteria.

- As part of the receiving water sampling and monitoring program, a continuous release dye study was conducted on one CSO from each community. The purpose of the dye studies was to evaluate the mixing and dispersion characteristics of the CSOs entering the Androscoggin River. This was accomplished by injecting dyed-water into a CSO conduit to create a simulated CSO and tracking the dye in the river using a fluorometer.

- Temporary flow monitoring at the Jepson Brook drainage channel was conducted for the duration of the sampling and monitoring program to determine the quantity of CSOs conveyed by the channel. The flow monitoring was located where the flow enters a circular conduit, and most CSOs occur upstream.

CSO AND RECEIVING WATER DATA

The collected data illustrate the quality of wastewater flow during dry weather, CSO and storm water flows during wet weather, and receiving water quality during both dry and wet weather. The data indicate impacts on receiving water quality from storm-induced CSOs and storm water discharges. Violations of the *E. coli* bacteria standards in the area receiving water are widespread during wet weather conditions and, to a limited extent, during dry weather.

CSO Data

Wet weather flow and quality data were collected during three storm events and, as indicated Exhibit 2-12, were analyzed for BOD_5, TSS, and *E. coli* bacteria. The data are within typical ranges for CSO quality and generally show a "first-flush" phenomenon. In addition, the collected samples from one storm event were composited and analyzed for selected metals, nutrients, PCBs, herbicides, and hydrocarbons. No PCBs or herbicides were detected in any of the CSO samples. The composite samples were also analyzed for a series of metals (see Exhibit 2-13), which are often present in runoff and CSOs.

Exhibit 2-12. Lewiston-Auburn CSO Quality Data

Location	BOD_5, mg/l		TSS, mg/l		*E. coli* Range
	Range	Average	Range	Average	Colonies/100 ml
Auburn					
CSO 002	41 - 139	43	40 - 200	111	$9.0x10^4$ - $2.1x10^6$
CSO 005	13 - 110	43	38 - 276	108	$1.1x10^5$ - $2.7x10^6$
Lewiston					
CSO 004	5 - 151	59	4 - 230	101	$5.0x10^3$ - $1.3x10^6$
CSO 007	12 - 139	52	28 - 310	123	0 - $7.0x10^5$
CSO 012	5 - 50	25	55 - 144	98	$2.0x10^4$ - $8.8x10^5$
CSO 015	4 - 6	5	21 - 28	25	$6.0x10^4$
X-2	4 - 21	12	14 - 48	34	$1.2x10^5$ - $1.1x10^6$
LAWPCF					
Structure B	31 - 195	25	72 - 200	129	$3.7x10^3$ - $1.2x10^6$
Typical CSO Characteristics$^{(a)}$	60 - 220	--	270 - 550	--	$2.0x10^5$ - $1.1x10^6$

(a) Source: Metcalf & Eddy, Inc., 1991

Exhibit 2-13. Lewiston-Auburn CSO Metals Data

Parameter	Data Range (mg/l)	EPA Freshwater Acute Criteria (mg/l)
Arsenic	.0011 - .0022	.36
Cadmium	.0002 - .0019	.0039
Chromium	.0040 - .0085	.016
Copper	.07 - .15	.018
Lead	.0213 - .0810	.0830
Mercury	<.0002 - <.0004	.0024
Nickel	.002 - .006	1.400
Silver	.0008 - .002	.0041
Zinc	.09 - .13	.12

Receiving Water Data

Wet weather data were collected during two storm events where CSO and storm water sampling were also conducted (Exhibit 2-14). *E. coli* bacteria levels increased significantly in the Androscoggin River during both events. At Station R-1, the upstream station at Gulf Island Pond, little to no bacteria were detected in the samples during either storm event, indicating negligible bacterial contamination entering the study area from upstream areas. During the course of both storm events, bacterial concentrations at the downstream stations on the Androscoggin River were elevated in response to the storm-induced CSOs and storm water discharges.

DO and pH also exhibited a measurable response to the storm-related discharges. In general, when the peak levels of bacteria were observed, the DO levels declined to the lowest values and then rebounded. The variation in DO was generally less than 2 mg/l and, even at the lowest levels, DO was well above the Class C standard of 5.0 mg/l. By contrast, pH exhibited the opposite trend from the dissolved oxygen data. The pH levels generally climbed in response to the storm event.

At the downstream station of the Little Androscoggin River, significant levels of bacteria were measured during the peak periods of the September storm. These levels exceeded the Class C criterion, reaching concentrations of 8,000 colonies/100 ml. The high levels did not persist for an extended period of time. In the October storm, the bacterial levels increased as a result of the storm-induced CSOs, but not to a level that exceeded the Class C criterion.

DO at both stations on the Little Androscoggin indicated a noticeable sag in response to the storm-induced CSOs. Oxygen levels at both stations are normally elevated due to aeration as a result of the dams immediately upstream of each sampling site. DO concentrations declined by approximately 1 to 2 mg/l in the September storm, while less sag was observed during the October storm. During both storm events, the DO sag was temporary, with the oxygen concentrations returning to pre-storm conditions relatively quickly. Because both upstream and downstream stations exhibited the DO sag and increase, upstream influences appear to have a significant impact on oxygen levels.

The highest *E. coli* counts measured in the receiving water sampling program were detected in Jepson Brook. Bacteria levels at both sampling stations exceeded the Class B criterion of 427 colonies/100 ml during the two storm events. Levels of *E. coli* rose significantly in response to the storms. This was expected for the downstream sampling station, Station R-8, due to the number of CSO outfalls and storm drains discharging to the brook. The elevated *E. coli* levels at the upstream end of the brook were not anticipated, however. Similar levels were observed in both storm events.

DO levels exhibited a decrease in response to the storm events. The dissolved oxygen sag was significant, as the lowest value for oxygen measured was 5.0 mg/l, well below the Class B criterion of 7.0 mg/l.

The wet weather receiving water data clearly indicated the impacts of CSOs and storm drain discharges on the local receiving waters during storm events. These data, together with the background dry weather water quality data, CSO and storm drain flow and load data, and the continuous dye study, provided the basis for the CSO and receiving water modeling effort described in the next case study, following Section 2.6.2.3.

Exhibit 2-14. Lewiston-Auburn Receiving Water *E. Coli* Data

	Dry Weather		Wet Weather			
			September 26-28, 1993		October 12-14, 1993	
Station	**Range (colonies/100ml)**	**% of Samples Above Standards**	**Range (colonies/100 ml)**	**% of Samples Above Standards**	**Range (colonies/ 100 ml)**	**% of Samples Above Standards**
Androscoggin River						
R-1	0	0	0 - 20	5	0	0
R-2	480 - 2,280	67	0 - 1,440	8	0 - 980	4
R-3	100 - 135	0	160 - 6,800	58	10 - 3,500	25
R-4	280 - 355	0	60 - TNTC	71	90 - TNTC	29
Little Androscoggin River						
R-5	5 - 115	0	0 - 810	0	0 - 210	0
R-6	35 - 80	0	0 - 8,000	17	0 - 280	0
Jepson Brook						
R-7	60	0	20 - 2,400	33	40 - 2,500	31
R-8	115	0	40 - 30,000	83	140 - TNTC	62

Note: Class C Standard: Instantaneous level of 949 colonies/100 ml
TNTC = Too numerous to count

2.6 COMBINED SEWER SYSTEM AND RECEIVING WATER MODELING

Section 2.6 summarizes the use of mathematical models to characterize CSSs and evaluate CSO control alternatives and CSO impacts to receiving waters. This section discusses modeling objectives, as well as model selection and application, for the CSS and receiving water. As with other sections of this chapter, the intent is to provide an introduction to the information presented in greater detail in EPA's guidance on monitoring and modeling (1995d).

2.6.1 Combined Sewer System Modeling

This section briefly summarizes CSS modeling objectives, model selection strategy, and model development and application, including model calibration and validation and the different types of model simulations (e.g., long-term continuous versus storm event simulations).

2.6.1.1 CSS Modeling Objectives

The primary objective of CSS modeling is to understand the hydraulic response of the CSS to a variety of precipitation and drainage area inputs. CSS modeling can also be used to predict pollutant loadings to receiving waters. Once the model is calibrated and verified, it can be used for numerous applications that support CSO planning efforts, including (EPA, 1995d):

- To predict overflow occurrence, volume, and, in some cases, quality for rain events other than those which occurred during the monitoring phase. These can include a storm event of large magnitude (long recurrence period) or numerous storm events over an extended period of time.

- To predict the performance of portions of the CSS that have not been extensively monitored.

- To develop CSO statistics, such as annual number of overflows and percent of combined sewage captured in response to the presumption approach of the CSO Control Policy.

- To optimize CSS performance as part of NMC implementation. In particular, modeling can assist in locating storage opportunities and hydraulic bottlenecks and demonstrate that system storage and flow to the POTW are maximized.

- To evaluate and optimize control alternatives, from simple controls described under the NMC to more complex controls proposed in a municipality's LTCP. An example of a simple control would be to raise weir heights to increase in-line storage. The model can be used to evaluate the resulting reductions in CSO volume and frequency.

CSS Modeling and the CSO Control Policy

The CSO Control Policy "*...supports the proper and effective use of models, where appropriate, in the evaluation of the nine minimum controls and the development of the long-term CSO control plan*" (II.C.1.d). Every CSS does not need to be analyzed using complex computer models. In simple systems, computation of hydraulic profiles using basic equations (e.g., Manning's equation) and spreadsheet programming might be sufficient for identifying areas where certain measures can be implemented and for evaluating their hydraulic effect. Mathematical simulation can play an important role in credibly predicting the performance of any CSS, however. In many cases, especially in complex CSSs that have looped networks or sections that surcharge, a hydraulic computer model will be a useful tool to assess both NMC and LTCP options.

As discussed in the CSO Control Policy, continuous simulation refers to the use of long-term rainfall records (from several months to several years) rather than rainfall records for individual storms (design storms). Continuous simulation has several advantages: (1) simulations are based on a sequence of storms so that the additive effect of storms occurring close together can be examined, (2) storms with a range of characteristics are included, and (3) in cases where the municipality intends to use the presumption approach to WQS attainment, long-term simulations enable the development of performance criteria based on long-term averages, which are not readily determined from design storm simulations. Continuous simulation need not involve the application of extremely complex models. Models that simulate runoff without complex simulation of sewer system hydraulics (e.g., STORM, SWMM RUNOFF) might be appropriate if rough estimates are acceptable or for CSSs with simple basic hydraulics.

Modeling can support either the demonstration or presumption approach of the CSO Control Policy. The demonstration approach requires demonstration that a control plan is adequate to meet CWA requirements. Meeting this requirement can necessitate detailed CSS modeling to define inputs to receiving water impact analyses. The presumption approach, however, involves numeric limits on the number or volumes of CSOs. This approach may require less modeling of receiving water impacts. However, the presumption approach is acceptable only if "*...the permitting authority determines that such presumption is reasonable in light of the data and analysis conducted in the characterization, monitoring and modeling of the system and the consideration of sensitive areas...*" (II.C.4.a).

2.6.1.2 CSS Model Selection

Several guidance documents present strategies for selecting the appropriate CSS model (EPA, 1995d; Shoemaker et al., 1992; Donigian and Huber, 1991; WPCF, 1989). This section briefly summarizes the model selection process.

CSS modeling involves two distinct elements—hydraulics and water quality:

- Hydraulic modeling consists of predicting flow characteristics in the CSS. These characteristics include the different flow rate components (i.e., sanitary, infiltration, and runoff), the flow velocity and depth in the interceptors and sewers, and the CSO flow rate and duration.
- CSS water quality modeling consists of predicting the quality of the combined sewage in the system, particularly at CSOs and at the treatment plant. Water quality is measured in terms of critical parameters, such as bacterial counts, and concentrations of constituents, such as BOD, suspended solids, nutrients, and toxic contaminants.

Some models include both hydraulic (e.g., number and magnitude of overflows) and water quality components, while others are limited to one or the other. The type and complexity of modeling depends on the aspect of the CSO Control Policy being evaluated. Exhibit 2-15 shows the different combinations of hydraulic and contaminant simulation that might be appropriate under different circumstances.

Exhibit 2-15. Relevant CSS Hydraulic and Contaminant Transport Modeling for the CSO Control Policy

	CSS Hydraulic Modeling	CSS Contaminant Transport Modeling
Nine Minimum Controls		
Demonstrate implementation of the nine minimum controls	Simple to complex models of duration and peak flows	Limited - Not usually performed
Presumption Approach		
Limit number of overflow events per year	Long-term continuous simulations (preferred) or design storm simulation	Limited - Not usually performed
Capture at least 85% of wet weather combined sewage volume per year	Same	Limited - Not usually performed
Eliminate or reduce mass of pollutants equivalent to 85% capture requirement	Same	Use measured concentrations or simplified transport modeling
Demonstration Approach		
Demonstrate that a selected control program is adequate to meet the water quality-based requirements of the CWA	Design storm simulations or long-term continuous simulations	Use measured concentrations or contaminant transport simulations

Source: EPA, 1995d

Hydraulic Models

The hydraulic models appropriate for CSS simulations can be divided into three main categories (EPA, 1995d):

- **Water-budget models** based on Soil Conservation Service (SCS) curve numbers, runoff coefficients, or other similar method for the generation of flow. These models can estimate runoff flows influent to the sewer system and, to a lesser degree, flows at different points in the system. However, these models do not actually simulate flow in the CSS and, therefore, do not predict such parameters as the flow depth, which frequently control CSO occurrence.

- **Models based on the kinematic wave approximation** of the hydrodynamic equations. These models can predict flow depths and, therefore, overflows in systems not subject to surcharging or backups (backwater curves).

- **Complete, dynamic models** are based on the full hydrodynamic equations and can simulate surcharging, backwaters, or looped systems.

Examples of these three classes of models are the RUNOFF, TRANSPORT and EXTRAN blocks, respectively, of the EPA Storm Water Management Model (SWMM). EPA's guidance on monitoring and modeling lists the capabilities and limitations of these models (1995d). The following list provides criteria for selecting a CSS hydraulic model:

- Ability to accurately represent the physical characteristics and flow processes relevant to CSS performance
- Extent of monitoring activity underway
- Need for long-term simulations
- Needs for CSS water quality simulations
- Needs for receiving water quality analysis
- Ability to assess the effects of control alternatives
- Use of the presumption or demonstration approach
- Ease of use and cost.

Water Quality Models. CSS water quality models can be divided into the following categories:

- **Land Use Loading Models**—These models provide pollutant loadings as a function of the distribution of land uses in the watershed. Although there are variations, the basic approach is to attribute to each land use a concentration for each water quality parameter. The overall runoff quality is then calculated as a weighted sum of these concentrations. Pollutant concentrations for the different land uses can be derived from local data bases or the NURP studies, if local data are not available (local data are strongly recommended).

- **Statistical Methods**—A more sophisticated version of the previous method is based on a derived frequency distribution for Event Mean Concentrations (EMCs), usually based on lognormality assumptions. Documents on NURP discuss the use of statistical methods to characterize CSO quality in detail (Hydroscience, Inc., 1979) and in summary form (EPA, 1983).

- **Buildup/Washoff Models**—These models attempt to deterministically simulate the basic processes that control the quality of runoff. This approach can consider such factors as time periods between events, rainfall intensity and best management practices. Calibration is required, however.

For some pollutants, chemical reactions and transformations within the CSS might be important. Few models address this topic, and calibration is difficult because loading into the CSS is never exactly known. If a CSS water quality model is warranted, criteria for the selection of a model for the LTCP include the following (EPA, 1995d):

- Needs of the receiving water quality simulation
- Ability to assess control and best management practice (BMP) alternatives
- Ability to accurately represent significant characteristics of pollutants of concern
- Capability for pollutant routing
- Expense and ease of use.

EPA and Army Corps of Engineers have developed numerous hydraulic and water quality models, ranging from simple to complex, which are available for use. A description of these models and their characteristics is beyond the scope of this guidance. EPA's guidance on monitoring and modeling provides detailed information (EPA, 1995d).

2.6.1.3 CSS Model Application

In modeling terminology, the model's level of discretization (i.e., coarse versus fine scale) determines the accuracy with which it will represent the geometry of the CSS or the land characteristics of the drainage basin. In determining the appropriate level of discretization, the modeler must ask the following questions. What is the benefit of a finer level of detail? What is the penalty (in accuracy) in not modeling a portion of the system? For systems controlled hydraulically at their downstream ends, modeling only the larger downstream portions of the CSS might be successful. This strategy would not be wise, however, if it is known that surcharging in upstream areas of the CSS (in small pipes) occurs, limiting flows. In this case, a simulation neglecting the upstream portion of the CSS would overestimate flows in the system.

In some cases, it is difficult to determine ahead of time the appropriate level of detail. In these cases, the modeler can take a phased approach, determining the value of additional complexity or data added in the previous step.

A model general enough to fit a variety of situations typically should be adjusted to the characteristics of a particular site and situation. Modelers use model calibration and verification first to perform this adjustment and then to demonstrate the credibility of the model simulation results. Using an uncalibrated model might be acceptable for screening purposes. Without supporting evidence, however, the uncalibrated result might not be accurate. To use model simulation results for evaluating control alternatives, the modeler should supply evidence demonstrating the model's reliability.

Model Calibration

Calibration is the process of using a set of input data and then comparing the results to measurements of the system. For example, a CSS hydraulic model used to simulate overflows is calibrated by running the model using measured rainfall data to simulate attributes of CSOs, such as volume, depth, and timing. The model results are then compared to actual measurements of the overflows. The modeler then adjusts parameters, such as the Manning roughness coefficient or the percent imperviousness of subcatchments, and runs the model a second time, again comparing the results to observations. Initial calibration runs often point to features of the system, such as a connection or bypass, that might not have been evident based on the available maps. The modeler repeats this procedure until satisfied that the model produces reasonable simulations of the overflows.

Verification

Verification is the process of testing the calibrated model using one or more independent data sets. Verification is important to modeling because it assesses whether the model retains its generality (i.e., a model that has been adjusted extensively to match a particular storm exactly might lose its ability to predict the effects of other storms). In the case of the hydraulic simulation, the model is run without any further adjustment using an independent set of rainfall data. Then, the results are compared to the field measurements collected concurrently with these rainfall data. If the results are suitably close, the model is considered to be verified. The modeler can then use the model with other sets of rainfall data or at other outfalls. If verification fails, the modeler must recalibrate the model and verify it again using a third independent data set. If the model fails a verification test, the next test must use a new data set. Re-using a data set from a previous verification test does not constitute a fair test, because the modeler has already adjusted model parameters to ensure compliance.

2.6.2 Receiving Water Modeling

This section describes the use of models in evaluating CSO impacts on receiving waters.

2.6.2.1 Receiving Water Modeling Objectives

The goal of the receiving water analysis (which may include modeling) is to characterize CSO impacts on receiving water quality and to predict the improvements from different CSO controls.

Receiving Water Quality Modeling and the CSO Policy

Under the CSO Control Policy, a municipality should develop an LTCP that adopts either the demonstration or the presumption approach to attainment of WQS. The demonstration approach is based on adequately demonstrating that the selected CSOs will provide for the attainment of WQS, including designated uses in the receiving water. The presumption approach does not explicitly call for analysis of receiving water impacts. The presumption approach usually involves at least screening-level models of receiving water impacts, however, because the approach will not apply if the NPDES permitting authority determines that the LTCP will not result in attainment of CWA requirements.

2.6.2.2 Receiving Water Model Selection

Three factors need to be considered when selecting a receiving water model:

- The type and physical characteristics of the receiving water body. Rivers, estuaries, coastal areas, and lakes typically require different models.
- The water quality parameters that need to be modeled, which include bacteria, dissolved oxygen, suspended solids, toxics, and nutrients. These parameters are affected by hydrodynamics and by other processes (e.g., die-off for bacteria, settling of solids, biodegradation for DO, adsorption for metals), which have different time scales (e.g., hours for bacterial die-off, days for biodegradation) and different kinetics. The time scale in turn affects the extent of the receiving water modeled (e.g., a few hundred feet for bacteria to a few miles for dissolved oxygen).
- The number and geographical distribution of discharge points and the need to simulate sources other than CSOs.

Receiving water modeling may consist of hydrodynamic modeling (to assess flow conditions) and/or water quality modeling. Both hydrodynamic and water quality receiving water models can be *steady-state* or *transient*. Steady-state models assume that conditions do not change over time, while transient models can simulate time varying conditions. Depending on the application, various combinations of steady-state and transient models can be used for receiving water models.

Hydrodynamic Models

For simple cases, hydrodynamic conditions can be determined from the receiving water monitoring program; otherwise, flow conditions are calculated using a hydrodynamic model. The main purpose of a hydrodynamic model is to provide the flow conditions, characterized by the water depth and velocity, for which water quality must be predicted. Because the same basic transport equations apply, the major models for receiving waters can generally simulate more than one type of receiving water body (i.e., rivers, estuaries, coastal areas, lakes). Whether a model can be used with a particular hydraulic regime depends upon several factors: whether the model is a one-, two-, or three-dimensional simulation; the ability of the model to handle specific boundary conditions, such as tidal boundaries; whether the model assumes steady-state conditions or allows for time varying pollutant loading. In general, steady-state loading models cannot accurately model CSO problems that require analysis of far-field effects.

Water Quality Models

Because CSO loads are typically delivered in short pulses during storm events, the selection of appropriate time scales for receiving water modeling depends upon the time and space scales necessary to evaluate the WQS. If analysis requires determining the concentration of a toxic at the edge of a relatively small mixing zone, a steady-state mixing zone model might be satisfactory. When using a steady-state mixing zone model in this way, the modeler should apply appropriately conservative assumptions about instream flows during CSO events. For pollutants such as oxygen demand, which could result in an impact over a period of several days and often several miles downstream of the CSO, incorporating the pulsed nature of the loading might be warranted. Assuming a constant loading is much simpler (and less costly) to model, however, it is conservative (i.e., leads to impacts larger than expected). For pollutants such as nutrients where the response time of the receiving water body might be slow, simulating only the average loading rate might suffice.

Detailed receiving water simulation models do not need to be implemented in all situations (EPA, 1995d). In some cases, the use of dilution and mixing zone calculations or simulation with simple spreadsheet models is sufficient to assess the magnitude of potential impacts or to evaluate the relative merit of various control options. EPA's guidance on monitoring and modeling discusses the simulation of different water quality parameters in rivers, lakes, and estuaries and summarizes available water quality models (EPA, 1995c).

2.6.2.3 Receiving Water Model Application

The application of receiving water models for CSO programs includes the following steps:

- Development of the model
- Model calibration and verification

- Model analysis
- Interpretation of results.

Although the general principles of establishing the data needs for receiving water models are similar to those discussed for CSS models, the specific requirements depend upon the hydraulic regime and model employed (EPA, 1995d). For specific input data requirements, the municipality should refer to the documentation for individual models, the relevant sections of the *Guidance for State Water Monitoring and Wasteload Allocation Programs* (EPA, 1985), or to texts such as *Principles of Surface Water Quality Modeling and Control* (Thomann and Mueller, 1987).

Model Calibration and Verification

Like CSS models, receiving water models need to be calibrated and verified. This is accomplished by running the model to simulate events for which receiving water hydraulic and quality monitoring was conducted and comparing the model results with the measurements. Calibration and verification are often conducted in two steps: first for receiving water hydrodynamics and then for water quality. Calibration of a receiving water quality model typically cannot be achieved with the same degree of accuracy as that of a CSS model for the following reasons:

- Pollutant loadings, which are required input to the receiving water quality model, are typically not known accurately, whether they are determined by monitoring or modeling of the CSS system.

- Because three-dimensional receiving water models are still not commonly available and used in CSO control efforts, receiving water models involve spatial averaging (over the depth, width, or cross-section). Thus, model results are not directly comparable with measurements, unless the results have sufficient spatial resolution to allow comparable averaging.

- Loadings from non-CSO sources (such as storm water), upstream boundaries, other point sources, and atmospheric deposition, are frequently not known.

- Receiving water hydrodynamics are affected by numerous factors which are difficult to account for, including fluctuating winds, large-scale eddies, and density effects.

These uncertainties, however, make calibration all the more important to ensure that the model reasonably reflects receiving water characterization data. *Measures of Verification, Workshop on Verification of Water Quality Models* presents a detailed discussion of the validation procedure for water quality models (Thomann, 1980).

Model Analysis

Analyses can be conducted using single events or long-term simulations. Single event simulations are usually favored when using complex models, although advances in computer technology keep extending the limits of what can practically be achieved. Long-term simulations can provide predictions of water quality impacts on an annual basis.

While a general goal might be to determine the number of WQS exceedances, models allow evaluation of these exceedances using different measures, such as duration of exceedance at critical points (e.g., beaches), acre-hours of exceedance, and mile-hours of exceedance along a shore. These provide a more refined measure of CSO impacts on water quality and of the improvements that would result from implementation of different CSO controls. A frequently used approach is to conduct separate simulations for CSO loadings alone to gage the CSO impacts relative to other sources. Chapter 3 discusses the application of this approach. This procedure is appropriate because the equations governing receiving water quality are linear and, consequently, the effects are additive.

It is useful to assess the sensitivity of modeling results due to variations and changes in parameters, rate constants, and coefficients. Results of such sensitivity analyses determine the key parameters, rate constants, and coefficients that merit particular attention in evaluating CSO control alternatives. The modeling approach should accurately represent features that are fully understood and also be supported by sensitivity analyses to develop an understanding of the significance of other factors or features that are not as clearly defined. Sensitivity or uncertainty analyses can define the extent of variation in predicted future water quality conditions due to a variation of water quality parameters or factors that are not well defined or well established.

Interpretation of Results

Using averages over space and time, simulation models predict CSO volumes, pollutant concentrations, and other variables of interest. The extent of this averaging is a function of the model structure, model implementation, and resolution of the input data. The purpose of modeling generally includes assessing the attainment of WQS, the number or volume of overflow events, or other conditions proposed by the permit writer. The model's space and time resolution should match that of the necessary analysis. For instance, the applicable WQS can be expressed as a 1-hour average concentration not to exceed a given concentration more than once every 3 years on average. Spatial averaging can be represented by a concentration averaged over a receiving water mixing zone or implicitly by the specification of monitoring locations to compare results with in-stream criteria. In any case, the municipality should note whether the model predictions use the same averaging scales required in the permit or relevant WQS.

The key output of the receiving water modeling is the prediction of expected conditions due to CSO control alternatives and their associated reductions of pollutant loads. In most cases, the municipality will use the modeling results to determine which load reductions are necessary for achieving WQS.

CASE STUDY: LEWISTON-AUBURN, MAINE—CSO AND RECEIVING WATER MODELING

The CSSs in Auburn and Lewiston were analyzed to determine the flow quantities and pollutant loads discharged to area receiving waters from CSSs within each community. The CSO analysis was accomplished using the Storm Water Management Model (SWMM), which mathematically simulates the time varying nature of CSOs, including both quantity and quality variation over time, under various hydrologic conditions. As part of the analysis, the CSO response to short-term rainfall, including a range of design storm events, and the effects of long-term rainfall, using annual precipitation records, were evaluated for existing and future no-action conditions.

In addition, the Androscoggin and Little Androscoggin Rivers were analyzed to assess the impacts of CSOs on receiving waters. This analysis focused on *E. coli* bacteria levels in the two rivers because the wet weather monitoring program indicated that only this criterion was exceeded.

CSO MODEL DEVELOPMENT

To use SWMM to determine the CSO flows and loads discharged by each community, the physical characteristics of each CSS and their combined sewer tributary areas were discretized into individual elements for model input. For this study, a coarse level of discretization was used to characterize the CSOs. The level of discretization involved modeling the main trunk sewers, interceptors, and CSO regulators in detail and modeling the area tributary to each CSO as a single drainage area, or subcatchment, depending on land use. The discretization provided the necessary degree of accuracy for the hydraulics controlling CSOs, while maintaining an economical analysis effort for the study area.

SWMM was used to predict the quantity and quality of CSOs from both the Auburn and Lewiston CSSs under various conditions, which were not directly measured, and under proposed future conditions. First, however, the model's ability to predict such conditions was demonstrated through the following steps:

- Flow monitoring, block testing, rainfall monitoring, and quality sampling during dry weather and wet weather storm events were conducted, as described in the case study following Section 2.5.3.6.
- Necessary input data for SWMM were established by reviewing existing record information and field measurements.
- SWMM was run with data collected during one storm event, and the model results were compared to the observed field results. Physical parameters were adjusted within acceptable limits to obtain the "best fit" between observed and computed data.
- A second storm event was then run using SWMM with the same physical parameters used to model the first storm. Model results were compared with observed data, thereby establishing confidence in the model's results.
- Flow and pollutant concentration data from monitored CSOs were extrapolated to the remainder of the study area in order to model the entire area.
- Overall study area simulations were compared with block testing data from non-monitored locations to confirm accurate predictions.

CSO MODEL CALIBRATION AND VERIFICATION

The SWMM models were calibrated using the flow and quality data collected at the eight monitored CSOs and the treatment plant during September 26-28, 1993. Several parameters were used to assess the accuracy of the calibration process, including:

- Duration, peak flow, and volume of CSOs
- Hydrographs of measured flows versus predicted model results
- Magnitude and timing of peak flow and quality values.

To achieve agreement between measured values and predicted modeling results, adjustments were made to the hydraulic and hydrologic input data developed for each system. The major factor affecting the magnitude of runoff peaks and volumes was the percent of impervious area of the individual subcatchments. The initial values for percent imperviousness were based on the review of existing sewer record plans and topographical maps, which show the study area drainage patterns. Consequently, these values were considered likely candidates for adjustment during calibration. A second parameter that affected the magnitude and timing of peak flows is the subcatchment width. Other factors that could alter the timing and magnitude of peak flows included ground slope and surface storage, as well as resistance parameters. These factors were also used during calibration, although their impact on runoff peaks and volumes is significantly less than the percent of impervious area and the subcatchment width.

For the calibration of CSO quality, pollutant washoff coefficients and constituent fractions of dust and dirt were the major adjustment parameters. The pollutant washoff coefficients and constituent fractions affect the magnitude of surface runoff pollutant concentrations, while the washoff coefficients alter the distribution of the pollutant concentration over time during a storm. Once a generally close match was obtained between actual and model results, the models were verified. Verification involved running additional storms without adjusting model parameters. The models were verified using the October 12-13, 1993 storm event, which yielded 1.22 inches of rainfall over a 13-hour period, activating all of the monitored CSOs for a sustained period of time.

CSO MODEL RESULTS

Once the model was calibrated and verified, CSO flow and pollutant loads were simulated for a range of developed design storms. Design storms with return periods of 1 week, 1 month, 3 months, 6 months, 1 year, 2 years, 5 years, and 10 years were selected for analysis. The design storms were run in SWMM to determine the storm size required to trigger CSOs under existing and future no-action conditions.

Total CSO volume and pollutant loads were estimated for the 1-week through 10-year design storms for existing conditions. These served as the basis for sizing and evaluating CSO control alternatives. Once the baseline existing conditions had been developed, the future no-action conditions were analyzed. These conditions changed from the existing condition as a result of increases in population or major projects scheduled in the study area that would affect the quantity and quality of CSOs. For the purposes of this study, the CSO analysis for future conditions was based on estimates of wastewater flows and pollutant loads for a 20-year planning period, or until the year 2015.

Values were estimated for annual population growth, domestic wastewater contribution rates, annual increase in commercial/industrial flows, and pollutant loadings for domestic and commercial/industrial wastewater. The projected incremental growth, together with the flow and load values for the baseline year, were then totaled to provide flow and load estimates for the year 2015 and project incremental growth in wastewater flow and pollutants loads between the baseline year (1992) and the planning year (2015).

In comparison, the results for this future no-action condition showed a slight increase in CSO volumes and pollutant loads over existing conditions.

In addition to the design storm study outlined, the continuous simulation mode of SWMM was used to develop annual CSO flows and loads for the study area. Hourly precipitation data for a long-term period were used to generate CSO flows and loads during wet weather periods, while pollutant buildup on subcatchment areas was calculated during dry weather periods. A historical rainfall analysis identified 1974 as the most representative year for the period of record, in which 95 storms occurred totaling 43.3 inches of rainfall. The hourly precipitation data recorded for 1974 were then input to the SWMM models for a continuous simulation of annual CSO flows and loads in the study area under existing and future no-action conditions.

RECEIVING WATER MODEL DEVELOPMENT

To assess CSO impacts on area receiving waters, the Androscoggin and Little Androscoggin Rivers were analyzed. The wet weather monitoring data indicated that the existing CSOs only result in exceedance of the criterion for *E. coli* bacteria. For this reason, the receiving water analysis conducted in this study only considered *E. coli* bacteria levels within the Androscoggin and Little Androscoggin Rivers under existing and future no-action conditions.

After reviewing available approaches to conducting the receiving water analysis, a simplified modeling effort was selected to provide a useful definition of the duration of impacts from wet weather discharges at a relatively low cost. The simplified modeling approach was used, therefore, for the analysis of the two major rivers in the study area. In addition, CSOs in Lewiston affect several small receiving waters, including Goff Brook, Gully Brook, Jepson Brook, and Stetson Brook. With the exception of Gully Brook, there is very little or, in some cases, no flow in these brooks during dry weather. Any CSO to these receiving waters causes significant exceedances of bacterial standards. Gully Brook, an extension of the Upper Canal from the Androscoggin River, flows within and normally is contained within the CSS, only discharging to the canal during a CSO event. Consequently, Gully Brook was not considered as a separate receiving water, but as part of the Androscoggin River.

Jepson Brook is also somewhat unique in the study area. Once a natural drainage brook tributary to the Androscoggin River, Jepson is now a concrete-lined trapezoidal drainage channel that receives discharges from 15 CSOs and many separate storm drains. Although designated as a Class B receiving water suitable for swimming and aquatic life, there is no evidence that either use exists in Jepson Brook. The base flow in the brook is quite low, less than 0.5 cfs, and similar to the other brooks, any CSO will cause exceedances of the water quality criteria for bacteria.

An adaptation of the CHARLESA model was used to simulate CSO and storm water impacts on the Androscoggin and Little Androscoggin Rivers. The CHARLESA model, developed by the Massachusetts Institute of Technology, is a simplified version of the one-dimensional, time-dependent QUAL2EXP water quality model. This modified version of the QUAL2EXP model only simulates the transport and first-order decay (bacterial die-off) of *E. coli* bacteria.

The receiving water model requires discretization of the river into a number of model "elements," each representing a short length of the river. The model determines the volume of water and pollutant load passed from one element to the next over short-time intervals. Pollutant loads from CSOs are added to elements that correspond to outfall locations along the river banks. Water quality is assumed to be fully mixed laterally. The hydraulic portion of the model is semi-transient with constant model element volumes but varying flows. Conservation of mass (continuity) is ensured by increased river discharge downstream of inflows. A completely transient hydraulic model was determined not to be necessary for the scope of the modeling effort in this project.

Model inputs included river segment volumes (river geometry), upstream flows and pollutant loads, and source flows and pollutant loads. River geometry was determined using cross-sections from previous hydraulic modeling efforts performed by the USGS to delineate flood zones along the river. Using these cross-sections and river discharge information recorded by the USGS gaging station in Auburn, river surface elevations were estimated for both monitored rainfall events (September 26-27 and October 12-13) and used to determine river segment volumes. Upstream flows were set equal to the measured river discharges. Upstream bacterial loads were assumed to be negligible.

CSO loads from both communities were estimated using SWMM results, discussed previously. Other source loadings included the flow and pollutant load contributions from the Little Androscoggin River and Jepson Brook, as well as dry weather overflows in Auburn during the time of the sampling and monitoring period. Pollutant loadings from the Little Androscoggin River were simulated using the receiving water model, while the dry weather overflows were estimated based on the monitoring data collected on the rivers during dry weather conditions.

RECEIVING WATER MODEL CALIBRATION AND VERIFICATION

The model was calibrated and verified to determine the optimum dispersion and decay coefficients for use in simulations of future conditions and to ensure that the model could reasonably reproduce river quality for a known rainfall event. The two storms during which water quality sampling was performed were used for calibration and verification of the model. The calibration runs were performed with a decay coefficient of 1.0 (/day) and a longitudinal dispersion coefficient of 5.0 (m^2/sec). Additional runs of the model with varied coefficients did not change model results in any significant manner. It was observed that, due to the huge variations in loadings and the relatively large volume of clean upstream flow, the modeled pollutant concentrations were dominated by advection effects (the transport of pollutants due to movement of the river water) with relatively little decay occurring within the model bounds. Simulations of the verification storm that occurred on October 12-13, 1993, confirmed the reasonable accuracy of the water quality models.

RECEIVING WATER MODEL RESULTS

Once the receiving water models were calibrated and verified, water quality simulations for the full range of design storms were performed for existing and future no-action conditions under the worst case scenario of 7-day, 10-year low flow (7Q10) conditions. Because the stages of both the Androscoggin and Little Androscoggin Rivers are regulated extensively by the various dams in the Lewiston-Auburn area, however, a true quantification of the 7Q10 flow condition was not possible. For the purpose of these simulations, therefore, the design flows for the Androscoggin and Little Androscoggin Rivers were assumed to be the minimum release requirements for the Lewiston Falls Dam on the Androscoggin River and the lower Barker Mills Dam on the Little Androscoggin River.

CSO pollutant loads, developed in the CSS analyses, were input to the water quality model for each design storm simulation. In general, water quality criteria exceedances in the Androscoggin River occurred for a longer period of time for the future condition simulations than the calibration and verification runs with similar rainfall. This indicated that water quality conditions depend greatly upon the flushing capabilities of the Androscoggin River. Whereas the design flow was only 1,000 cfs, the average flows for the calibration and verification storm events were 2,590 and 3,370 cfs, respectively. A similar trend was also observed in the modeling of the Little Androscoggin River. The design storm simulations also indicated that storms in excess of the 1-month storm do not increase significantly the period of water quality criteria exceedances. Thus, larger quantities of pollutants would be expected to increase the magnitude of exceedances, but not the duration. The analysis demonstrated that wet weather discharges cause exceedances of the WQS for bacteria in all area receiving waters.

CHAPTER 3

DEVELOPMENT AND EVALUATION OF ALTERNATIVES FOR CSO CONTROL

This chapter provides guidance on the development and evaluation of alternatives for long-term control of combined sewer overflows (CSOs). The information presented includes the following:

- The role of public participation and the need to coordinate with the National Pollutant Discharge Elimination System (NPDES) permitting and State water quality standards (WQS) authorities
- An overview of general approaches for developing the long-term control plan (LTCP), including the demonstration and presumption approaches for showing compliance with CWA requirements, as well as small system considerations
- Specific approaches to and aspects of developing alternatives, including definition of CSO control goals, identification of control measures, sizing, cost, and siting issues
- Approaches for evaluating alternatives, including cost/performance evaluations, non-monetary factors, and financial capability.

The chapter concludes with two case studies.

3.1 PUBLIC PARTICIPATION AND AGENCY INTERACTION

It is important to develop and maintain avenues for public involvement throughout LTCP development. Opportunities for public involvement in the assessment of existing conditions and the development of system monitoring information were presented in Chapter 2. During the development and evaluation of alternatives, the goal of the public participation program should be to involve citizens in the development of alternative solutions that protect the local waterways and consider the financial impacts to the community as a whole.

During development and evaluation of CSO control alternatives, the following key information can be presented to the public as it is developed:

- Water quality goals for each receiving water segment
- CSO control goals for each receiving water segment as developed under the presumption and/or demonstration approach options
- Types of control alternatives available to meet CSO control goals
- CSO control alternatives identified to meet the control goals
- The process of evaluating and comparing various alternatives for CSO control.

These issues can be technically complex and require effort and imagination to present in a manner that will be understandable to the public. Technical jargon and complex charts and figures might be useful to and understandable by engineers but might not be clear or understandable to the lay person. Public confusion or lack of understanding can lead to skepticism, hostility, and the inability or unwillingness to participate. These reactions can be avoided by understanding the audience and taking the time to arrange and present the information in an appropriate format. A well-designed public participation program will involve the public in the decision-making process as it proceeds.

Citizen advisory committees can serve as liaisons between municipal officials, the general public, the NPDES permitting agency, and the State WQS agency. Public meetings, public hearings, workshops, and discussion panels provide effective forums to explain the alternatives and to obtain input from as many neighborhood, business, environmental, and civic organizations as possible. These meetings should be well advertised in local papers and on local radio stations. Interested parties should be encouraged not only to speak but also to provide written comment and input. The public participation program can include activities designed to educate children about the CSO program, informational material distributed through general mailing lists or inserted into monthly utility bills, and media briefings concerning specific projects or issues.

Interaction with the NPDES permitting authority and State WQS authority should continue during development and evaluation of CSO control alternatives with a sharing of the technical information noted previously. It is important to gain ongoing agency input during this phase for many reasons. Expectations for CSO control measure performance and interpretations of wet weather data are often subject to debate, due to such factors as the relative shortage of historical data and the inherent variability of wet weather flows. The community and the regulatory agency should agree on such fundamental issues early in the project to avoid costly misunderstandings later. States have also developed their own CSO strategies, which might differ from the EPA CSO Control Policy. In these cases, a municipality should ensure through agency coordination that its LTCP addresses the appropriate State and Federal policy requirements. In addition, if CSOs occur to sensitive areas, the municipality should consult with the NPDES permitting authority, as well as other appropriate State and Federal agencies, to ensure consistency with CSO Control Policy provisions regarding sensitive areas (II.C.3). Ultimately, the NPDES permitting authority should be satisfied that the municipality has studied all reasonable options in developing a list of final alternatives for evaluation and that the evaluation process incorporates all identified concerns.

3.2 LONG-TERM CONTROL PLAN APPROACH

The LTCP should provide site-specific, cost-effective CSO controls that will provide for attainment of WQS. It should provide flexibility to municipalities in recognition of the variable impacts of CSOs on water quality and the ability of different municipalities to afford varying levels of CSO control. EPA expects that the LTCP will consider a reasonable range of alternatives and varying control levels within those alternatives, using cost-effectiveness as a consideration to help guide consideration of the controls.

3.2.1 Demonstration Versus Presumption Approach

The CSO Control Policy identifies two general approaches to attainment of WQS: the demonstration approach and the presumption approach. The demonstration and presumption approaches provide municipalities with targets for CSO controls that achieve compliance with the Clean Water Act, particularly protection of designated uses. As described in Chapter 2, all municipalities should characterize their CSSs in order to establish a baseline and provide a basis for implementing and evaluating the effectiveness of the nine minimum controls (NMC). Characterization will likely include monitoring and modeling to characterize CSO flow and pollutant loads, impacts on receiving water quality from CSO and non-CSO sources, and efficacy of CSO controls. This characterization will enable the NPDES permitting authority, in conjunction with the municipality and with input from the public and appropriate review committees, to determine whether the demonstration or presumption approach is the most suitable.

Generally, if sufficient data are available to demonstrate that the proposed plan would result in an appropriate level of CSO control, then the demonstration approach will be selected. The demonstration approach is particularly appropriate where attainment of WQS cannot be achieved through CSO control alone, due to the impacts of non-CSO sources of pollution. In such cases, an appropriate level of CSO control cannot be dictated directly by existing WQS but must be defined based on water quality data, system performance modeling, and economic factors. These factors might ultimately support the revision of existing WQS. If the data collected by a community do not provide *"...a clear picture of the level of CSO controls necessary to protect WQS"* (II.C.4.a.), the presumption approach may be considered. Use of the presumption approach is contingent, however, on the municipality presenting sufficient data to the NPDES permitting authority to allow the agency to make a reasonable judgment that WQS will probably be met with a control plan that meets one of the three presumption criteria (see Section 3.2.1.2).

The CSO Control Policy recommends flexibility in allowing a municipality to select controls that are cost-effective and tailored to local conditions. For this reason, the choice between the demonstration approach and presumption approach does not necessarily have to be made before a municipality commences work on its LTCP. In some cases, it might be prudent for a municipality to assess alternatives under both approaches. In addition, if a municipality has CSOs that occur to two different water bodies, a control plan that includes the demonstration approach for one receiving water and the presumption approach for the other may be appropriate. Because of the flexibility in selecting an approach, it is imperative that the municipality coordinate closely with the NPDES permitting authority. Involving the public and other stakeholders will also provide a foundation for subsequent LTCP acceptance.

3.2.1.1 Demonstration Approach

Under the demonstration approach, the municipality would be required to successfully demonstrate compliance with each of the following criteria (II.C.4.b):

> *i. the planned control program is adequate to meet WQS and protect designated uses, unless WQS or uses cannot be met as a result of natural background conditions or pollution sources other than CSOs;*
>
> *ii. the CSO discharges remaining after implementation of the planned control program will not preclude the attainment of WQS or the receiving waters' designated uses or contribute to their impairment. Where WQS and designated uses are not met in part because of natural background conditions or pollution sources other than CSOs, a total maximum daily load, including a wasteload allocation, a load allocation or other means should be used to apportion pollutant loads;*
>
> *iii. the planned control program will provide the maximum pollution reduction benefits reasonably attainable; and*
>
> *iv. the planned control program is designed to allow cost-effective expansion or cost-effective retrofitting if additional controls are subsequently determined to be necessary to meet WQS or designated uses.*

Under Criterion i, the CSO Control Policy reiterates that NPDES permits must require attainment of WQS, but recognizes that in many receiving water segments, sources other than CSOs might be contributing substantially to nonattainment of WQS. In these cases, even complete elimination of CSOs might not result in attainment of WQS. Criterion ii is intended to ensure that the selected level of CSO control would be sufficient to allow attainment of WQS if other sources causing nonattainment were controlled. Criterion iii reiterates the emphasis on developing cost-effective levels of control, while Criterion iv ensures that sufficient flexibility is incorporated into the LTCP to allow upgrading to higher levels of control if necessary.

The demonstration approach encourages the development of total maximum daily loads (TMDLs) and/or the use of a watershed approach throughout the LTCP process. In conducting the existing baseline water quality assessments as part of the system characterization, for example, the specific pollutants causing nonattainment of WQS, including existing or designated uses, would be identified, and then the sources of these pollutants could be identified and loads apportioned and quantified. Assessments would be made of the relative contribution of CSOs and other sources to the total pollutant loads to the receiving waters, and then a range of controls could be identified to target the CSO contribution. Controls for the non-CSO sources of pollutants could also be assessed at the same time, depending on the overall scope of the LTCP, jurisdictional issues within the municipality, and other issues.

The statutory basis for defining the relative contributions of different sources of pollution is the CWA, under Section 303(d), which requires the identification of "water quality limited" stream segments still requiring TMDLs. These are areas where water quality does not meet applicable WQS and/or is not expected to meet applicable WQS even after the application of required controls, such as the technology-based control measures (40 CFR 131.3(h)). A TMDL is defined as the sum of the individual wasteload allocations (WLA) for point sources; load allocations (LA) for nonpoint sources of pollution and natural background sources, tributaries, or adjacent segments; and a margin of safety. The objective of the TMDL is attainment of WQS. The process uses water quality analyses to predict water quality conditions and pollutant concentrations. The establishment of a TMDL for a particular water body depends on the location of point sources, available dilution, WQS, nonpoint source contributions, background conditions, and in-stream pollutant reactions and effluent toxicity. A TMDL can be expressed in terms of chemical mass per unit time, by toxicity, or by other appropriate measures.

In cases where the natural background conditions, or pollution sources other than CSOs, are contributing to exceedances of WQS, the State is responsible for the development of a TMDL and the WLA for any CSOs. The municipality must then demonstrate compliance with the effluent limitation derived from the WLA established as part of the TMDL (EPA, 1995g). The NPDES permitting authority will also specify what constitutes a reasonable effort by the municipality to demonstrate the maximum pollution reduction benefits reasonably attainable.

The term "reasonably attainable" generally refers to the cost of implementing the planned control program in relation to the pollution reduction benefit achieved (EPA, 1995g).

3.2.1.2 Presumption Approach

The CSO Control Policy recognizes that *"...data and modeling of wet weather events often do not give a clear picture of the level of CSO controls necessary to protect WQS"* (II.C.4.a). For this reason, the presumption approach was included in the CSO Control Policy as an alternative to the demonstration approach. The presumption approach is based on the assumption that an LTCP that meets certain minimum defined performance criteria "*...would be presumed to provide an adequate level of control to meet the water quality-based requirements of the CWA, provided the permitting authority determines that such presumption is reasonable in light of the data and analysis conducted in the characterization, monitoring, and modeling of the system and the consideration of sensitive areas...*" (II.C.4.a).

Under the presumption approach, controls adopted in the LTCP should be required to meet one of the following criteria (II.C.4.a):

> *i. No more than an average of four overflow events per year, provided that the permitting authority may allow up to two additional overflow events per year. For the purpose of this criterion, an overflow event is one or more overflows from a CSS as the result of a precipitation event that does not receive the minimum treatment specified...* [see definition of minimum treatment, below]*; or*
>
> *ii. The elimination or the capture for treatment of no less than 85% by volume of the combined sewage collected in the CSS during precipitation events on a system-wide annual average basis; or*
>
> *iii. The elimination or removal of no less than the mass of the pollutants identified as causing water quality impairment through the sewer system characterization, monitoring, and modeling effort for the volumes that would be eliminated or captured for treatment under paragraph ii above.*

The minimum level of treatment applicable to Criteria i and ii is defined in the CSO Control Policy as follows (II.C.4.a):

- *Primary clarification; removal of floatable and settleable solids may be achieved by any combination of treatment technologies or methods that are shown to be equivalent to primary clarification;*
- *Solids and floatables disposal; and*
- *Disinfection of effluent, if necessary, to meet WQS, protect designated uses and protect human health, including removal of harmful disinfection chemical residuals, where necessary.*

Use of the presumption approach does not release municipalities from the overall requirement that WQS be attained. If data collected during system characterization suggest that use of the presumption approach cannot be reasonably expected to result in attainment of WQS, the municipality should be required to use the demonstration approach instead. Furthermore, if implementation of the presumption approach does not result in attainment of WQS, additional controls beyond those already implemented might be required. This is why the CSO Policy recommends *"The selected controls should be designed to allow cost-effective expansion or cost-effective retrofitting if additional controls are subsequently determined to be necessary to meet WQS, including existing and designated uses"* (II.C).

As noted in Chapter 2, the existing baseline should be established following the system characterization. This is the point at which one of the presumption approach criteria is applied. Implementation of the NMC following system characterization could reduce the number of overflows and/or the amount of flow subject to 85-percent capture, therefore potentially reducing the costs associated with LTCP implementation.

Criterion i. The CSO Control Policy defines an overflow event under Criterion i as *"...one or more overflows from a CSS as the result of a precipitation event that does not receive the minimum treatment specified..."* (II.C.4.a.i). In a CSS with three outfalls, therefore, if one, two, or three of the outfalls discharge untreated or inadequately treated combined sewage during a rain event, then a single overflow event has occurred. Furthermore, in terms of defining an overflow event, a "CSS" is not necessarily the entire set of combined sewers within a municipal or regional boundary. In some cases, a municipality or regional sewer authority might be considered to have more than one CSS if the systems are not hydraulically related. In such a case, the calculation of four overflow events per year would apply for each system individually and not to the entire set of combined sewers within the municipality or regional jurisdiction (this concept would apply to Criteria ii and iii, as well). In addition, the prohibition of more than four overflow events per year (with up to two more if the NPDES permitting authority approves) applies to overflows *not receiving the minimum treatment of primary clarification, solids and floatables disposal, and disinfection, if necessary.* Outfalls may overflow more frequently if they receive the minimum specified treatment.

Criterion ii. Under Criterion ii, the "*85 percent by volume of the combined sewage*" refers to 85 percent of the total volume of flow *collected* in the CSS during precipitation events on a system-wide, annual average basis (not 85 percent of the volume being discharged). In other words, no more than 15 percent of the total flow collected in the CSS during storm events should be discharged without receiving the minimum specified treatment. The total volume of flow collected during wet weather on a system-wide annual average basis would be most readily computed using a model of the CSS, such as SWMM. Similarly, the total volume of flow discharged without receiving the minimum treatment can also be computed using an annual simulation with a CSS model, such as SWMM. Comparing these two volumes under existing conditions will indicate the extent of additional controls necessary to meet the criterion for 85 percent elimination or capture. Sizing facilities to meet a performance criterion based on annual average performance, however, will probably require iterative evaluations of annual simulations. Depending on the size and complexity of the system being modeled, as well as the speed of the hardware used for the simulation, this process can require a great deal of computer time and follow-up analysis.

Analysis performed in conjunction with EPA's 1992 CSO Control Policy dialogue has shown that criteria i and ii are approximately equal. Based on regional rainfall patterns, and primary clarification provided by an appropriately designed sedimentation/storage basin, the number of annual overflows corresponding to primary clarification of 85 percent of the combined sewage was determined. On a nationwide basis, the number of overflows not receiving primary treatment and corresponding to 85 percent capture for treatment, ranged from four to six depending on location. In practice, a CSO control facility that captures for treatment 85 percent of the combined sewage collected in the system may experience more than six overflows on an annual average basis, although a significant deviation from this range of overflows would not be expected. In cases where a significant deviation due to local conditions is encountered, the permit writer's judgment should be used to determine whether use of the 85 percent capture criterion is appropriate. Also, as previously stated, use of either of the presumption approach options should be based on reasonable assumption that implementation of controls meeting these criteria will be sufficient to prevent violations of WQS.

Criterion iii. Criterion iii, meanwhile, makes the distinction between the control of CSO volume and the control of the specific pollutants within that volume that cause water quality impairment. As noted earlier, CSS modeling could provide the total volume of flow collected during wet weather in the CSS on an annual average basis. The volume needed to be captured to meet Criterion ii would then be 85 percent of that total. Using average pollutant concentrations and removal efficiencies associated with the equivalent of primary treatment, one could compute the mass of the pollutants that would be removed if 85 percent of the wet weather flow received the equivalent of primary treatment. Comparing this value with the mass of pollutants that is currently removed during wet weather would yield the additional mass of pollutants needed to be removed to meet Criterion iii.

For example, suppose a municipality's CSS had the following characteristics, based on the system characterization:

- Total volume of combined sewage collected in the CSS on an annual average basis during wet weather—100 MG
- Total volume of combined sewage receiving secondary treatment at the municipality's POTW during wet weather—10 MG
- Pollutant causing water quality impairment in receiving water body—BOD

- Average concentration of BOD in CSO from the municipality's CSS—80 mg/l
- Wet weather BOD removal efficiency for primary clarification as determined for the municipality based on review of local POTW performance and historical data—20 percent
- Wet weather BOD removal efficiency from municipality's secondary POTW—80 percent.

The mass of BOD removed by providing the equivalent of primary clarification for 85 percent of the combined sewage collected during wet weather on an annual average basis would be computed as follows:

$$100 \text{ MG} \times 85\% \times 80 \text{ mg/l} \times 8.34 \times 20\% = 11{,}342 \text{ lbs.}$$

Since 10 MG of combined flow receives secondary treatment at the municipality's POTW during wet weather, the remaining load of BOD to be captured from CSOs to meet Criterion iii would be:

$$11{,}342 \text{ lbs} - (10 \text{ MG} \times 80 \text{ mg/l} \times 80\% \times 8.34) = 6{,}005 \text{ lbs.}$$

Criterion iii also considers pollution prevention measures. Activities such as street sweeping, litter control, and erosion control programs would reduce the load of certain pollutants carried to the receiving water, without affecting overflow volumes. Similarly, if more sophisticated modeling and monitoring programs support the use of time varying concentrations to compute pollutant loads, it might be possible to demonstrate that capture of the appropriate load of pollutants could be achieved with capture of a lower volume of flow.

The specific pollutants causing WQS nonattainment may vary from water body to water body. The pollutants of concern to a given municipality will, therefore, depend on the specific water resources affected by CSOs and their desired uses. The intent of the minimum level of treatment recommended in the presumption approach is to control floatables, pathogens, and solids. The primary impact of floatable material on receiving waters is aesthetic. Pathogens are bacteria, protozoa, and viruses that can cause disease in humans through ingestion, inhalation, and skin contact. These potential health risks are associated with uses of receiving waters for water supplies, primary contact recreation, such as swimming; secondary contact recreation, such as boating; and with the consumption of contaminated fish and shellfish. Although not pathogenic themselves, the presence of coliform bacteria is used as an indicator of the potential presence of pathogens and of potential risk to human health. Solids can cause problems in either the suspended or deposited state and their removal is important for several reasons. Suspended solids can make the water look cloudy or turbid, diminishing the aesthetic and recreational qualities of the water body. Turbidity limits light penetration into the water column and reduces the growth of microscopic algae and submerged aquatic vegetation. Suspended solids can also impede feeding by filter-feeding organisms, such as shellfish and small aquatic invertebrates.

In addition, deposited sediments can change the physical nature of the bottom, altering hydrology and habitat and affecting navigation. Sedentary bottom-dwelling species can be smothered by accumulating sediment, and the change in habitat can preclude the continued success of many species that use the bottom habitat to feed, spawn, or live. Sediments are also a sink for adsorbed pollutants, such as nutrients (e.g., nitrogen, phosphorus), toxic metals, and organics, which can affect both water-column and bottom-dwelling organisms. These toxic pollutants can be remobilized if sediments are disturbed and can pose a health hazard to humans consuming fish and shellfish.

Defining "minimum treatment" and "primary clarification." As stated above, the minimum level of treatment applicable to Criteria i and ii of the presumption approach consists of:

- Primary clarification or equivalent;
- Solids and floatables disposal; and
- Disinfection, as necessary, and removal of disinfection residuals, as necessary.

The definition of "primary clarification" is one of the key implementation issues underlying the presumption approach and has generated considerable debate among regulators, municipalities, consultants, and equipment suppliers. The intent of primary clarification is removal of settleable solids from the wastestream, which will result in the environmental benefits outlined above.

The CSO Control Policy does not define specific design criteria or performance criteria for primary clarification, however. This guidance document does not provide a definition either; instead, it discusses general considerations for primary clarification under the presumption approach, recognizing the variable nature of CSOs and general lack of historical data on CSO treatment facility performance. EPA recognizes the need for flexibility and urges municipalities and NPDES permitting authorities to coordinate to develop a site-specific definition of CSO primary clarification as "minimum treatment" under the presumption approach.

This definition should take the form of target ranges for design criteria (overflow rate, sidewall depth, residence time) and/or performance (removal rates), rather than a specific number or limit and should be based on several factors, including:

- Wet weather performance of primary treatment facilities at the municipality's POTW
- Historic data (e.g., literature values, existing POTW primary treatment data, existing CSO facility performance data).

The following documents provide additional information on defining primary clarification for a specific application:

- *Water and Wastewater Engineering* (Fair et al, 1968)
- *Recommended Standards for Wastewater Facilities (Ten States Standards)* (Great Lakes-Upper Mississippi River Board of State Public Health and Environmental Managers, 1990)
- *Wastewater Engineering: Treatment, Disposal, Reuse* (Metcalf & Eddy, Inc., 1991a)
- *Design of Municipal Wastewater Treatment Plants, WEF Manual of Practice No. 8: ASCE Manual and Report on Engineering Practice No. 76.* (WEF, 1992)

These documents describe performance and design parameters commonly associated with POTW primary treatment facilities.

In determining an equivalent of primary clarification for CSO flows, the following differences between CSO control facilities and POTWs should be considered:

- Influent hydrographs for CSO control facilities tend to exhibit more sharply defined peaks, not typical of POTW influent hydrographs, as well as periods of no flow. Therefore, the concept of "average" flow is less significant for a CSO control facility than a POTW. For example, the peak influent flow rate can occur before the sedimentation/storage tank is full; therefore, the maximum overflow rate would occur on the falling leg of the influent hydrograph, and the actual maximum overflow rate would be less than a calculated overflow rate associated with the actual peak influent flow.
- Compared to relatively constant influent pollutant concentrations at POTWs, influent pollution loads and concentrations to CSO treatment facilities can be highly variable within a single storm event and between different events.
- CSO flows generally have a higher fraction of heavier solids than separate sanitary flows.

Exhibit 3-1 illustrates how a CSO storage/sedimentation facility might perform during a rainfall event. The lower vertical axis represents the total flow rate of the combined sewage collected upstream of the storage/sedimentation facility, while the upper vertical axis indicates rainfall intensity. The horizontal dashed lines represent surface loading rates within the storage/sedimentation facility. The capacity of the CSS corresponds to the "0 gpd/ft^2" line, and thus the volume of flow above that line is diverted into the storage/sedimentation facility.

Between hours 0 and 4, the conveyance system carries the entire combined sewage volume to the POTW treatment plant. At hour 4, the capacity of the conveyance system is exceeded, and the excess flow is diverted to the storage/sedimentation facility. Between hours 4 and 7.25, the facility tanks are filling, and no overflow is discharged. At hour 7.25, the tanks are completely filled, and excess flow is discharged at an overflow rate of between 1,000 and 2,000 gpd/ft^2. Overflow rates within this range are assumed to provide at least 40 percent TSS removal, based on typical sedimentation system design criteria. Between hours 8 and 10, the overflow rate exceeds 2,500 gpd/ft^2, and the volume of overflow occurring during this period

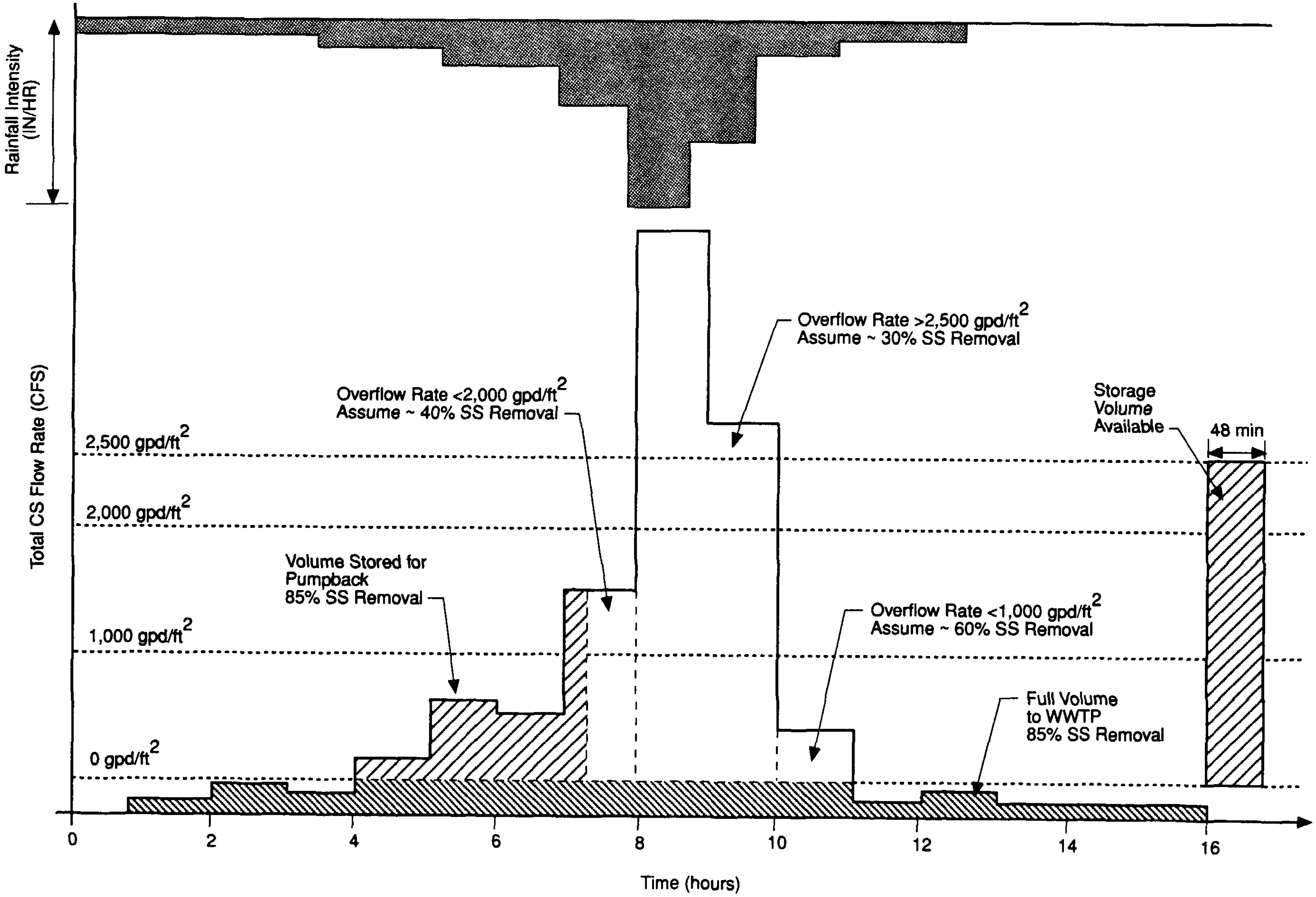


Exhibit 3-1. An Example of Overflow Rates Versus Pollutant Removal During a Rainfall Event

is assumed to receive 30 percent TSS removal. At hour 10, the overflow rate drops to less than 1,000 gpd/ft^2 as the storm begins to subside. Overflow volumes in this range are assumed to receive 60 percent TSS removal. After hour 11, flows have dropped back below the capacity of the conveyance system, and flow into the facility ceases. At hour 16, dewatering of the facility begins, thus restoring the available storage volume. The dewatered volume is assumed to be returned to the POTW for full secondary treatment, with 85 percent TSS removal.

Thus, a CSO treatment facility designed for storage and sedimentation would typically provide the following levels of control:

- Full secondary treatment (85 percent TSS and BOD_5 removal) for small rainfall events where the total CSO volume diverted to the storage/sedimentation facility is less than the volume of the storage/sedimentation basin, and all of the CSO flow is stored and directed back to the POTW. While providing secondary treatment of overflows from small storms is not specifically included as part of the presumption approach, it would be an additional benefit of using the storage/sedimentation tank technology.

- A combination of primary and secondary treatment for storms that exceed the volume of the storage/sedimentation tanks, but where the overflow rates are within the determined range for primary treatment. The flow discharged from the facility would receive the equivalent of primary treatment, while the volume of the tanks would be returned to the POTW for secondary treatment.

- Lower levels of treatment for major storm events where the peak overflow rate exceeds the design range for primary treatment. Under the presumption approach, the CSO Control Policy recommends that NPDES permitting agencies allow the exceedance of the design overflow rates four times per year or, alternatively, 15 percent of total annual combined sewage flow to be discharged without receiving the equivalent of primary treatment.

Because storage/sedimentation is only one potential CSO control alternative, the municipality and the NPDES permitting agency might also have to determine the effectiveness of other types of CSO control alternatives to meet the performance criteria of the presumption approach. This task can be challenging, given the shortage of published CSO performance data. In many cases, published data are site-specific and cannot necessarily be generalized for other locations due to differences in CSO quality and flow characteristics. For further discussions of related CSO control technologies, refer to the *Manual on Control of CSO Discharges* (EPA, 1993a).

In summary, the municipality should consider the following points when selecting the presumption approach:

- The NPDES permitting authority must be able to judge that the system characterization data submitted by the municipality provide a reasonable assurance that WQS would be met with the presumption approach. Based on the available data, the NPDES permitting authority may disallow use of the presumption approach or may restrict the selection of the criterion (i, ii, or iii) to be adopted in the LTCP. Close coordination between the municipality and the NPDES permitting and WQS authorities is necessary at all times to ensure appropriate data development to support selection of the presumption approach.

- The NPDES permitting authority has the ultimate authority to determine the number of allowable overflow events.

- The four overflows per year criterion is only one option available to municipalities in choosing an approach to comply with the CWA. A municipality may prefer to consider the demonstration approach, or the 85 percent capture or pollutant mass options under the presumption approach where appropriate.

- Selection of the presumption approach does not relieve the municipality from the need to characterize the CSS. This characterization should provide the basis for the NPDES permitting authority to determine whether the presumption approach would likely result in attainment of WQS.

- The selected LTCP option to be included in an NPDES permit must "*...ultimately result in compliance with the requirements of the CWA*" (II.C). For this reason, if post-construction compliance monitoring indicates WQS nonattainment due to CSO impacts, a greater level of control should be required than was originally contemplated under the selected presumption approach criterion.

- The decision to choose either the presumption or the demonstration approach is important because it will affect the development of alternatives for the LTCP. It might be appropriate to evaluate a range of alternatives under both approaches so that the level of control, costs, and benefits can be compared in making a decision.

3.2.2 Small System Considerations

The CSO Control Policy acknowledges that "*...the scope of the long-term CSO control plan, including the characterization, monitoring and modeling, and evaluation of alternatives...may be difficult for some small CSSs*" (I.D). EPA recognizes that smaller communities with limited resources might benefit more than investment in CSO controls than from these aspects of LTCP development (EPA, 1995g). For this reason, at the discretion of the NPDES permitting authority, municipalities with populations of less than 75,000 need not be required to complete each of the formal steps outlined in the CSO Control Policy.

At a minimum, however, the permit requirements for developing an LTCP should include compliance with the NMC, consideration of sensitive areas, a post-construction compliance monitoring program sufficient to determine whether WQS are attained, and public participation in the selection of the CSO controls (EPA, 1995g). In developing a small system LTCP, municipalities should consult with both the NPDES permitting and WQS authorities to ensure that the plan includes enough information to allow the NPDES permitting authority to approve the proposed CSO controls.

3.3 DEVELOPMENT OF ALTERNATIVES FOR CSO CONTROL

Development of alternatives for CSO control is generally based on the following sequence of events:

1. Definition of water quality goals
2. Definition of a range of CSO control goals to meet the CSO component of the water quality goals
3. Development of alternatives to meet the CSO control goals.

Within this general context, this section is organized as follows. Section 3.3.1 presents some general considerations, primarily regarding the relationships between the LTCP and other related aspects of a municipality's collection and treatment system, including the NMC. Section 3.3.2 discusses and highlights an example of possible definitions for water quality goals and corresponding CSO control goals. Section 3.3.3 provides a series of approaches to structuring CSO control alternatives. These approaches are intended to provide a means for focusing or organizing CSO control alternatives and include such categories as evaluation of outfall-specific solutions, local or regional consolidation of outfalls, utilization of POTW capacity (including CSO-related bypass), and special considerations for sensitive areas. Depending on the size of the CSS, different approaches might be appropriate in different parts of the CSS. Having discussed the goals of CSO control and general approaches to structuring alternatives to meet those goals, Sections 3.3.4 to 3.3.9 provide guidance on the scope of initial alternatives development. Section 3.3.4 introduces this topic, while Sections 3.3.5 to 3.3.9 present specific aspects of initial alternatives development, such as identification of control measures or technologies, preliminary sizing considerations, cost/performance considerations, preliminary siting issues, and preliminary operating strategies.

3.3.1 General Considerations

This section presents general concepts that should be considered when developing CSO control alternatives.

3.3.1.1 Interaction with Nine Minimum Controls

Certain minimum control measures developed in conjunction with the CSO system characterization might affect baseline flows and loads. In particular, measures associated with maximizing collection system storage and flows to the POTW might reduce the volume and/or frequency of predicted overflows at specific locations. Minimum control measures associated with the control of solid and floatable material in CSOs might be sufficient in scope to be considered as long-term alternatives. Because minimum controls would be implemented before the completion of the LTCP, the LTCP should incorporate the expected benefits of the minimum controls.

3.3.1.2 Interactions with Other Collection and Treatment System Objectives

Implementation of CSO controls is likely to affect other point and nonpoint source control activities occurring within the same watershed. The CSO Control Policy encourages municipalities to evaluate water pollution control needs on a watershed management basis, and to coordinate CSO control efforts with other point and nonpoint source control activities (see Section 1.6.6). For example, if a municipality evaluates sewer separation as an alternative, it should consider the impact of increased storm water loads on receiving waters. Similarly, the system characterization model should explore the interrelationships between inflow/infiltration removal, interceptor capacity, CSO control alternatives, and POTW capacity. The LTCP provides an opportunity to optimize the operation of new and already-planned components of the treatment system, and to explore new system modifications that affect the operation of these components.

3.3.1.3 Creative Thinking

The initial identification of alternatives should involve some degree of brainstorming and free thinking. CSO control can be a challenging problem, where lack of available sites, potential impacts on sensitive receptors, and stringent water quality goals are common issues. The CSO Control Policy encourages *"Permittees and permitting authorities...to consider innovative and alternative approaches and technologies that achieve the objectives of this policy and the CWA"* (I.F). Some of the more successful urban CSO projects have incorporated original ideas for multiple use facilities and for mitigating impacts on neighboring areas. For example:

- **Rochester, NY**—A tunnel system was designed to cross the Genesee River by way of a conduit suspended across the Genesee Gorge. Crossing the gorge above rather than below the river surface eliminated the need for downstream pumping to the POTW and also allowed the construction of a pedestrian walkway along the suspended conduit, providing access between parks located on either side of the gorge.

- **Newport, RI**—Below-grade, covered storage/sedimentation tanks located on a commercial block were designed to allow parking on the roof slab. Architectural features of the facility were designed to blend in with historic homes in an adjacent neighborhood.

3.3.2 Definition of Water Quality and CSO Control Goals

This section discusses the first two aspects of development of alternatives: identifying water quality goals and identifying CSO control goals to meet the water quality goals.

The CSO Control Policy clearly states that the ultimate goal of the LTCP is "*compliance with the requirements of the CWA*" (II.C). The CSO Control Policy also recommends that a range of control levels be evaluated as part of the LTCP (II.C.4), while State CSO policies sometimes identify specific control goals for evaluation. The initial definition of CSO control goals, however, should be based on an identification of watershed-specific or receiving water segment-specific water quality goals. Water Quality goals are defined without regard to sources of pollution. Examples of water quality goals might include meeting WQS at all times, or meeting WQS except for four times per year. CSO control goals refer to specific levels of pollution control from CSO sources only. Defining a CSO control goal based on a water quality goal means identifying a level of CSO control which will allow attainment of the water quality goal, assuming non-CSO sources of pollution are also controlled to an appropriate level. Once a CSO control goal is defined, CSO control alternatives, comprised of technologies or other control measures, can then be developed to meet the CSO control goal.

For example, a water quality goal of meeting existing WQS at all times might correspond to a CSO control goal of eliminating the CSO impacts on a given receiving water. CSO control alternatives to meet this goal might include sewer separation or CSO relocation. A water quality goal of meeting existing WQS except for four times per year might correspond to a CSO control goal of eliminating the CSO impacts except for four times per year. CSO control alternatives to meet this goal might include, storage or treatment of overflows from storms with a recurrence interval of four times per year. In this second case, the existing WQS would not be attained at all times. The CSO Control Policy recognizes, however, that existing WQS might not be appropriate in all cases for a given receiving water: "*...this Policy allows consideration of... WQS review...*" (II.E). In order for a water quality goal that does not fully support existing WQS to conform with the CWA, either a variance, a partial use designation, or a revision to WQS would have to be obtained, as outlined in Part III of the CSO Control Policy. A review of WQS might also be appropriate if non-CSO sources of pollution are contributing substantially to nonattainment, making the definition of an appropriate water quality goal for an LTCP less clear.

Through the evaluation process, a specific water quality goal might ultimately drive the selection of the recommended plan. For example, a goal of meeting a bacteria criterion that allows unrestricted shellfishing could require a CSO control goal of eliminating CSOs to a particular receiving water containing shellfish beds. While less aggressive CSO control goals might be more cost effectively attained, if stakeholders agree that the goal of unrestricted shellfishing is desired and appropriate, then that goal should govern the selection of a recommended plan. Alternatively, cost-effective analysis in conjunction with a use attainability analysis might identify instances where attainment of an existing WQS is not an appropriate goal. For example, suppose an industrial shipping channel is currently rated for primary contact recreation. The cost of the CSO controls required to achieve that goal might be excessive compared with the benefit gained (e.g., even if the bacteria criterion for swimming were met, swimming would not be allowed in the channel for safety reasons due to ship traffic). Coordination with State WQS authorities regarding the possible revision of the existing WQS (consistent with 40 CFR 131.10) to allow a limited number of wet weather excursions from the standard for primary contact recreation might be an appropriate part of the recommended plan. In this case, determination of the ultimate water quality goal would have been driven by the alternatives development and evaluation process.

Under the demonstration approach, the initial system characterization should identify the specific pollutants causing nonattainment of WQS and, where possible, their sources. The CSO Control Policy recognizes that total elimination of the CSO sources of these pollutants might not be technically or economically feasible, nor might it be required to meet the appropriate water quality goals. Determining the appropriate level of control of these pollutants from the point of view of WQS, available technology, cost, and non-monetary factors is one of the goals of the CSO control alternative development and evaluation process. By evaluating a range of control levels, the municipality, NPDES permitting agency, and other stakeholders will be sure that the most cost-effective solution has been developed to address the appropriate level of CSO control.

As an example of one way to derive CSO control goals, consider the following scenario for a particular receiving water segment. System characterization indicates wet weather fecal coliform bacteria counts and floatables are causing nonattainment of WQS, while wet weather dissolved oxygen, TSS, nutrients, metals, and other constituents are within acceptable ranges. In addition, the fecal coliform contributions from storm water alone would continue to cause WQS violations. In this case, elimination of CSOs would not result in attainment of existing WQS. Under the demonstration approach, the appropriate water quality goal would be a level where remaining CSO pollutant loads *"...will not preclude the attainment of WQS or the receiving waters' designated uses or contribute to their impairment"* (II.C.b.ii).

To determine an appropriate level of CSO control, a municipality can start by identifying a "reasonable range" of control goals, such as the following:

- Level I: Eliminate the impact of CSOs on receiving water quality.
- Level II: Reduce the CSO fecal coliform load and control floatables to a level that would not alone cause nonattainment of existing WQS and reduce the impact of other CSO constituents on the receiving water segment.
- Level III: Reduce the CSO fecal coliform load and control floatables to a level that would not alone cause nonattainment of existing WQS.

With this range of controls, the constituents contributing to nonattainment of WQS are in all cases targeted for control, while varying levels of control are identified for other constituents that do not directly affect attainment of WQS. General categories of CSO control technologies could be identified that would achieve each particular level of control. Within Levels II and III, controls could be evaluated over a range of design conditions, such as 1 to 3, 4 to 7, and 8 to 12 overflow events per year, as suggested in the CSO Control Policy. Level I would be equivalent to zero overflow events per year.

While this approach is intended to provide flexibility and facilitate cost/benefit analysis, it is clear that even with a fairly simple CSS, the number of possible alternatives can become very large. For example, five outfalls discharge to a receiving water segment and, at each outfall, three technologies are identified as potentially feasible, and each technology could be sized for three different design conditions (i.e., 1-month, 3-month, and 1-year storm). Therefore, cost and performance data would have to be generated for 45 facilities. This point emphasizes the need for iterative screening of alternatives, particularly where multiple CSOs occur to a single receiving water segment. Where a CSS discharges CSOs to receiving water segments in different watersheds, it would be appropriate to at least initially evaluate the alternatives within the different watersheds separately.

This example of developing a range of CSO control goals is intended to be just that—an example. Individual municipalities should develop an approach that is best suited to their own CSS, receiving waters, and control needs. Smaller communities in particular might be able to simplify this process to some degree, but the general concept of defining goals and evaluating a range of controls should be maintained. In all cases, early coordination with appropriate regulatory agencies in the development of the LTCP approach is necessary. Consensus among stakeholders, including the public, on the methodology for developing the LTCP is desirable and contributes to achieving consensus on the recommended plan.

3.3.3 Approaches to Structuring CSO Control Alternatives

A first step in identifying CSO control alternatives to meet the initial range of CSO control goals is to identify ways to structure the alternatives, given the geographic layout of the CSS, as well as hydraulic and other constraints. In other words, how will the alternatives developed for each outfall be related to alternatives developed for other outfalls. This evaluation can be conducted somewhat independently of the specific technologies to be applied to the overflows. For example, the municipality can determine whether local or regional consolidation of outfalls appear to be feasible or whether outfall-specific solutions appear more practical. At this stage, it is not necessary to identify the specific control technologies to be applied. Rather, general categories of projects such as "storage," "treatment," or "in-system controls" would suffice. This "brainstorming" can help focus the initial identification of alternatives, particularly with regard to identifying opportunities for consolidation of outfalls and regional solutions. A given LTCP could ultimately include various combinations of approaches to structuring alternatives. For example, an LTCP featuring regional consolidation of outfalls might also include a number of outfall-specific facilities to control remote outfalls that would not be part of the consolidation system. The following subsections discuss typical approaches to structuring CSO control alternatives. Each of the following approaches should be considered in developing the LTCP. It is possible, however, that for a given collection system, a particular approach might yield no feasible alternatives.

3.3.3.1 Projects Common to All Alternatives

Projects common to all alternatives would be part of the LTCP regardless of the recommendations for other alternatives. These projects might be associated with the NMC or be specific fast-track projects for which the need and the expected benefit have already been defined (perhaps as part of an earlier study). For example, if a previous study recommended modifying the operation of a pumping station to relieve upstream surcharging in a particular interceptor, the project can be incorporated into each alternative for long-term control, whether the alternative be for end-of-pipe treatment or for local or regional consolidation. Subsequent alternatives development should consider the effect of these common projects on predicted system performance and implementation schedules.

3.3.3.2 Outfall-Specific Solutions

These alternatives are intended to control CSOs at individual outfalls. This approach might be appropriate for outfalls that are located remotely from other outfalls. Typical alternatives for single-outfall abatement include localized sewer separation, off-line storage, and end-of-pipe treatment.

3.3.3.3 Localized Consolidation of Outfalls

Where several outfalls are near each other, municipalities should investigate whether to consolidate them to a single location for storage and/or treatment. Consolidation can provide more cost-effective control of CSOs, minimizing the number of sites necessary for abatement facilities, and the institutional benefit of reducing the number of permitted outfalls.

Consolidation conduits between outfalls may present opportunities for in-line storage, which may reduce the required size of the abatement facilities.

3.3.3.4 Regional Consolidation

Municipalities with multiple outfalls and limited available space for near-surface facilities should consider consolidation of outfalls on a regional basis using deep tunnels or other appropriate technologies. Depending on the geographic distribution of outfalls, subsurface geological conditions, and other factors, a deep tunnel alternative can include near-surface consolidation conduits or satellite near-surface storage/treatment facilities for remotely located outfalls. Alternatives involving deep tunnels should consider whether the tunnels will serve primarily as storage facilities to be pumped out to the POTW at the end of a storm event or whether they will also serve to convey wet weather flows to the POTW for treatment during a storm event.

3.3.3.5 Utilization of POTW Capacity and CSO-Related Bypass

The CSO Control Policy encourages municipalities to consider the use of POTW capacity for CSO control as part of the LTCP. The use of POTW capacity is presented in the CSO Control Policy within three general contexts. First, as a minimum control, maximizing flow to the POTW is intended to ensure that optimum use is made of existing POTW capacity. Second, the CSO Control Policy states that *"...the long-term control plan should also consider expansion of POTW secondary and primary capacity in the CSO abatement alternative analysis"* (II.C.4). In some cases, it might be more cost-effective to expand existing POTW facilities than to site separate facilities for CSO control. Third, the CSO Control Policy addresses the specific case where existing primary treatment capacity at a POTW exceeds secondary treatment capacity and it is not possible to utilize the full primary treatment capacity without overloading the secondary facilities. For such cases, the CSO Control Policy states that at the request of the municipality, EPA may allow an NPDES permit *"...to authorize a CSO-related bypass of the secondary treatment portion of the POTW treatment plant for combined sewer flows in certain identified circumstances"* (II.C.7). Under this provision, flows to the POTW within the capacity of primary treatment facilities but in excess of the capacity of secondary treatment facilities may be diverted around the secondary facilities, provided that *"...all wet weather flows passing the headworks of the POTW treatment plant will receive at least primary clarification and solids and floatables removal and disposal, and disinfection, where necessary, and any other treatment that can reasonably be provided"* (II.C.7). In addition, the CSO-related bypass should not cause exceedance of WQS.

The regulatory basis for permitting a CSO-related bypass is included at 40 CFR 122.41(m), which defines a bypass as "...the intentional diversion of waste streams from any portion of a treatment facility." At 40 CFR 122.41(m)(4), bypasses are prohibited except where unavoidable to prevent loss of life, personal injury, or severe property damage and where there were no feasible alternatives to the bypass. "Severe property damage" is defined at 40 CFR 122.41(m)(1) to include "...damage to treatment facilities which causes them to become inoperable...." Under the CSO Control Policy, severe property damage could *"...include situations where flows above a certain level wash out the POTW's secondary treatment system"* (II.C.7).

Thus, the CSO-related bypass provision applies only in situations where the POTW meets the requirements of 40 CFR 122.41(m), as evaluated on a case-by-case basis. The municipality is responsible for developing and submitting the technical justification supporting the request for a CSO-related bypass. As with other aspects of the long-term plan development, coordination between the municipality and the permitting agency on this issue is very important. For the purpose of applying the requirements of 40 CFR 122.41(m) to the CSO-related bypass, the municipality must demonstrate that the following criteria are met:

- The bypass was unavoidable to prevent severe property damage, the definition of which includes damage to the treatment facilities that causes them to become inoperable (i.e., washout of the secondary treatment system)
- There was no feasible alternative to the bypass, such as the use of auxiliary treatment facilities, retention of untreated wastes, or maintenance during normal periods of equipment downtime.

To satisfy the first criterion, *"...the long-term control plan, at a minimum, should provide justification for the cut-off point at which the flow will be diverted from the secondary treatment portion of the treatment plant"* (II.C.7). Examples of the types of information that support the "no feasible alternative" criterion include:

- Records demonstrating that the secondary treatment system is properly operated and maintained
- A demonstration that the system has been designed to meet secondary limits for flows greater than the peak dry weather flow plus an appropriate quantity of wet weather flow
- A demonstration that it is either technically or financially infeasible to provide secondary treatment for greater amounts of wet weather flow.

In presenting alternatives incorporating the CSO-related bypass in the context of the LTCP, the municipality should also provide *"...a benefit-cost analysis demonstrating that conveyance of wet weather flow to the POTW for primary treatment is more beneficial than other CSO abatement alternatives such as storage and pump back for secondary treatment, sewer separation, or satellite treatment"* (II.C.7).

The permit can include the conditions under which a CSO-related bypass would be approved and can specify appropriate treatment, monitoring, or effluent limitation requirements related to the bypass event. An example of permit language for the CSO-related bypass requirement is included in the permit writer's guidance document (EPA, 1995g).

3.3.3.6 Consideration of Sensitive Areas

The CSO Control Policy states that *"EPA expects a permittee's long-term CSO control plan to give the highest priority to controlling overflows to sensitive areas, as determined by the NPDES authority in coordination with State and Federal Agencies, as appropriate..."* (II.C.3). Examples of sensitive areas presented in the CSO Control Policy include designated Outstanding National Resource Waters, National Marine Sanctuaries, waters with threatened or endangered species and their habitat, waters supporting primary contact recreation (e.g., bathing beaches), public drinking water intakes or their designated protection areas, and shellfish beds. As described in Chapter 1, the CSO Control Policy (II.C.3) provides a hierarchy of approaches for controlling overflows to sensitive areas. Each of the approaches to developing alternatives could be applied to controlling overflows to sensitive areas, and an awareness of the locations of sensitive areas might guide the development and selection of control alternatives, as well as the identification of priorities for project implementation.

3.3.4 Goals of Initial Alternatives Development

Once a range of CSO control goals has been developed and approaches to structuring CSO control alternatives have been identified, the next step is to develop specific alternatives to achieve the various CSO control goals. As noted previously, in the initial alternatives development steps, the number of alternatives necessary to cover the range of control levels for each CSO can be very large. Judgment is necessary to develop a manageable array of alternatives. It is important to remember that the iterative screening of alternatives is flexible and not a rigid process. Alternatives initially rejected might become more feasible as more information is developed. Similarly, agency interaction and public participation throughout the process might contribute additional alternatives.

Municipalities should generally include the following steps during the initial development of alternatives to meet CSO control goals:

1. Identification of control alternatives (Section 3.3.5)
2. Preliminary sizing of control alternatives (Section 3.3.6)
3. Preliminary development of cost/performance relationships (Section 3.3.7)
4. Identification of preliminary site options and issues (Section 3.3.8)
5. Identification of preliminary operating strategies (Section 3.3.9).

3.3.5 Identification of Control Alternatives

A municipality's LTCP should contain one or a combination of CSO control alternatives to achieve receiving water segment-specific CSO control goals. Each alternative, in turn, will likely consist of one or more control measures. Control measures can include technologies, operating strategies, public policies and regulations, or other measures that would contribute to some aspect of CSO control. Control measures can generally be classified under one of the following categories:

- Source controls
- Collection system controls
- Storage technologies
- Treatment technologies.

Given the number of specific control measures within each of these categories and the range of sizing options for specific measures, initially it might be practical to consider general categories, such as storage or treatment, rather than specific storage or treatment technologies. Alternatively, it might be appropriate to identify "representative" technologies, with the understanding that specific technologies would be considered as part of more detailed evaluations. For example, if the consolidation of three outfalls appears to be feasible, the general categories of alternatives for these outfalls would include consolidation to storage or treatment. Representative technologies could include storage in the consolidation conduit, a storage tank downstream of the conduit, or a storage/sedimentation facility downstream of the conduit. The storage/sedimentation tank could be representative of or a "place-holder" for other treatment technologies, which could be evaluated in more detail once the general feasibility of achieving CSO control goals with the representative technology is established. In general, receiving water-specific CSO control goals will provide a basis for initial screening of CSO control measures. As the feasibility of the general categories of controls is resolved, the concepts will be developed gradually to higher levels of detail, allowing further screening of specific measures within the general categories.

The following discussion briefly introduces some common control measures under the above categories. The list is for general information only and is not intended to be comprehensive or imply EPA endorsement. Municipalities should also be open to evaluating new and emerging control measures. More detailed discussions of specific CSO control measures are given in the *Manual—Combined Sewer Overflow Control* (EPA, 1993a) and *Combined Sewer Overflow Pollution Abatement* (WPCF, 1989).

3.3.5.1 Source Controls

Source controls affect the quantity or quality of runoff that enters the collection system. Since source controls reduce the volumes, peak flows, or pollutant loads entering the collection system, the size of more capital-intensive downstream control measures can be reduced or, in some cases, the need for downstream facilities eliminated. The source controls discussed below include both quantity control and quality control measures:

- **Porous Pavements**—Porous pavements reduce runoff by allowing storm water to drain through the pavement to the underlying soil. Porous pavements, most commonly used in parking lots, require skill and care in installation and maintenance to ensure that the pores in the pavement do not become plugged. The benefits of porous pavements in cold climates might be limited.

- **Flow Detention**—Detention ponds in upland areas and roof-top storage can store storm water runoff temporarily, delaying its introduction into the collection system, and thereby helping to attenuate peak wet weather flows in the collection system. The detention facilities drain back to the collection system when peak wet weather flows subside.

- **Area Drain and Roof Leader Disconnection**—In highly developed areas with relatively little open, pervious space, roof leaders and area drains are commonly connected directly to the combined drainage system. Rerouting of these connections to separate storm drains or available pervious areas can help reduce peak wet weather flows and volumes.

- **Use of Pervious Areas for Infiltration**—Detention of storm flow in pervious areas not only helps attenuate peak wet weather flow in the collection system but also reduces runoff volume through infiltration into the soil. Grassed swales, infiltration basins, and subsurface leaching facilities can be used to promote infiltration of runoff. Infiltration sumps can be used in areas with well draining soils. This type of control might be more appropriate as a requirement for future development or redevelopment and could be implemented through sewer use ordinances and through strict review of proposed development plans.

- **Air Pollution Reduction**—One way to control pollutant loadings from combined sewer areas is to limit the amount of pollutants contributed to local air. Particulate and gaseous pollutants in air are carried to the ground by rainfall and airborne particulates also settle to the ground during dry weather. It is extremely difficult, however, to quantify the potential reduction in storm water pollution associated with air quality improvement.

- **Solid Waste Management**—Although littering is generally prohibited everywhere, it is a common problem in many communities. Street litter typically includes metallic, glass, and paper containers; cigarettes; newspapers; and food wrappers. If not removed from the street surfaces by cleaning equipment, some of these items often end up in combined sewer overflows, creating visible pollution due to their floatable nature.

  Enforcement of anti-litter ordinances is generally given a relatively low priority by law enforcement agencies due to the limited availability of personnel and funds, as well as the difficulty of identification and conviction of violators. Both public education programs and conveniently placed waste disposal containers might be effective, low-cost alternatives, especially in urban business areas. The proper disposal of leaves, grass clippings, crankcase oil, paints, chemicals, and other such wastes can be addressed in a public education program. Because the results of such a program depend on voluntary cooperation, the level of effectiveness can be difficult to predict.

- **Street Sweeping**—Street sweeping may be evaluated as a best management practice (BMP) for CSO pollution control. Frequent street sweeping can prevent the accumulation of dirt, debris, and associated pollutants, which may wash off streets and other tributary areas to a combined collection system during a storm event. Current sweeping practices can be analyzed to determine whether more frequent cleaning will yield CSO control benefit. The overall effectiveness of street sweeping as a CSO control measure has been debated and depends on a number of factors, including frequency of sweeping, size of particles captured by sweeping, street parking regulations, and climatic conditions, such as rainfall frequency and season.

- **Fertilizer and Pesticide Control**—Fertilizers and pesticides washed off the ground during storms contribute to the pollutant loads in storm water runoff. The municipal parks department is probably the user easiest to control. It is important, therefore, that these departments follow proper handling and application procedures. The use of less toxic formulations should also be encouraged. In highly urbanized areas, the use of these chemicals by the general public is not likely to be a major source of pollution. Because most of the problems associated with these chemicals are a result of improper or excessive usage, however, a public education program might be beneficial.

- **Snow Removal and De-Icing Control**—This abatement measure involves limiting the use of chemicals for snow and ice control to the minimum necessary for public safety. This, in turn, would limit the amount of chemicals (normally salt) and sand washed into the collection system and ultimately contained in CSOs. Proper storage and handling measures for these materials might also reduce the impacts of runoff from material storage sites.

- **Soil Erosion Control**—Properly vegetated and/or stabilized soils are not as susceptible to erosion and, thus, will not be washed off into combined sewers during wet weather. Controlling soil erosion is important in relation to CSOs and water quality for a number of reasons: soil particles create turbidity in the receiving water, blocking sunlight and causing poor aesthetics; soil particles carry nutrients, metals, and other toxics which may be released in the receiving water, contributing to algal blooms and bioaccumulation of toxics; and eroded soil can contribute to sedimentation problems in the collection system, potentially reducing hydraulic capacity. Like fertilizer and pesticide control, an educational program may be useful in controlling soil erosion, and implementation and enforcement of erosion control regulations at construction sites can also be effective.

- **Commercial/Industrial Runoff Control**—Commercial and industrial lands, including gasoline stations, railroad yards, freight loading areas, and parking lots, contribute grit, oils, grease, and other pollutants to CSSs. Such contaminants can run off into CSSs. Installing and maintaining oil and grease separators in catch basins and area drains can help control runoff from these areas, while pretreatment requirements can be identified as part of the community's sewer use regulations.

- **Animal Waste Removal**—This measure refers to removing animal excrement from areas tributary to CSSs. As with air pollution control, the impact of this control measure is difficult to quantify; however, it might be possible to achieve a minor reduction in bacterial load and oxygen demand. This BMP can be addressed by a public information program and "pooper-scooper" ordinances.

- **Catch Basin Cleaning**—The regular cleaning of catch basins can remove accumulated sediment and debris that could ultimately be contained in CSOs. In many communities, catch basin cleaning is targeted more toward maintaining proper drainage system performance than pollution control.

3.3.5.2 Collection System Controls

Collection system controls and modifications affect CSO flows and loads once the runoff has entered the collection system. This category of control measures can reduce CSO volume and frequency by removing or diverting runoff, maximizing the volume of flow stored in the collection system, or maximizing the capacity of the system to convey flow to a POTW and includes the following control alternatives:

- **Sewer Line Flushing**—Sediments that accumulate in sewers during dry weather can be a source of CSO contaminants during storm events. Periodically flushing sewers during dry weather will convey settled materials to the POTW. A 2-year study conducted in Boston, Massachusetts, addressed the cost-effectiveness and feasibility of sewer line flushing as part of a CSO management program (EPA, 1976a). The study determined that flushing combined sewer laterals removed pollutant accumulations. The cost effectiveness of such a program, however, depends on treatment, labor costs, physical sewer characteristics, and productivity.

  Sewer cleaning usually requires the use of a hydraulic, mechanical, or manual device to resuspend solids into the waste flow and carry them out of the collection system. This practice might be more effective for sewers with very flat slopes. Cleaning costs increase substantially for larger interceptors due to occasional accumulations of thick sludge blankets in inverts.

- **Maximizing Use of Existing System**—This control measure involves maximization of the quantity of flow collected and treated, thereby minimizing overflows. It involves ongoing maintenance and inspection of the collection system, particularly flow regulators and tidegates. In addition, minor modifications or repairs can sometimes result in significant increases in the volume of storm flow retained in the system. Strict adherence to a well-planned preventive maintenance program can be a key factor in controlling dry and wet weather overflows.

- **Sewer Separation**—Separation is the conversion of a CSS into separate storm water and sanitary sewage collection systems. This method has historically been used by many communities as a way to eliminate CSOs and their effects altogether. Separation has been reconsidered in recent years because it typically results in increased loads of storm water runoff pollutants (e.g., sediments, bacteria, metals, oils) being discharged to the receiving waters, is relatively expensive, and can disrupt traffic and other community activities during construction. Sewer separation is a positive means of eliminating CSOs and preventing sanitary flow from entering the receiving waters during wet weather periods, however, and might still be applicable and cost-effective. It also can be considered in conjunction with the evaluation of sensitive areas in accordance with the CSO Control Policy, although storm drain discharges will likely still remain. In some cases, municipalities that separate their combined sewers might be required to file for NPDES storm water permit coverage.

- **Infiltration/Inflow Control**—Excessive infiltration and inflow (I/I) can increase operations and maintenance costs and can consume hydraulic capacity, both in the collection system and at the treatment plant. In CSSs, surface drainage is by design the primary source of inflow. Other sources of inflow in CSSs might be appropriate to control, including tidal inflow through leaking or missing tidegates and inflow in separate upstream areas, which might be tributary to a downstream combined system.

  Infiltration is ground water that enters the collection system through defective pipe joints, cracked or broken pipes, manholes, footing drains, and other similar sources.

Infiltration flow tends to be more constant but of lower volume than inflow. The control of infiltration is difficult and often expensive, since infiltration problems are usually difficult to isolate and reflect a more general sewer system deterioration. Significant lengths of sewers usually must be rehabilitated to effectively remove infiltration, and the rehabilitation effort often must include house laterals. Controlling infiltration might have minimal impact on CSO volume due to its small magnitude compared to inflow.

- **Polymer Injection**—Polymers can increase the hydraulic capacity of pipelines by correcting specific capacity deficiencies in a transport system. The injection of polymer slurries into sewers is intended to increase pipe capacity by reducing pipe friction. In certain cases, this increase can be significant and might reduce system surcharging and backups during wet weather. This method has mostly been tested in relatively small sanitary sewers during dry weather.

- **Regulating Devices and Backwater Gates**—Flow regulating devices have been used for many years in CSSs to direct dry weather flow to interceptors and to divert wet weather combined flows in excess of interceptor capacity to receiving waters. The following discussion of regulators was adapted from the *Manual—Combined Sewer Overflow Control* (EPA, 1993a).

  In general, regulators fall into two categories: static and mechanical. Static regulators have no moving parts and, once set, are usually not readily adjustable. They include side weirs, transverse weirs, restricted outlets, swirl concentrators (flow regulators/solids concentrators), and vortex valves. Mechanical regulators are adjustable and might respond to variations in local flow conditions or be controlled through a remote telemetry system. They include inflatable dams, tilting plate regulators, reverse-tainter gates, float-controlled gates, and motor-operated or hydraulic gates.

  Many of the older float-operated mechanical regulators have proven to be erratic in operation and require constant maintenance. In Saginaw, Michigan, many existing float-operated regulators were replaced by vortex valves, due to the unreliability and excessive maintenance associated with the mechanical regulators. In Boston, Massachusetts, many float-operated regulators have been replaced over the years with static regulators.

  The following types of regulators and gates have been installed in more recent CSO control projects or have been used to replace older, less reliable types:

  - **Vortex Valves**—Vortex valves are static regulators that allow dry weather flow to pass without restriction but control higher flows by a vortex throttling action. Vortex valves have been used to divert flows to CSO treatment facilities, control flow out of storage facilities, and replace failed mechanical regulators. They have the following advantages over standard orifices:

  - -- The discharge opening on the vortex valve is larger than the opening on a standard orifice sized for the same discharge rate, thereby reducing the risk of blockage.

  - -- The discharge from the vortex valve is less sensitive to variations in upstream head than a standard orifice (Urbonas and Stahre, 1993).

- **Inflatable Dams**—An inflatable dam is a reinforced rubberized fabric device that, when fully inflated, forms a broad-crested transverse weir. When deflated, the dam collapses to take the form of the conduit in which it is installed. Inflatable dams can be positioned to restrict flow in an outfall conduit or combined sewer trunk. The dams, when fully inflated, can act as regulators by directing flow into an interceptor and preventing the diversion of flow to an outfall until the depth of flow exceeds the crest of the dam. Alternatively, when installed upstream of a regulator, dams can be inflated during wet weather to create in-system storage. Inflatable dams are controlled by local or remote flow or level sensing devices, which regulate the height of the dam to optimize in-line storage and prevent upstream flooding. The dam height is controlled by the air pressure in the dam. Because inflatable dams are typically constructed of rubber or strong fabric, they are subject to puncturing by sharp objects. These devices generally require relatively little maintenance, although the air supply should be inspected regularly (WPCF, 1989).

- **Motor- or Hydraulically Operated Sluice Gates**—Similar to the inflatable dams, motor- or hydraulically operated gates typically respond to local or remote flow or level sensing devices. Normally closed gates can be located on overflow pipes to prevent overflows except under conditions when upstream flooding is imminent. Normally open gates can be positioned to throttle flows to the interceptor to prevent interceptor surcharging or to store flow upstream of regulators. Controls can be configured to fully open or close gates, or to modulate gate position. The level of control and general reliability of motor-operated gates make them well suited for use with real-time control systems.

- **Elastomeric Tidegates**—While not actually regulators, tidegates are intended to prevent the receiving water from flowing back through the outfall and regulator and into the conveyance system. Inflow from leaking tidegates takes up hydraulic capacity in the downstream interceptors and increases the hydraulic load on downstream treatment facilities. Elastomeric tidegates provide an alternative to the more traditional flap-gate style tidegates, which are prevalent in many CSO communities. Tidegates have historically required constant inspection and maintenance to ensure that the flaps are seated correctly and that no objects or debris are preventing the gate from closing. Warpage, corrosion, and a tendency to become stuck in one position are also characteristic of flap-gate style tidegates. Elastomeric tidegates are designed to avoid the maintenance problems associated with the flap gates. In particular, the elastomeric gates are designed to close tightly around objects which might otherwise prevent a flap gate from closing (Field, 1982).

Several documents provide detailed descriptions of other regulator types (WPCF, 1989; Metcalf & Eddy, 1991; and Urbonas and Stahre, 1993).

- **Real-Time Control**—System-wide real-time control (RTC) programs can provide integrated control of regulators, outfall gates, and pump station operations based on anticipated flows from individual rainfall events, with feed-back control adjustments based on actual flow conditions within the system. Computer models associated with the RTC system allow an evaluation of expected system response to control commands before execution. Localized RTC might also be provided to individual dynamic regulators, based on feedback control from upstream and/or downstream flow monitoring elements. As with any plan for improving in-line storage, to take the greatest advantage of RTC, a CSS should have relatively flat upstream slopes and sufficient upstream storage and downstream interceptor capacity (EPA, 1993a).

- **Flow Diversion**—Flow diversion is the diversion or relocation of dry weather flow, wet weather flow, or both from one drainage basin to another through new or existing drainage basin interconnections. Flow diversion can relieve an overloaded regulator or interceptor reach, resulting in a more optimized operation of the collection system. Flow diversion can also be used to relocate combined sewer flow from an outfall located in a more sensitive receiving water area to an outfall located in a less sensitive one.

3.3.5.3 Storage Technologies

Wet weather flows can be stored for subsequent treatment at the POTW treatment plant once treatment and conveyance capacity have been restored. Technologies include the following:

- **In-Line Storage**—In-line storage is storage in series with the sewer (Urbonas and Stahre, 1993). In-line storage can be developed in two ways: (1) construction of new tanks or oversized conduits to provide storage capacity or (2) construction of a flow regulator to optimize storage capacity in existing conduits. The new tanks or oversized conduits are designed to allow dry weather flow to pass through, while flows above a design peak are restricted, causing the tank or oversized conduit to fill. A flow regulator on an existing conduit functions under the same principle, with the existing conduit providing the storage volume. Developing in-line storage in existing conduits is typically less costly than other, more capital-intensive technologies, such as off-line storage/sedimentation, and is attractive because it provides the most effective utilization of existing facilities. The applicability of in-line storage, particularly the use of existing conduits for storage, is very site-specific, depending on existing conduit sizes and the risk of flooding due to an elevated hydraulic grade line. Examples of flow regulating technologies used to develop in-line storage were discussed previously.

- **Off-Line Near Surface Storage**—This technology reduces overflow quantity and frequency by storing all or a portion of diverted wet weather combined flows in off-line storage tanks. The storage arrangement is considered to be parallel with the sewer. Stored flows are returned to the interceptor for conveyance to the POTW treatment plant once system capacity is available. In some cases, flows are conveyed to a CSO treatment facility.

- **Deep Tunnel Storage**—This technology provides storage and conveyance of storm flows in large tunnels constructed well below the ground surface. Tunnels can provide large storage volumes with relatively minimal disturbance to the ground surface, which can be very beneficial in congested urban areas. Flows are introduced into the tunnels through dropshafts, and pumping facilities are usually required at the downstream ends for dewatering.

3.3.5.4 Treatment Technologies

Treatment technologies are intended to reduce the pollutant load in the CSO to receiving waters. Specific technologies can address different pollutant constituents, such as settleable solids, floatables, or bacteria. Where treatment facilities are to be considered, the LTCP should contain provisions for the handling, treatment, and ultimate disposal of sludges and other treatment residuals. The following list highlights selected treatment technologies:

- **Off-Line Near Surface Storage/Sedimentation**—These facilities are similar to off-line storage tanks, except that sedimentation is provided for flows in excess of the tank volume. Coarse screening, floatable control, and disinfection are commonly provided as part of these facilities.

- **Coarse Screening**—This technology removes coarse solids and some floatables. Coarse screening is typically provided upstream of other control technologies, such as storage facilities or vortex units, and is also used in end-of-pipe treatment applications.

- **Swirl/Vortex Technologies**—These devices provide flow regulation and solids separation by inducing a swirling motion within a vessel. Solids are concentrated and removed through an underdrain, while clarified effluent passes over a weir at the top of the vessel. Types of swirl/vortex devices include the EPA swirl concentrator and commercial vortex separators. Conceptually, the EPA swirl concentrator is designed to act as an in-line regulator device. In addition to flow routing or diversion, it removes heavy solids and floatables from the overflow. The commercial vortex separators are based on the same general concept as the EPA swirl concentrator but include a number of design modifications intended to improve solids separation. The commercial designs have been applied as off-line treatment units. Each type of swirl/vortex unit has a different configuration of depth/diameter ratio, baffles, pipe arrangements, and other details designed to maximize performance.

- **Disinfection**—This process destroys or inactivates microorganisms in overflows, most commonly through contact with forms of chlorine. Various disinfection technologies are available both with and without chlorine compounds. Some of the more common technologies include gaseous chlorine, liquid sodium hypochlorite, chlorine dioxide, ultraviolet radiation, and ozone. For disinfection of CSOs, liquid sodium hypochlorite is the most common of the above technologies.

- **Dechlorination**—A major disadvantage of chlorine-based disinfection systems is that the residual chlorine concentration can have a toxic effect on the receiving waters, due either to the free chlorine residual itself or to the reaction of the chlorine with organic compounds present in the effluent. With the relatively short contact times available at many CSO control facilities, disinfection residuals can be of particular concern and can require consideration of dechlorination alternatives. Two of the more common means for dechlorinating treated effluent are application of gaseous sulfur dioxide or liquid sodium bisulfite solution.

- **Other Treatment Technologies**—A number of other treatment technologies have been identified as applicable to CSOs and have been studied in pilot tests, but have not been widely implemented in operating facilities. These technologies include dissolved air floatation, high-rate filtration, fine screens and microstrainers, and biological treatment. Fine screens and microstrainers have been used in full-scale facilities but, in some cases, have been unreliable due to mechanical complexity and blinding of the screens. Biological treatment at a POTW treatment plant of pump back flows from a CSO storage facility is a common practice, but a biological treatment facility dedicated solely to CSO treatment would not likely be successful due to the impact of prolonged dry periods on the biological media.

3.3.6 Preliminary Sizing Considerations

The preliminary sizing of CSO control alternatives will likely depend on the following factors:

- Predicted CSO flow rates, volumes, and pollutant loads under selected hydraulic conditions

- Level of abatement of predicted CSO volumes and pollutant loads necessary to meet CSO control goals

- Design criteria for achieving the desired level of abatement with the selected control measure or technology.

The collection system hydraulic model developed for system characterization is an appropriate tool for predicting CSO flow rates and volumes (EPA, 1995d). The design hydrologic conditions can include historical storms of specified recurrence intervals, a continuous simulation based on a statistical year or multiple years of rainfall data, or both. The system model should be used to define a baseline condition, which will serve as a basis for evaluating reductions in CSO impacts resulting from the implementation of minimum technologies or other currently planned, short-term projects that are likely to be implemented before the major components of the LTCP. A "future planned conditions" baseline, incorporating short-term projects as well as design year base flows, would provide the basis for evaluating the impacts of the CSO control alternatives proposed as part of the LTCP. The future planned conditions baseline would be equivalent to a "future no-action condition" in facilities planning, although, in the case of CSOs, this nomenclature is misleading because near-term actions, such as implementation of minimum controls, are generally required and would be incorporated into the model.

The level of abatement of predicted flows necessary to meet CSO control goals depends on the definition of the specific goals. A goal of CSO elimination means that discharges from a given CSO location would be eliminated under all possible hydraulic and hydrologic conditions. This goal essentially dictates either sewer separation or CSO relocation, in which the relocation conduit is sized for the absolute peak flow from the CSO outfall. This peak flow can be determined by analyzing increasingly larger storm events (e.g., 5-year, 10-year, 20-year storms) until a storm is reached above which the peak flow from the CSO outfall does not increase. At this point, the collection system is at absolute capacity, and additional runoff cannot enter the collection system.

Sizing to meet goals of providing storage for 1 to 3, 4 to 7, and 8 to 12 overflows per year can be estimated initially by capturing the volumes from the 1-year, 3-month, and 1-month storms, respectively. Similarly, sizing to provide treatment over that range can be estimated using the peak flow rates from the range of storms, in conjunction with sizing criteria for treatment, which are usually based on flow rates. As CSO control alternatives are further developed, the basis for sizing should be evaluated against a long-term simulation, which would incorporate the impacts of dewatering rates and antecedent storms, particularly if the CSO control goals are tied to average annual overflow frequencies.

It is also important to evaluate the impact of remaining overflows on the receiving waters. A receiving water model might be required, for example, to evaluate whether the remaining overflow from the 6-month or 1-year storm would cause exceedances of WQS if a storage tank is sized to capture the volume from a 3-month storm. This evaluation might indicate whether flow in excess of the capacity of the tank should continue to pass through the tank receiving a level of treatment or whether excess flows should be diverted upstream of the tank.

As is evident from this discussion, the issues of sizing and performance are closely related. The relationships between sizing criteria and expected performance might not be as clearly defined for CSO treatment as they are for sizing of POTW treatment plant unit processes. This latter issue was addressed earlier in the discussion of the definition of equivalent primary treatment under the presumption approach. For the purposes of initial alternatives development, reasonable assumptions regarding design criteria should be made to allow a preliminary sizing and estimate of performance. These assumptions can then be revisited during further steps or refinements in the alternatives development and evaluation process, as more information becomes available and as the general feasibility of alternatives becomes better defined.

3.3.7 Cost/Performance Considerations

The CSO Control Policy states that cost/performance evaluations should be *"...among the other considerations used to help guide selection of controls"* (II.C.5). These analyses typically involve estimating costs for a range of control levels, then comparing performance versus cost and identifying the point of diminishing returns, referred to as the "knee" of the curve. Cost/performance analyses, used for the evaluation of alternatives, are discussed in more detail in Section 3.4. For the development of alternatives, it is likely that more than one alternative will be identified to achieve each level of control. During the alternatives development, a simpler cost/performance approach might be appropriate to eliminate non-cost-effective alternatives. For example, a computation of capital cost per gallon controlled might provide a reasonable basis for screening certain alternatives. During the more detailed alternatives evaluation process described later, present worth costs, incorporating annual O&M costs, would be developed for the remaining alternatives.

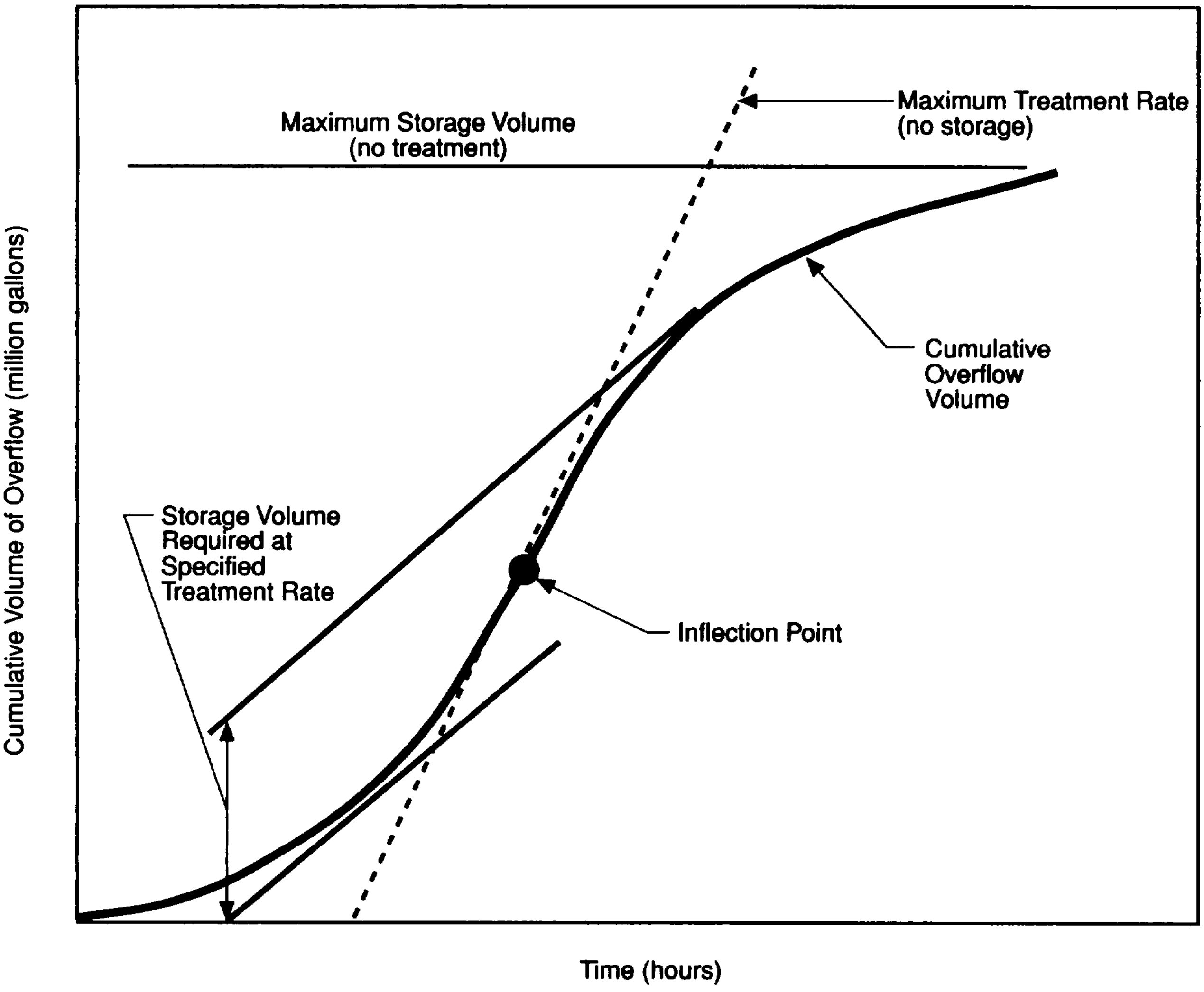
During alternatives development, non-monetary factors can also be defined and compared. For example, siting and environmental impacts and construction-related issues can be identified and used as a basis for the preliminary screening of alternatives. While at a more detailed level of alternatives development and evaluation, it might be appropriate to assign dollar values to some of these factors, in the initial development phase, qualitative assessments might be sufficient to eliminate certain alternatives from further consideration.

Thus, more formal cost/benefit analyses are appropriate during the detailed alternatives evaluation phase. For municipalities with larger or more complex CSSs where more initial screening of alternatives is necessary to make the alternatives evaluation analyses more manageable, simpler cost/benefit relationships provide an appropriate basis for that screening.

Another approach to cost-performance evaluations is the optimization of combinations of storage and treatment facilities. Given a design condition, the desired level of control could be achieved by providing storage of the entire CSO volume, sedimentation/treatment based on a maximum overflow rate for the peak CSO flow, or a combination of storage and treatment. Providing sufficient storage volume to capture all of the CSO or sufficient surface area to meet the maximum overflow rate at peak flow might not be feasible due to site or cost constraints. A more feasible alternative might be to size a sedimentation tank for a maximum flow that is less than the peak and provide storage for flows between the design maximum and the actual peak flows.

A mass diagram for the selected design storm (Exhibit 3-2) can be used to determine the range of combinations of storage and treatment to meet a given control goal. The mass diagram consists of a plot of cumulative volume of overflow versus time, based on a hydrograph developed by a collection system hydrologic/hydraulic model, such as SWMM. The slope at any given point on the curve represents the flow rate (change in volume with respect to time) at that point in time, and the end of the storm is indicated where the slope of the curve approaches zero (flow equals zero). The total volume at the end of the storm represents the storage volume required if no treatment is provided. The inflection point on the curve, where the slope is at a maximum, represents the peak flow rate to be treated if no storage is provided. The intermediate combinations of storage and treatment required to achieve a level of control between all-storage and all-treatment can be determined from the mass diagram. The changing slope of the curve represents the increase then decrease in CSO flow rate during the storm event. If a given flow rate (less than the peak) is selected as the maximum design flow rate for treatment, then flows above this maximum rate must be stored. Graphically, the selected maximum flow rate can be identified as two points on the curve, one above and one below the inflection point. All points between these two points on the curve represent flow rates greater than the design maximum. The vertical distance between the tangents at these two points, therefore, represents the volume of flow occurring while the flow rate is greater than the maximum design flow rate and, thus, represents the necessary storage volume.

Exhibit 3-3 is an alternative representation of this approach. In this figure, the predicted CSO flow rate to a facility is plotted against time. A horizontal line is drawn at the selected maximum flow rate for treatment, corresponding to a peak hydraulic loading rate. The volume of flow associated with flow rates in excess of the design maximum, which is to be captured for storage, is represented by the area of the curve above the maximum treatment rate. To optimize the storage/treatment combinations, cost estimates are developed for the all-storage, all-treatment, and selected intermediate combinations, and then the points are plotted and the minimum cost alternatives identified. Alternatives for the intermediate combinations of storage and treatment would require separate tankage for treated flows and for stored flows, with a regulator to limit peak flows to the treatment tanks. Flow would be introduced into the treatment tanks first. When the influent flow exceeded the design maximum, flow to the



Source: Camp, Dresser & McKee, 1989

Exhibit 3-2. Typical Mass Diagram

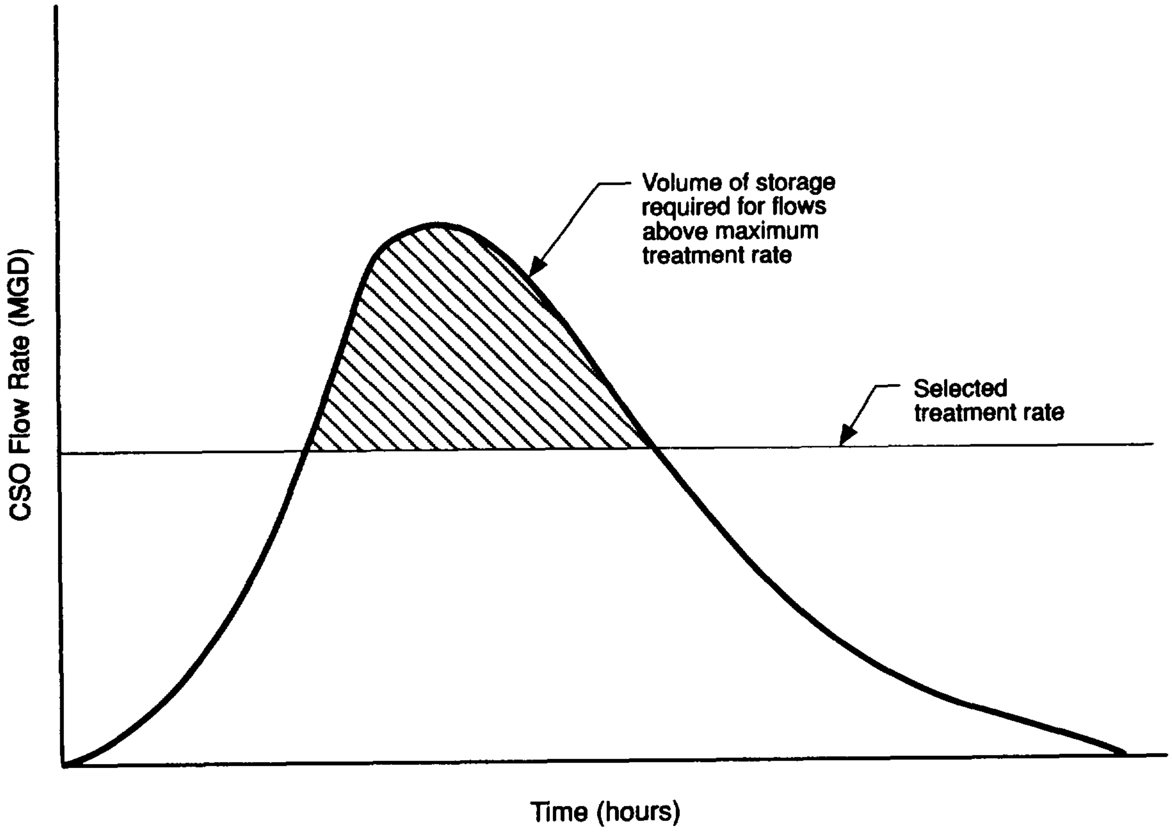


Exhibit 3-3. Typical Representation of Interaction Between Storage and Treatment Needs

treatment tanks would be throttled, with flows in excess of the design maximum diverted to the storage tanks. Once flows subsided to below the design maximum, the diversion of flow to the storage tanks would cease, and all flows would again be diverted to the treatment tanks. A vortex valve with an upstream overflow weir is an example of the type of regulator device that could be used to achieve the necessary flow control. The vortex valve would limit flow into the treatment tanks to a design maximum, with the excess flows diverted over the upstream weir to the storage tanks.

The mass diagram approach might be most applicable where an existing tank is available for CSO sedimentation. If the tank is not big enough to meet the maximum allowable overflow rate at peak flow, the size of a new storage facility to work in conjunction with the existing tank can be readily determined from the mass diagram, using the procedure described above.

One drawback to the mass diagram analysis is that the level of CSO control provided by each alternative is not equal. Storage of the full volume of CSO from a given storm for subsequent pumpback to a POTW treatment plant will likely provide a higher level of control than providing the equivalent of primary treatment at a satellite facility, particularly if pumpback occurs once secondary treatment capacity is available at the POTW treatment plant. A second drawback is that this analysis does not consider the storage volume available in the sedimentation tank. Depending on the total volume, peak flow, and hydrograph shapes for the selected design storm, the volume of the sedimentation tank might have more or less of an impact on performance. It is possible that the peak influent flow to a sedimentation facility will occur before the tank volume is full, so that the actual peak overflow rate occurs on the falling leg of the influent hydrograph, at a value less than the peak influent flow. The mass diagram could be used to estimate the total CSO volume associated with the point of maximum flow for comparison with the volume of the sedimentation tank.

In general, the evaluation of storage/treatment optimization can provide an additional level of information from which to identify potential alternatives. The analysis does not predict the performance or impact on water quality, other than that the performance will be between the boundary conditions of all-storage and all-treatment. In addition, questions of reliability, operability, and increased maintenance needs associated with maintaining separate tankage for storage and treatment should be considered in evaluating such alternatives.

3.3.8 Preliminary Siting Issues

One of the key considerations in assessing the overall feasibility of a CSO control alternative is the identification of an appropriate site. Siting issues can overshadow technical and even financial issues in the process of gaining public acceptance of a CSO control program. As with other aspects of the alternatives development process, identifying and evaluating potential sites calls for iterative screening. The objective of preliminary site development is to identify potential locations for the range of facilities identified based on the sizing procedures. Common sense and engineering judgement are used at the preliminary siting level to identify possible locations for facilities.

Initial criteria for screening potential sites can include:

- Availability of sufficient space for the facility on the site
- Distance of the site from CSO regulator(s) or outfall(s) that will be controlled
- Environmental, political, or institutional issues related to locating the facility on the site.

Recent aerial photographs or relatively small-scale maps, such as USGS topographic maps, are useful for the initial identification of potential sites. To assess whether sufficient space is available on a site, however, larger-scale maps, such as 100-scale sewer maps, are more useful. It is helpful to develop an estimate of the footprint of the proposed facility, then lay the footprint over an assessor's map, or other larger-scale plan view of the site. Consolidation or connecting conduits, where required, should also be located on the preliminary site plans. Site inspections are extremely valuable to confirm geographic information and to identify obvious features that might not appear on the available maps or aerial photographs.

If possible, it is usually beneficial to identify more than one potential site for each facility. Later evaluation of alternate sites may involve tradeoffs and comparisons between sites. Public participation through public meetings and workshops provides key input for the evaluation of these trade-offs, as well as to other aspects of preliminary site development.

Deciding whether a site is within a reasonable distance of the required point of control requires engineering judgment, particularly if an apparently ideal site is located further from the point of control than an apparently less-ideal site. The tradeoffs between distance and other factors can be evaluated during the detailed alternative evaluation process described in the next section. During alternatives development, however, initial comparisons might eliminate some options from further consideration.

Detailed analysis of the environmental, political, and socioeconomic impacts of locating a facility at a particular site is also part of the detailed alternative evaluation process. In some areas, however, a municipality might have specific knowledge of the history or existing plans for a particular site, which would preclude that site for consideration as a location for a CSO control facility. For example, a vacant lot might be known to contain contaminated soil or might to be already committed to commercial development. In such a case, a more detailed analysis of the site would not be worthwhile, unless perhaps no other feasible sites were available.

The municipality also needs to consider issues of "environmental justice" at the preliminary siting level. If the initially identified sites for CSO control facilities are all in low-income neighborhoods, the municipality should attempt to identify alternative sites in other areas to balance perceived inequities in project siting. If no other sites are technically feasible, then the municipality should recognize the need for additional effort in public participation, such as public meetings with concerned members of the community or multilingual fact sheets about the proposed facility. Development of multiple-use facilities with special architectural considerations or linkage with neighborhood improvement projects can also foster public acceptance of the proposed plan.

3.3.9 Preliminary Operating Strategies

Once a preliminary size and location have been identified for an alternative, the municipality should develop conceptual operating considerations to ensure that the alternative can function reasonably in the context of its geographic location and relationship to the collection system. For an off-line storage/treatment facility, the preliminary operating considerations might include the location of regulators and conduits for diverting flow into the facility, identification of influent or effluent pumping needs, route of a dewatering force main and facility outfall, identification of solids handling needs, and coordination of dewatering rates with POTW capacity. For a deep tunnel, the alternative development process might include preliminary identification of diversion structures, consolidation conduits, dropshaft, access and work shaft locations, screening facilities, and pumping requirements.

3.4 Evaluation of Alternatives for CSO Control

The evaluation of CSO control alternatives can be a complex process, and no one methodology is appropriate for all CSO control programs. Certain general considerations, however, apply to most evaluation approaches. In general, evaluations focus on cost, performance, and non-monetary factors. Cost evaluations are quantitative, performance evaluations can be both quantitative and qualitative, and non-monetary factor evaluations are generally qualitative. One of the challenges to alternatives evaluation is how to assess the relative importance of cost, performance, and non-monetary factors in selecting a preferred alternative. The following sections present discussions and examples of ways to evaluate these issues.

3.4.1 Project Costs

Project costs include capital costs, annual O&M costs, and life-cycle costs. Capital cost, the cost to build a particular project, includes construction cost, engineering costs for design and services during construction, legal and administrative costs, and typically a contingency. The contingency is usually developed as a percentage of the construction cost, and the engineering, legal, and administrative costs are usually combined as a percentage of the construction plus contingency. Annual O&M costs reflect the annual costs for labor, utilities, chemicals, spare parts, and other supplies required to operate and maintain the facilities proposed as part of the project.

At the facilities planning level, published cost curves are usually acceptable for estimating capital and O&M costs. Care should be taken to determine whether the cost curves to be used are for a specific technology or for a complete facility. For example, a capital cost curve for a storage/sedimentation facility might not include costs for coarse screening, disinfection, pumping, or other unit operations, which are often included in such a facility. Most curves also do not include allowances for land acquisition, utility relocation, engineering and contingencies, and special site considerations, such as removal of contaminated material or difficult permitting.

Cost curves should also be indexed to account for inflation, using an index such as the Engineering News Record Cost Correction Index (ENR CCI). The ENR CCI allows a cost estimate based on, for example, 1990 costs to be adjusted to current costs by multiplying the 1990 cost by the ratio of the current ENR CCI to the 1990 ENR CCI. The ENR CCI varies with geographic location, so local ENR CCI information needs to be used.

Life-cycle costs refer to the total capital and O&M costs projected to be incurred over the design life of the project. Life-cycle costs can be conveniently expressed in terms of total present worth (TPW), which is the sum of money that, if invested now, would provide the funds necessary to cover all present and future costs of a project over the design life of the project. Life-cycle costs can also be expressed as an equivalent annual cost (EAC), which converts a non-uniform time-series of costs (such as 2 years of construction costs followed by 20 years of annual O&M costs) into a uniform annual cost over the design life of the project. One benefit of these analyses is that they allow for direct comparison of projects with high capital costs and relatively low annual O&M costs against projects with lower up-front capital costs but higher annual O&M costs. The TPW can also be expressed as a cost per volume of CSO controlled to indicate the relative cost-effectiveness of an alternative.

The TPW of a project is calculated by adding the initial capital cost to the present worth of annual O&M costs and then subtracting the present worth of the salvage value of the project (i.e., the depreciated value of the project at the end of its design life). The present worth of annual O&M costs is computed by multiplying the average annual O&M cost by the appropriate uniform series present worth factor, based on the given discount rate and design life. The discount rate to be used in the TPW analysis for facilities planning is set each year by EPA; the uniform series present worth factor can be obtained from tables in standard engineering economics textbooks. The present worth of the salvage value is computed by multiplying the salvage value by the appropriate single payment present worth factor, based on the given discount rate and design life. The value of land generally should not be depreciated and might even be assumed to increase in value over the course of the project design life. The value of the land should then be added to the depreciated value of the facility to obtain the total salvage value. Exhibit 3-4 presents an example using this procedure.

3.4.2 Performance

The expected performance of CSO control alternatives can be evaluated in a number of ways, depending in part on the technologies under consideration. The benefits of source controls are generally the hardest to quantify, particularly management practices such as street sweeping and catch basin cleaning. Although some studies have been conducted to quantify the benefits of BMPs, their performance is variable, site-specific, and difficult to quantify. Thus, the performance of source controls might need to be described qualitatively, such as "reduces floatables." Collection system controls, such as sewer separation or I/I removal, are more readily quantified and can be simulated in models such as SWMM. The performance of collection system controls can be expressed in terms of reduction in overflow volume and/or frequency as predicted by SWMM. If pollutant concentrations are known or can be predicted, then the overflow volumes can be converted into pollutant loads. These flows and loads, in turn, can be used as input to a receiving water model to assess the impact of load reduction on beneficial use criteria. The benefits of certain collection system controls, such as interceptor relief, can also be evaluated using a hydraulic model to assess the reduction in flooding or surcharging.

Exhibit 3-4. Example Calculating Total Present Worth

Two alternatives for CSO control are proposed, with the following estimated costs.

	Alternative A	Alternative B
Capital Cost	$5,200,000	$4,300,000
Annual O&M Cost	$50,000	$150,000
Salvage Value	$500,000	$400,000
Land Value	$150,000	$100,000

Assume that the following conditions apply:

- Design life = 20 years
- Discount rate = 8 percent
- Annual rate of increase in land value = 3 percent.

Based on these conditions, the following factors are obtained from tables:

- Uniform series present worth factor = 9.8181
- Single payment present worth factor = 0.2145.

The total present worth of each alternative is computed as follows.

Alternative A:

Present Worth, Capital Cost = $5,200,000

Present Worth, Annual O&M Cost
$50,000 x 9.8181 = $491,000

Present Worth, Salvage Value

Land: $150,000 x 1.03^{20} = $271,000

Facility: 500,000

771,000 x 0.2145 = (-) 165,000

Total Present Worth $5,526,000

Alternative B:

Present Worth, Capital Cost = $4,300,000

Present Worth, Annual O&M Cost
$150,000 x 9.8181 = 1,473,000

Present Worth, Salvage Value
Land: $100,000 x 1.03^{20} = $181,000
Facility: 400,000
581,000 x 0.2145 = (-) 125,000

Total Present Worth $5,648,000

Over the design life of the project, the lower annual O&M cost of Alternative A compensates for the higher capital cost, making it the lower cost alternative on a TPW basis.

Similarly, the performance of storage alternatives can be evaluated in terms of reduction in overflow volume and/or frequency, based on the volume to be stored. Storage facilities can be sized to capture the volume from statistical design storms, such as a 3-month, 6-hour storm, or a 1-year, 24-hour storm. SWMM can be used to develop the volumes to be captured from the selected design storm event(s). The volume reduction can then be translated into pollutant load reduction, based on estimated or simulated pollutant concentrations. Performance can also be evaluated on an annual basis, using a statistically average year or multiple years of rainfall data. For storage alternatives, a means of simulating the dewatering of the storage facilities is necessary in order to evaluate the impact of antecedent storms on facility performance.

The evaluation of treatment alternatives is less straightforward because pollutant removal performance criteria should be assigned to the treatment technology. The selected pollutant removal criterion is then applied to the volume predicted to be discharged from the treatment facility. For example, if a tank was sized to provide primary treatment for the 3-month, 24-hour storm, SWMM would predict the volume of flow tributary to the treatment facility. The resultant pollutant load to the receiving water would be calculated by subtracting the volume of the tank from the influent volume, multiplying by the assumed pollutant removal efficiency, and then multiplying by the appropriate conversion factor for units of measure. For time-varying performance assessments, a model that includes the treatment process can be considered.

The measures of performance used will depend on the water quality goals to be achieved, as well as the level of sophistication of the evaluation tools available to the municipality. If receiving water modeling is not available, the reduction in pollutant loads compared with future planned conditions or other appropriate baseline condition is another measure of performance. Changes in pollutant loads to receiving waters can be computed in a number of ways. For example, the reduction in pollutant load from a CSO can be determined as a percent of baseline load from a CSO, or the reduction in pollutant load from all sources (CSO, storm water, upstream sources) can be calculated as a percentage of baseline load from all sources.

The reduction in overflow frequency is also a useful measure of performance. If a municipality does not have the capability to perform long-term model simulations, overflow frequencies can be estimated from the recurrence interval of the storm serving as the basis of design. If receiving water modeling is available, isopleths (maps indicating areas of similar concentration) of in-stream pollutant concentrations can be developed. Other statistics can also be generated, such as hours of exceedances of water quality criteria, acre-days of exceedances, and changes in concentrations of pollutants at given locations over time.

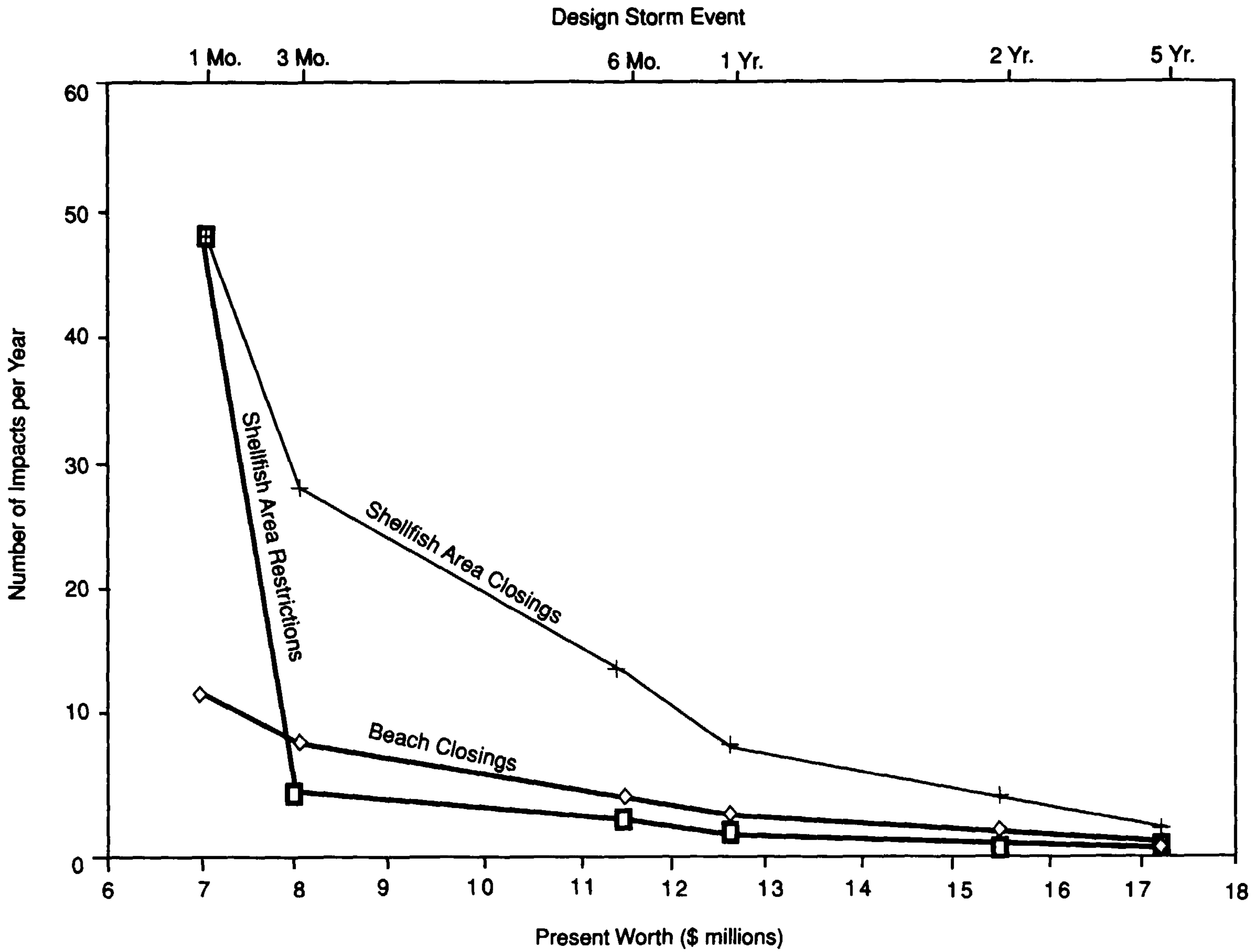
All of these factors can be valid measures of performance, depending on the circumstances. One of the challenges to alternatives evaluation is to determine ways to use such performance factors to make rational decisions on the relative merits of various CSO control alternatives. One method is to look at cost/performance relationships, while another is to apply qualitative rating and ranking methodologies to the performance data. These methods are discussed in following sections.

Performance can also be evaluated in terms of conformance with general objectives. Criteria under this category include the control of major discharges, impact on sensitive areas, and elimination of problem areas. The degree to which a particular alternative incorporates control of the larger CSOs is important because the majority of the pollutant load from a community, in most cases, originates from the largest CSOs. Continuous modeling analyses have shown that a municipality's minor CSOs often contribute a smaller percentage of overflow volume and pollutant load on an annual basis than they do during a design event. Mitigating impacts on sensitive areas is a significant concern, as expressed in the CSO Control Policy (Section II.C.3). Sensitive areas are often the focus for public access and use of the receiving water and are identified by the NPDES permitting authority in coordination with State and Federal agencies, as appropriate. Eliminating existing problem areas identified in the CSS potentially can improve system performance in many ways. Existing problem areas can include locations of repeated sewer backups and flooding, as well as recurring system maintenance problems, including grit deposition, pumping station flooding, and river or tidal inflow. The effectiveness of each alternative in addressing each of these general objectives can be rated qualitatively (e.g., good, fair, poor) or quantitatively (e.g., number of large CSOs, sensitive areas, or problem areas abated).

3.4.3 Cost/Performance Evaluations

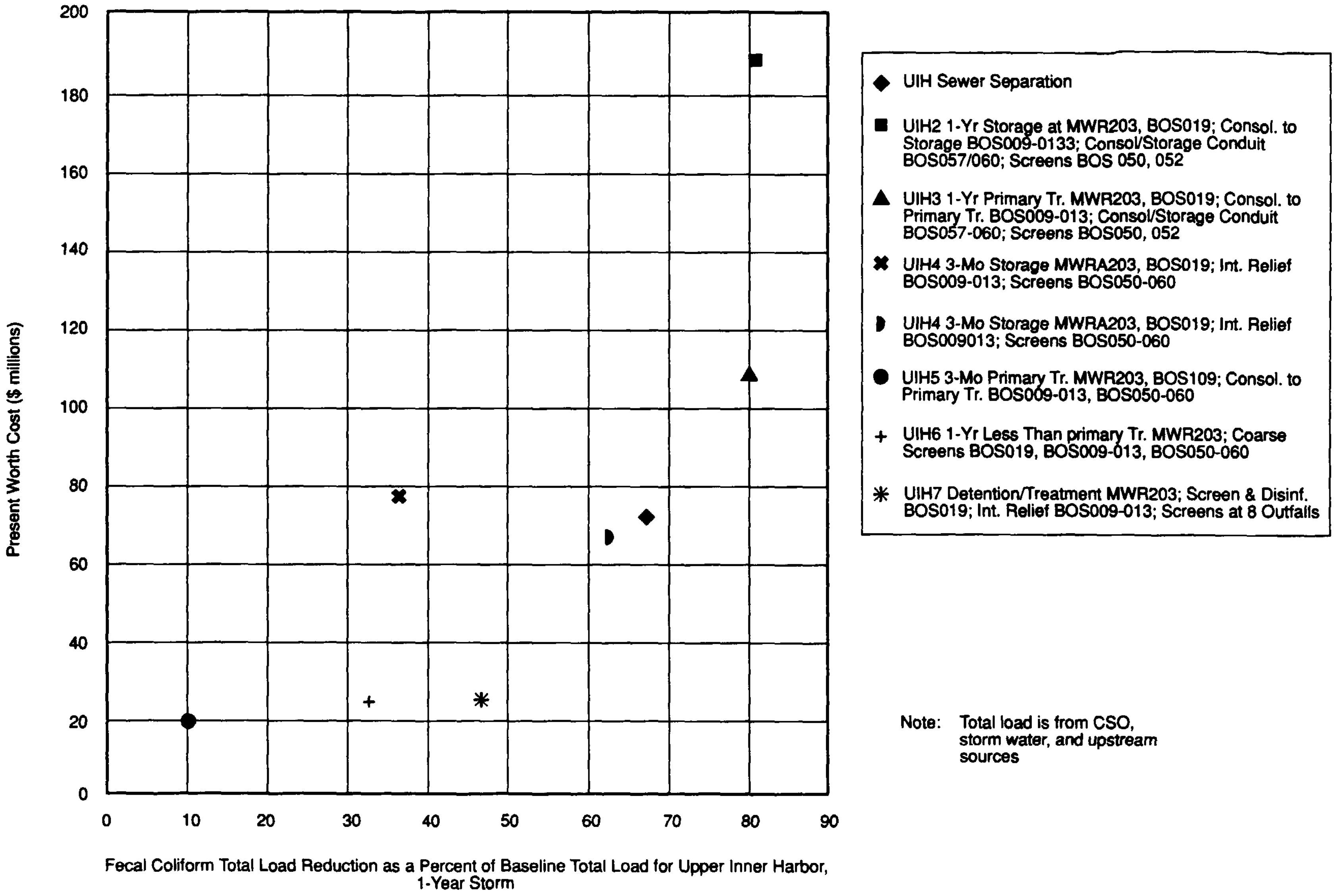
Having developed present worth costs and measures of performance, one of the traditional methods for evaluating engineering alternatives is by constructing cost/performance curves. Two common methods are to compare similar alternatives over a range of design conditions (such as 1-month, 3-month, 6-month, and 1-year storms) and to compare a range of control alternatives for a given design condition. Ideally, these comparisons would indicate that for lower levels of control, small increments of increased cost would result in large increments of improved performance, and for high levels of control, large increments of increased cost would result in small increments of improved performance. The optimal point, or "knee of the curve," is identified as the point where the incremental change in cost per change in performance changes most rapidly, indicating that the slope of the curve is changing from shallow to steep, or vice versa. Theoretically, if a smooth curve were fit through the data points, the knee of the curve would be the point where the second derivative of the function describing the curve is at a maximum. In practice, four or five points are plotted, then the point of the knee is determined from the shape of the curve. Because the points reflect planning-level estimates, a rigorous mathematical determination of the knee is generally not warranted and might imply false precision.

Exhibits 3-5 and 3-6 are examples of knee-of-the-curve analyses. In Exhibit 3-5, a proposed storage facility was sized to control CSOs from each of six design storm conditions, and the costs for each facility size were estimated. The impact of the various levels of control on critical uses (shellfishing and beach usage) was then determined. The resulting plot indicates the most cost-effective level of control using storage in terms of critical use impacts. In this example, the knee of the curve for shellfish area restrictions is clearly at the 3-month storm. For the other two criteria, shellfish area and beach closings, the location of the knee is less obvious. These curves are typical of the ambiguity often associated with knee-of-the-curve evaluations.



Source: Metcalf & Eddy, 1991

Exhibit 3-5. Example of Cost-Performance Curves Indicating Impacts on Critical Uses



Note: Total load is from CSO, storm water, and upstream sources

SOURCE: Metcalf & Eddy, 1994

Exhibit 3-6. Example of Cost-Performance Curve Indicating Removal of a Specific Pollutant (fecal coliform bacteria)

Exhibit 3-6 is an example of the second method of using cost/performance evaluations. In this figure, alternatives were compared for controlling fecal coliform bacteria loads into a coastal receiving water during a 1-year, 24-hour storm. Ten CSO outfalls discharge to this receiving water segment, and the alternatives evaluated included a range of control technologies for individual outfalls and groups of outfalls. Performance is measured as the reduction in total fecal coliform loads (from CSO, storm water, and upstream sources) as a percent of baseline total load. In this case, the knee of the curve corresponded to alternative "UIH7." This alternative included continuing treatment at an existing detention/treatment facility, providing a screening and disinfection facility at outfall BOS019, reducing overflow frequencies and volumes at outfalls BOS009 to BOS013 through interceptor relief, and installing screens at the remaining outfalls, which activate approximately four times per year or less. Two other observations from Exhibit 3-6 are noteworthy. First, the most expensive alternative, which involves complete capture for storage of all CSOs active during the 1-year storm, only results in approximately 80-percent removal of bacterial loads to the receiving water. The remaining 20 percent of the baseline load is contributed by storm water, which is not affected by the CSO control technologies. This example demonstrates the importance of considering sources of pollutants other than CSOs.

The second point demonstrated by this example is the need to screen alternatives before reaching this level of evaluation. This receiving water segment was just one of fourteen receiving water segments evaluated as part of an LTCP. Within that one receiving water segment, the 10 outfalls were divided into four groups, based on system hydraulic relationships. For each of those four groups of outfalls, alternatives were initially developed to address a range of control levels. In order to evaluate cost/performance on a receiving water basis, alternatives for each group of outfalls had to be combined. In addition, other design conditions (e.g., annual rainfall series and other design storm events) were used during this project. Using this approach, the number of possible combinations of alternatives for this receiving water segment could become very large, very quickly. To obtain a reasonable number of alternatives, preliminary screening was necessary, along with reasonable judgment on possible combinations of alternatives for the various groups of outfalls. This concept applies both to large systems and smaller systems. Even for a municipality with only one receiving water segment and a total of 10 CSOs, the number of possible combinations of alternatives could be similar to this example.

3.4.4 Non-Monetary Factors

Non-monetary factors that can influence the selection of a recommended alternative generally fall into three categories: environmental issues and impacts, technical issues, and implementation issues. These factors are more qualitative than cost and performance evaluations, but they address decision factors critical in alternative evaluation and provide a necessary "reality check" on the overall implementability of CSO control alternatives, which cannot be obtained from cost and performance numbers alone.

3.4.4.1 Environmental Issues/Impacts

The evaluation of environmental issues and impacts involves site inspection, with reference to zoning, soils, floodway, and similar types of maps, as well as coordination with local and State agencies. Depending on the potential cost of the alternatives and scope of the planning effort, more detailed field surveys and/or geotechnical or hazardous waste investigations might be necessary. During this evaluation process, it may be appropriate to identify the various permits that would be required to implement the proposed CSO control alternatives, because the permit application process can require significant effort to support the implementation of certain types of projects. The specific environmental impacts to be evaluated vary from municipality to municipality, but the following general categories of impacts should typically be covered:

- **Land Use**—This category includes existing or planned land use of the proposed site; difficulty of property, easement, and right-of-way acquisition; zoning; and surrounding land use issues. Each of these issues could be considered a separate category for evaluation, if appropriate.

- **Traffic and Site Access**—Traffic impacts can include disruptions of traffic patterns or increases in truck traffic during construction, potential effects of traffic disruptions on local businesses, availability of alternate routes, changes to long-term traffic patterns following facility start-up, and impacts on residential areas. Site access considerations also include feasibility and/or impacts of new access roads.

- **Utilities Relocation**—Potential impacts on existing utilities can be rated qualitatively (e.g., high, medium, or low potential for impact) or, in some cases, included as an allowance on the estimated cost. Detailed investigation of utilities locations is usually performed during the design phase.

- **Noise and Vibration**—The impact of noise and vibration from construction and facility operation can be evaluated by comparing ambient and predicted noise and vibration levels and by determining the number, type, and proximity of sensitive receptors—i.e., land uses or facilities that might be particularly sensitive to project impacts, especially increased noise and traffic. Sensitive receptors typically include open space areas (including cemeteries), picnic areas, playgrounds, recreation and sports areas, parks, residences, hotels and motels, schools, churches, libraries, and hospitals.

- **Historic and Archaeologic Resources**—A project's effects on historic and archaeological resources can be determined by consulting with the local or State historic preservation commission or similar agency.

- **Soils/Rock**—The suitability of the soils at a proposed site to provide a foundation for CSO facilities is considered in this evaluation. In addition, ground-water table and bedrock depths should be considered with respect to constructibility and to effects on adjacent structures.

- **Wetlands**—The existence and location of wetlands on a site is a major factor in determining a site's suitability for a proposed facility. Depending on local or State wetlands regulations, the potential for indirect impact due to activities within specified buffer zones around coastal or riverine wetlands should also be considered. Upland sites are generally considered more favorable than sites with wetlands, within wetland buffer zones, or within regulated coastal resources areas.

- **Floodplains**—The extent to which proposed facilities would encroach upon the 100-year floodplain and the potential for mitigation by providing compensatory storage should be identified.

- **Water Quality**—Construction of the CSO facilities is intended to improve receiving water quality. Construction activities, however, can temporarily degrade water quality, and this should be considered in the evaluation process.

- **Air Quality**—Construction-related dust and odors from operating facilities can create significant air quality impacts, which could cause concern at sites located close to residential areas, hospitals, or other sensitive receptors.

- **Threatened and Endangered Species**—The presence of Federal- or State-listed threatened or endangered species or critical habitat for these species would likely eliminate a potential site from further consideration.

- **Hazardous Materials**—The potential for encountering hazardous materials at a proposed site should be evaluated carefully. A review of previous land use records can provide insight on the existence of hazardous wastes or contaminated soils.

  State agencies should maintain records of known hazardous waste spill locations. Detailed and rigorous onsite investigations are typically not undertaken in the planning phase of a project; however, a planning level review of existing documentation can reveal whether a proposed location was previously a site of commercial or industrial use or the location of routine use, storage, or disposal of hazardous materials. Some field testing might be necessary.

3.4.4.2 Technical Issues

Various technical issues require qualitative evaluation in addition to financial considerations. These include the following:

- **Constructibility**—While it is recognized that costs can be associated with anticipated requirements for rock excavation, sheeting, or dewatering at a proposed site, these and other constructibility issues can also be considered on a more qualitative level. For example, an alternative involving deep tunnels will generally involve more specialized or complex construction techniques than a near-surface storage/sedimentation facility. Similarly, an alternative that requires a river crossing for a consolidation conduit will likely be more challenging in terms of constructibility than an alternative that does not require a river crossing. The overall size and location of a proposed alternative are also relevant to the constructibility analysis.

- **Reliability**—The operating history of similar installations is a good basis for predicting the reliability of a proposed facility. Contacting and/or visiting similar existing facilities can provide useful information on operations and reliability, especially since the availability of published information on operating facilities is limited. The evaluation of reliability should also include expected operating conditions, particularly for CSO facilities that are commonly unstaffed, rely on automatic activation, and operate only on an intermittent basis. Generally, alternatives that rely on simpler or less extensive mechanical equipment are more reliable than alternatives that rely on more complex equipment. The extent of reliance on existing facilities also affects reliability. For example, if the operation of a new CSO treatment facility relies on the operation of an aging upstream pumping station, the overall reliability of the alternative might be limited by the reliability of the pumping station. This aspect might be very important in areas where the existing collection system is known to be in poor condition.

- **Operability**—Issues of operability involve both process considerations and personnel-related considerations. Process considerations include the methods of solids handling and potential flexibility of response to various loading conditions; personnel-related considerations include the degree of automation and level of operator skill necessary to fully optimize use of available process features, as well as the need for confined space entry and for increased staff levels.

3.4.4.3 Implementation Issues

In addition to the cost, performance, environmental impacts, and technical issues, several other issues, which pertain to the political and institutional aspects of a project, affect the decision to implement a potential alternative. The following list discusses these implementation issues:

- **Adaptability to Phased Implementation**—The CSO Control Policy provides that "*...schedules for implementation of the CSO controls may be phased based on the relative importance of adverse impacts upon WQS and designated uses, priority projects identified in the long-term plan, and on a permittee's financial capability*" (II.C.8). Given the cost of CSO control facilities, municipalities might determine that projects that can be implemented in smaller parts over a period of time are more affordable than a single, large, one-time project. Phased implementation also allows time for evaluating completed portions of the overall project and the opportunity to modify later parts of the project due to unanticipated changes in conditions. The initial stages of phased projects often can be implemented sooner than a single, more massive project, bringing more immediate relief to a CSO problem.

- **Institutional Constraints**—Political and institutional forces can affect proposed CSO control programs in a number of ways. Because most CSO programs are funded by tax payers or sewer rate payers, elected officials generally must be able to convince the general public that the proposed CSO control program is cost-effective and for the public good. Public rejection of a proposed project can jeopardize the chances of raising the funds needed for project implementation. The best way to ensure public acceptance of a project is through an ongoing public participation program, as stressed throughout this guidance document.

  In addition to cost, siting issues are commonly the subject of most public debate on CSO control projects. Issues involving facility location, land takings, and easements in both public and private lands can lead to disagreements among Federal, State, and local officials, public utilities, private companies, and private citizens. Involvement, coordination, and negotiation among politicians, institutions, and other stakeholders and interested parties are necessary to ensure that a technically feasible project is also politically feasible.

Regional CSO controls call for coordination among the regional authority and the individual municipalities within the region, particularly where individual municipalities have already expended funds for planning and/or implementation of local projects. Intermunicipal agreements might be necessary if a CSO control project affects the collection systems of bordering municipalities.

The CSO Control Policy encourages permittees to "*...evaluate water pollution control needs on a watershed management basis and coordinate CSO control efforts with other point and nonpoint source control activities*" (I.B). The overall goals of a CSO control plan and the steps for achieving those goals can be affected or influenced by the goals of storm water or nonpoint source control programs. Therefore, these programs should be considered in evaluating CSO control program options.

- **Multiple Use Considerations**—One means for gaining public and institutional acceptance of CSO projects is through the development of multiple-use facilities. Locating parking facilities over storage/treatment tanks, constructing bike paths over the routes of consolidation conduits, and improving river access are possible enhancements to CSO control projects that have been shown to provide additional public benefit.

3.4.5 Rating and Ranking of Alternatives

Because most of the non-monetary factors described are qualitative in nature, evaluation of these factors necessarily entails a degree of subjectivity. To make reasonable comparisons among multiple alternatives, the qualitative judgments should be standardized to the extent possible. While cost and performance criteria are generally quantitative, judgment should still be made as to the relative importance of specific cost and performance data both with respect to the range of cost and performance criteria identified for each alternative and with respect to the non-monetary factors. For example, performance criteria can include predicted duration of exceedance of fecal coliform bacteria standards, reduction in fecal coliform loading during a given design storm, and reduction in overflow frequency during a typical year. Each of these performance criteria is quantitative; the municipality must determine whether they are equally important, whether any criteria are more important than the others, and their importance compared with siting or constructability issues. Developing a methodology to evaluate the data compiled for each alternative in such a way that the appropriate weight is given to the appropriate evaluation criterion is a difficult, yet important, step in the evaluation process.

One approach for evaluating the information developed for each alternative is to construct a matrix listing each factor or criterion on the vertical axis and each alternative on the horizontal axis. A rating system is then established for each factor, defining the relative magnitude of the factor, the degree of impact each alternative has on that factor, or vice versa, as appropriate. Rating systems can be descriptive (e.g., high, medium, low impact), symbolic (+, 0, -), or numeric (1 to 5, with 1 = low impact, 5 = high impact). Using a numerical scale facilitates summing the individual ratings to produce an overall rating. A numerical scale is also most amenable to weighting factors. For example, if the annual overflow frequency is determined to be more important than the TSS load during a specific design storm, then the rating for annual overflow frequency can be multiplied by a weighting factor. This weighting increases the relative impact of that specific rating when all of the ratings for a given alternative are summed.

To provide as much consistency as possible, criteria must be defined for each rating value. Exhibit 3-7 provides examples of criteria for rating values.

Exhibit 3-7. Example Criteria for Rating Values

Category	Rating	Criteria
Constructibility	1	Standard construction techniques
	2	Standard techniques, but with restraints (such as limited staging area, difficult site access)
	3	Special techniques or more severe restraints on construction
TSS Load	1	Substantial improvement over existing conditions
	2	Limited improvement or no change compared with existing conditions
	2	Load increases compared with existing conditions

In this exhibit, for constructibility, certain construction activities, such as tunneling with tunnel boring machines (TBMs), can be defined as being "special techniques." For TSS load, "substantial improvement over existing conditions" can be defined further as a minimum percent reduction in load. In general, the greater the degree of definition of the ratings, the less subjective the rating process.

Exhibit 3-8 presents an example of a matrix for evaluating CSO control alternatives. In this example, non-monetary factors, such as conformance with objectives, operability, and constructibility, have been rated qualitatively. As a next step, numerical values can be assigned to the ratings of "good," "fair," "poor," "medium," and "low," as well as to the relative values of the monetary factors. If appropriate, the numerical values can be weighted, then the values in each column can be summed to create an overall rating for each alternative.

Exhibit 3-8. Example Matrix for Evaluating CSO Control Alternatives

Selection Criteria	Sewer Separation	Storage	Screening and Disinfection
Monetary Factors:			
Capital Costs	$2,690,000	$3,450,000	$3,740,000
Annual O&M Cost	------	$35,000	$47,000
Present Worth	$2,470,000	$3,570,000	$3,920,000
P.W. $/Design Storm CSO Gallons Abated	$8.40	$12.15	$13.35
Conformance with Objectives:			
Control of Major Discharges	Good	Good	Good
Elimination of Identified Problem Areas	Fair	Poor	Poor
Impact on Priority Areas	N/A	N/A	N/A
Operability:			
Number of Facilities	0	2	2
Reliability	Good	Fair	Fair
Level of O&M	Low	Medium	Medium
Reliance on Existing Facilities	Low	Medium	Medium
Impacts on Downstream Facilities	Low	Medium	Medium
Constructibility:			
Site Requirements	Low	Medium	Medium
Extent of Disruption	Medium	Low	Low
Degree of Difficulty	Medium	Low	Low
Adaptability to Phased Implementation	Good	Fair	Fair
Conformance with Current Plans	Good	Poor	Poor

N/A - Not Applicable
Source: Metcalf & Eddy, 1988

Rating and ranking systems should be viewed as a tool in the evaluation process and not necessarily as the final determinant of a recommended plan. Once a series of alternatives has been rated and/or ranked, it is sometimes necessary to "step back" from the evaluation process to ensure that the recommendations make sense and that program goals are being met. Public input, through workshops, public meetings, and written comments, can also reshape the recommended plan. These and other issues associated with the final selection of the recommended plan are addressed in Chapter 4. Additional guidance on rating and ranking procedures is provided in (EPA, 1995d).

3.5 Financial Capability

As part of LTCP development, the ability of the municipality to finance the final recommendations should be considered. The CSO Control Policy "*...recognizes that financial considerations are a major factor affecting the implementation of CSO controls...*[and]... *allows consideration of a permittee's financial capability in connection with the long-term CSO control planning effort, WQS review, and negotiation of enforceable schedules*" (I.E). The CSO Control Policy also specifically states that "*...schedules for implementation of the CSO controls may be phased based on...a permittee's financial capability*" (II.C.8). In considering the implementation costs of CSO controls, the municipality should investigate both the total cost of the various alternatives and its ability to absorb the costs. To this end, EPA is developing guidance on financial capability assessment (EPA, 1995e).

EPA's assessment process to determine a municipality's financial capability is a two-step process involving an initial screening followed by an investigation of overall financial condition. In the initial screening step, financial parameters are identified and the financial implications of the proposed wastewater treatment and CSO controls evaluated. In this step, the municipality determines the total wastewater and CSO capital and operating cost per household (CPH) to implement the proposed control plan and the median household income (MHI) in the service area. With these two numbers, the municipality can assess the financial impact of each CSO control alternative on residential users.

The second step is an assessment of the following selected indicators to evaluate the municipality's financial capability:

- **Debt Indicators**—These give an indication of the debt burden on the municipality and include the bond rating and overall net debt as a percent of full market property value.
- **Socioeconomic Indicators**—These give an indication of the long-term trends in the municipality and include the unemployment rate and the median household income.
- **Financial Management Indicators**—These give an indication of the municipality's ability to manage financial operations and include the property tax revenue collection rate and property tax revenue as a percent of full market property value.

Although the financial analysis can influence the selection of a recommended plan, the financial capability assessment is primarily intended to serve as a guide for developing an implementation schedule for the recommended plan. For example, a municipality might not be able to implement multiple CSO controls simultaneously, but the financial capability analysis would provide guidance on an approach to phasing the implementation of the controls so that the financial impacts are attenuated over a period of years. Chapter 4 provides additional details on project financing and other implementation issues.

CASE STUDY: MASSACHUSETTS WATER RESOURCES AUTHORITY (MWRA) - CSO CONCEPTUAL PLAN AND SYSTEM MASTER PLAN

The Massachusetts Water Resources Authority (MWRA) provides wastewater services to 43 communities in the greater Boston area. Within this service area, four communities—Boston, Cambridge, Somerville, and Chelsea—have CSSs with a total of 80 CSO outfalls in Boston Harbor and six tributary rivers. The MWRA's CSO Conceptual Plan and System Master Plan (CCP/SMP), December 1994, presented an LTCP for CSO control, as well as an evaluation of the impacts of sizing and selection of CSO control alternatives of other aspects of the MWRA system, such as interceptor performance, secondary treatment at Deer Island, and system-wide I/I.

The MWRA's CSO program involved three major components:

- Reduction in the overall CSO volume and increase in the percentage of flow receiving treatment as results of recent improvements to the conveyance system, POTW, and CSO treatment capability
- Further reduction in CSO volumes through system optimization
- Development of long-term CSO control recommendations.

The demonstration approach was selected for the development of long-term CSO control facilities. This approach featured a combination of detailed modeling and a watershed approach to evaluate causes of current nonattainment of WQS, to define appropriate water quality goals and associated CSO control goals, and to develop cost-effective alternatives to meet the CSO control goals. For the purpose of this study, the receiving waters affected by CSOs were divided into 14 separate receiving water segments. The receiving water segment boundaries were generally defined by physical features, such as dams, river influences, and embayments. In many cases, these boundaries also correlated with changes in water uses, level uses, hydrology, and/or pollution sources. Solutions were developed for each receiving water segment, while considering the interrelationships among segments.

The MWRA invested in a detailed system characterization, which provided a solid foundation for developing a detailed system model (SWMM EXTRAN). The model then allowed for comprehensive engineering evaluations, through which a recommended plan was developed. This plan will lower expected project costs by approximately $900 million over a previous CSO control plan. The approximately $2 million spent on the system characterization not only substantially reduced the expected project costs, but also provided stakeholders with a high level of confidence in the results of the engineering evaluations.

Although the four communities, 80 outfalls, and multiple receiving waters included in the MWRA's CCP/SMP would clearly constitute a large and complex system, the approach taken by the MWRA would generally be applicable to smaller systems as well. In effect, the MWRA applied its methodology to 14 smaller systems representing the 14 receiving water segments. Much of the complexity in this project derived from the interrelationships among the segments. A smaller municipality could apply the same principles in its approach to the LTCP; however, with fewer outfalls and receiving waters, the scope of the work could be reduced appropriately.

PUBLIC PARTICIPATION

The MWRA established the following goals for its public participation program:

- Provide education on CSO issues
- Provide opportunities for public review and comment on the CSO program during development
- Respond to questions and comments in a timely fashion
- Ensure stakeholder input at key project milestones.

Specific aspects of the MWRA's public participation program included the following:

- Working with a citizens advisory committee, which included representatives of environmental, business, and neighborhood associations, citizen activists, and municipal and elected officials.
- Working with agency and regulatory representatives, including EPA and the State WQS authority.
- Publication of the *CSO Bulletin* to explain key CSO issues and planning decisions, notify municipal officials and working group members of upcoming events, and provide information on how CSOs fit into other MWRA planning efforts.
- Presenting two series of interactive workshops at key junctures in the development of the CCP/SMP: one series to present baseline receiving water data, initial water quality and CSO control goals, and initial alternatives for CSO control and another series to present the results of more detailed evaluations of CSO control alternatives. Attendees included MWRA and CSO community staff, representatives from regulatory agencies, environmental groups and other stakeholders. Each series consisted of a number of individual workshop sessions to present information pertaining to individual receiving water segments.
- Conducting two series of neighborhood meetings (one addressing water quality evaluations and one addressing control technology alternatives) to present the results from the above workshop series. Neighborhood meetings were arranged to generally correspond with groupings of receiving water segments.
- Conducting individual presentations upon request to groups having particular technical and/or local area interests.

LONG-TERM CONTROL PLAN APPROACH

As an initial step in developing its LTCP, the MWRA conducted an extensive system characterization program, followed by a receiving water quality evaluation program. Key features of the system characterization program included:

- Collecting flow data from approximately 250 metering locations, including CSO outfalls, interceptors, system headworks, and existing CSO treatment facilities
- Conducting numerous inspections of CSO regulators and other system features
- Developing detailed piping schematics for each regulator
- Developing a detailed hydraulic/hydrologic model (SWMM) for the four CSO communities.

Key features of the receiving water quality evaluation program included:

- Defining existing water quality standards
- Defining existing water quality through wet and dry weather sampling
- Characterizing watersheds, waterbody hydrodynamics, CSO sources, and storm water sources
- Developing a receiving water quality model
- Defining causes of nonattainment of WQS.

Data from the MWRA's receiving water and combined sewer system characterization program indicated that non-CSO pollution sources contributed substantially to nonattainment of WQS in most receiving water segments. The MWRA considered both the presumption and demonstration approaches and determined that, for the impacted receiving water segments, the demonstration approach was necessary to fully evaluate attainment of WQS. Thus, the MWRA selected the demonstration approach for its LTCP. The demonstration approach allowed for the development of appropriate levels of CSO control for each receiving water segment and coordination of CSO control with appropriate water quality goals. Ranges of control were evaluated for each receiving water segment, with an emphasis on higher levels of control in critical use areas. Regulatory agency participation in the workshop series provided the opportunity for early coordination and presentation of the data, as well as the development of a mutual understanding of water quality issues.

DEVELOPMENT OF ALTERNATIVES FOR CSO CONTROL

Definition of CSO Control Goals

The MWRA developed a long-term conceptual plan for CSO control using a watershed-based approach, so that site-specific water quality conditions and impacts from CSOs relative to non-CSO sources of pollution could be determined. The process for selecting the recommended CSO control alternative for each receiving water segment integrated the concepts of watershed management and use attainability. A range of water quality goals was initially established for each receiving water segment, using information from an assessment of baseline receiving water conditions. The receiving water assessment included consideration of the major sources of pollutant loads in the watershed: CSOs, storm water discharges, and boundary or upstream sources. The flows and loads from these sources were estimated from modeled flows generated for various hydrologic conditions (design storm events and a design annual rainfall series) and from pollutant concentrations generated from statistical analyses of available site-specific data.

Receiving water models were used to assess the impacts of CSOs and storm water on selected riverine and coastal receiving water segments. These models were used to quantify the impacts of CSO sources only, storm water and upstream sources only, and a combination of CSO, storm water, and upstream sources on the attainment of bacteria standards for each segment.

In general terms, the range of water quality goals defined for each receiving water segment was as follows:

- Level I: Full attainment of designated uses
- Level II: Attainment of designated uses for most of the year (i.e., except for four or less overflows per year)
- Level III: Improvement over existing conditions (until other, more prominent sources of pollution are addressed).

A range of CSO control goals was then defined that would contribute to achievement of the water quality goals for each receiving water segment. The CSO control goals addressed only the CSO-related conditions that contributed to nonattainment of beneficial uses. In several receiving water segments, it was determined that pollution contributed by CSOs was only a small fraction of the total pollutant loads from other sources. In these segments, even complete elimination of CSO outfalls would not achieve the water quality goals because the other sources prevented the attainment of beneficial uses. The CSO control goals were developed with the assumption that if the other sources were remediated by the appropriate responsible parties, then the CSO controls would be stringent enough for water quality goals to be met.

Examples of a range of CSO control goals for a receiving water segment included the following:

- Level I: Eliminate all CSOs by sewer separation or relocation of the outfall(s)
- Level II: Reduce untreated CSOs to approximately four overflows per year by transport improvements, storage, or treatment
- Level III: Control floatables and meet other aesthetic criteria.

Initial Alternatives Development and Screening

Once CSO control goals were established to achieve the water quality goals in each receiving water segment, engineering and hydraulic analyses were conducted to develop and screen initial CSO control alternatives. The use of GIS and comprehensive system modeling allowed development and evaluation of alternatives where receiving water segment boundaries did not match collection and transport system hydraulic boundaries. While the impact of solutions focused on receiving water segments, hydraulic feasibility depended on the collection and transport system configuration. In some cases, structural modifications in one receiving water basin affected system performance in another receiving water basin. GIS maps provided an excellent backdrop for initial development of control alternatives, particularly with regard to identifying opportunities for consolidation of outfalls and geographic relationships among the most active outfalls and regulators.

The types of alternatives developed generally included elimination of CSOs through sewer separation or CSO relocation; near-surface storage, storage/sedimentation, or floatables control with disinfection; consolidation of outfalls to a regional storage or treatment facility, and use of consolidation conduits for storage; in-system storage; deep tunnel storage; interceptor or trunk sewer relief; upgrade of existing CSO control facilities; sewer separation upstream of selected regulators; and end-of-pipe floatables controls. Alternatives were generally sized for both a 3-month and 1-year design storms and were evaluated using continuous simulation for a 1-year period.

Hydraulically feasible alternatives were initially screened based on a range of criteria, including hydraulic performance, water quality improvement, cost, construction risks, mitigation concerns, and short- and long-term environmental impacts. The screening was conducted in a matrix format, with alternatives organized by receiving water segment or subarea. For each alternative, the criteria were rated qualitatively, and the ratings for each alternative were summed to create a total score for each alternative. The performance, construction risks, and other criteria associated with each alternative were rated in a similar manner. Alternatives within a given receiving water segment that scored substantially lower than others within that segment were not evaluated further. Compatible alternatives for the receiving water segments were combined to form regional and system-wide CSO control strategies. The screening process was conducted during the first series of workshops, mentioned previously, which incorporated stakeholder viewpoints and concerns and served to educate all parties regarding the system and possible solutions. The result was a relatively short list of alternatives for each receiving water segment that then underwent a more detailed evaluation.

Evaluation of Alternatives for CSO Control

CSO control alternatives remaining after the initial screening process were evaluated in more detail using a variety of tools, including SWMM EXTRAN simulations using a design annual rainfall series and design storm evaluations using one- and two-dimensional receiving water quality models. More detailed evaluation criteria were established, organized into the following categories:

- **Cost**—Capital, O&M, and net present worth
- **Performance**—Reduction in CSO frequency/volume and percent reduction in pollutant loads
- **Cost/Performance Relationships**—Knee of the curve analyses based on pollutant load reductions for selected design storms
- **Water Quality**—Duration of WQS exceedances, number and frequency of untreated overflows remaining, and relative impact of non-CSO sources of pollution
- **Siting Constraints**—Qualitative evaluations of site availability and constraints.

A numerical rating system was established for these criteria to rate and rank the alternatives for each receiving water segment. For example, for performance and water quality impacts, receiving water-specific criteria were identified, based on an assessment of the current status of attainment of water quality criteria and designated uses. If a given water quality criterion, such as a fecal coliform standard to support primary contact recreation, was not currently attained during wet weather, then an evaluation criterion, such as predicted hours of exceedance of the fecal coliform standard for primary contact recreation, was defined for that receiving water segment. An alternative would be assigned a rating of one to three for that criterion, based on whether the alternative resulted in a reduction, no change, or increase in the predicted hours of exceedance as compared with the baseline condition. The ratings for each alternative would be summed, then the alternatives would be ranked on an overall scale of one to three, based on the ratings. Other examples of the water quality and performance criteria used to evaluate alternatives included fecal coliform bacteria load, BOD and TSS loads, volume of untreated overflows, and annual frequency of untreated overflows. A similar rating and ranking process was conducted for cost. Rating and ranking of alternatives based on the more detailed evaluation were conducted in the second series of workshops, referenced previously.

Various combinations of alternatives for the 14 receiving water segments were developed into system-wide control strategies to allow the evaluation of a range of control levels, in accordance with provisions in the CSO Control Policy. For example, one strategy included the most preferred control alternative for each of the individual segments, one strategy consisted of system-wide sewer separation, and one strategy consisted of system-wide control of overflows to a frequency of one overflow per year. By developing the system-wide strategies, it was possible to compare total CSO plan costs for different levels of control and review combinations of alternatives for consistency and compatibility. A summary matrix of the system-wide strategies was developed, which served as a useful tool in presenting the results of the evaluations to the various stakeholders. The preferred system-wide CSO control plan consisted of a mixed level of control alternatives. The range of control alternatives that comprised the recommended plan included sewer separation, CSO outfall relocation, interceptor relief, end-of-pipe screening and disinfection, in-line storage, detention/treatment, upgrading of existing CSO treatment facilities, and end-of-pipe floatables control (for relatively inactive outfalls). The plan will eliminate CSOs from critical use areas (beaches and shellfish beds), while providing cost-effective levels of control in other receiving water segments with consideration of existing uses and impacts of non-CSO sources of pollution.

CASE STUDY: PORTLAND, OREGON - CSO MANAGEMENT PLAN

Portland's existing CSS captures and treats approximately 96 percent of the sewage from homes and businesses. The remaining 4 percent becomes part of the untreated overflow discharged at 42 outfalls on the Willamette River and 13 outfalls on the Columbia Slough. During a typical year, there are approximately 150 days of rainfall in Portland. The magnitude and frequency of overflow varies from one outfall to another, however. Some outfalls overflow virtually every time it rains, whereas others overflow as few as 30 days in a typical year. During an average year, the city's CSS discharges an estimated total of 6 billion gallons of urban storm water mixed with sewage, representing approximately 1,600 hours when bacterial standards are exceeded because of CSOs.

In 1990, the city began an engineering study to evaluate CSO control alternatives. The following year, the State of Oregon established requirements for CSO abatement, based on currently available information, that were enumerated in an agreement called the Stipulation and Final Order (SFO). This agreement, between the city and the State, called for the virtual elimination of CSO outfalls. The Draft Facility Plan for the CSO Management Program (CH2MHILL, 1993) presented a CSO control alternative that satisfies the CSO Control Policy and evaluates two levels of CSO control between the CSO Control Policy and the SFO.

The SFO was amended in August 1994 to require that untreated overflows to the Willamette River be reduced to the 3-year return summer storm and the four in 1-year return winter storm, or a reduction of 94 percent of the CSO volume currently discharged to the Willamette River. The level of control for the CSOs to the Columbia Slough was kept at the original SFO control level of 1 in 10-year storm in the summer and the 1 in 5-year storm in the winter (AMSA, 1994).

PUBLIC PARTICIPATION

The objective of the public education and involvement process was to reach as many residents as possible during LTCP development. The components of the public participation process for the Portland CSO management program are summarized in Chapter 4 (Exhibit 4-1). The key components included the River Alert Program, public education, and public involvement.

LONG-TERM CONTROL PLAN APPROACH

The objective of the CSO Management Study was to develop a planning approach to establish water quality goals and associated system performance criteria, in addition to integrating with other collection and treatment system needs. To examine the wide range of possible solutions to CSOs, the city adopted three simultaneous planning approaches: (1) results-based, (2) statistics-based, and (3) technology-based:

- **Results-Based Approach**—This begins with the reduction of storm water flow and pollutants at the source through inflow reduction and urban BMPs. Next, CSO control is reviewed as part of meeting larger water quality goals, including strengthened watershed protection elements.

- **Statistics-Based Approach**—This approach focuses on identifying a specific frequency of CSOs and developing control strategies to achieve that frequency. For example, the SFO designated the statistical frequency of CSOs to the Columbia Slough as once in 10 summers and once in 5 winters. This approach provided a clear, numerical goal that can be achieved without correlating that statistical yardstick with the benefit achieved.

- **Technology-Based Approach**—This approach generates the sewer separation alternative. A second sewer system would be constructed throughout the combined area to convey storm water, and the existing system would be rededicated to transporting only sanitary wastewater.

A single alternative was evaluated in which a completely new system was assumed and costs developed.

DEVELOPMENT OF ALTERNATIVES FOR CSO CONTROL

To lay the foundation for the development of the CSO Management Plan, control options or technologies were examined for their applicability in the city's sewer service area. These technologies represent the "building blocks" for the development of comprehensive alternatives that meet target levels of CSO control. Once a list of control alternatives to be considered for the program was compiled, each of the individual alternatives was evaluated for its ability to meet the needs of the program. This process began with a comprehensive list of CSO control alternatives. Then the list was narrowed to include only control alternatives that were appropriate or desirable to be considered further. Typically, a number of control alternatives will be inappropriate for the circumstances encountered in a given community, such as siting restrictions, financial constraints, nonconformance with WQS, or public or institutional opposition. These control alternatives can be eliminated from the list of potential controls by using an initial screening process. This initial screening makes it easier to develop realistic and appropriate control alternatives by reducing the number of possible controls to be considered, thus focusing effort on more viable alternatives.

A set of performance, implementation, and environmental criteria were developed (in conjunction with Bureau of Environmental Services staff) to evaluate the various CSO control technologies available for use in Portland.

PERFORMANCE FACTORS

The criteria grouped under the category of performance factors are related to pollutant removal, as well as overflow frequency and volume control. These criteria described the ability of the control alternative to meet an acceptable level of pollutant control and included the following:

- **CSO Volume/Frequency**—The control alternatives should be screened based on their ability to reduce the frequency of overflows and the overall volume discharged.

- **Pollutant Control**—Control alternatives more effective at controlling the primary pollutants of concern (e.g., bacteria, floatables, or suspended solids) in the municipality will generally be favored over measures that control other pollutants of lesser concern.

Implementation and Operation Factors

In addition to the performance factors, control measures are often assessed for their relative ease of implementation and operation according to the following criteria:

- **Complexity**—The more complex a control measure, the more likely there is to be a problem during implementation or operation.

- **Reliability**—Some control measures might be difficult to maintain and, therefore, should be eliminated from further consideration.

- **Flexibility**—Control measures that can be implemented in a number of configurations and across a wide range of circumstances will be preferred over more restrictive controls.

- **Land Required**—If a control technology has large land requirements, it might not be possible to implement in a highly developed watershed.
- **Public Acceptance**—In order for some control measures to be implemented, a high degree of public involvement is required. Public acceptance, therefore, can be important to the success of the control.
- **Development Time**—Controls that can be implemented immediately will generally be preferred over controls that must be developed over a number of years.
- **Cost**—The use of cost as a screening criterion at this early stage in the development of alternatives is not always appropriate, because the proposed control measures have not yet been sized. In certain cases, however, such as for treatment technologies that would provide a greater level of control than required to meet WQS, the higher level of control might not be justified by the cost of these technologies, allowing them to be eliminated from further consideration. More detailed cost evaluation is described under the Evaluation of Alternatives for CSO Control section of this case study.

Environmental Impacts

The following criteria are generally related to the potential negative side-effects resulting from constructing structural controls:

- **Construction Period**—Some control technologies require extensive construction activities that could adversely affect the surrounding environment. These would be ranked lower than corresponding controls that are less intrusive.
- **Operating Considerations**—The operation of some major structural controls can cause environmental impacts, such as noise or odor problems.
- **Siting Restrictions**—The implementation of some control technologies can be discouraged because of surrounding land use impacts that are more significant than the improvements provided by the control of CSOs.

The technologies were evaluated during meetings and workshops held in 1991 and 1992. Exhibit 3-9 summarizes the results of the evaluation, listing the range of rankings from excellent to adverse for each technology considered. The technologies were evaluated further in later phases of the project when additional information was obtained and during the development of the CSO Management Plan. The basic tenets of the screening methodology, including the basis of evaluation given above, were retained throughout plan development.

The selection of system components for inclusion in control alternatives was based on the screening results and input from BES staff. Technologies were either eliminated from further consideration or selected for one or more applications: widespread use throughout the system, localized use, or interim use. Exhibit 3-10 summarizes the selected components. Through this initial screening process, 12 of the original 31 potential control measures were eliminated from further consideration. Control technologies considered appropriate for widespread use were incorporated into the program elements for the alternatives development. Local solutions were included in specific applications when appropriate.

Exhibit 3-9. Ranking CSO Technologies

		Performance Factors				Implementation and Operation Factors							Environmental Impacts	
	CSO Control Technology	CSO Volume/ Frequency	Bacteria	Floatables	Suspended Solids	Complexity	Reliability	Flexibility	Land Required	Public Acceptance	Development Time	Construction Period	Operating	Siting
Source Controls	Street Sweeping				●	●	◓	◒	●	●	●	●	◓	●
	Construction Site Erosion Control					●	◓	⊙	●	●	●	●	◓	●
	Catch Basin Cleaning			◓	●	◓	◓	◒	●	◓	●	◒	◓	◓
	Industrial Pretreatment					◓	◓	◒	●	●	●	◓	◓	●
	Garbage Disposal Ban			⊗	●	◓	◒	⊙	●	⊗	●	●	◓	●
	Onsite Domestic WW Storage		⊙	⊙	⊙	◒	⊙	⊙	◓	⊙	◓	◒	◓	⊙
	Combined Sewer Flushing		⊙		◒	◒	◓	◒	●	◓	●	◓	◒	◓
Sewer System Optimization	Static Flow Control	●	●	●	●	●	●	◒	●	●	●	●	●	●
	Variable Flow Control	◓	◓	●	●	◒	◓	◓	●	●	●	◓	●	◓
	Real-Time Flow Control	◒	◓	●	●	⊙	◒	◓	●	●	◓	◓	●	◓
Inflow Reduction	Upland Storm Water Storage	●	●	●	●	◒	◓	⊙	⊙	◒	◓	⊙	◓	⊙
	Storm Water Sumps	◓	◓	●	●	◒	◒	⊙	◓	◒	●	◒	◓	◒
	Sewer Separation	⊙	◒	◓	◓	⊙	●	⊙	●	⊗	⊙	⊗	●	⊗
	Stream Diversion					◒	●	⊙	●	◒	●	⊙	●	⊙
Storage	Earthen Basins	◓	◓	●	●	◓	◓	◒	⊙	⊙	◒	◒	⊙	⊗
	Open Concrete Tanks	⊙	◒	◒	◒	◓	◓	◒	⊙	⊙	◒	◒	⊙	⊗
	Closed Concrete Tanks	⊙	◒	◒	◒	◓	◒	◒	◒	◒	◒	◒	◒	◒
	Storage Conduits	⊙	◒	◒	◒	◓	◒	◒	◒	◒	◒	◒	◒	◒
	Storage Tunnels	⊙	◒	◒	◒	◒	◒	◒	◒	◒	◒	⊙	◒	◒
Physical/Chemical Treatment (all options include chlorination/dechlorination)	Swirl Concentrator	◒	◓	◓	◒	◓	◓	⊙	◒	◒	◓	◒	◒	◒
	Vortex Separator	◒	◓	◓	◓	◓	◓	⊙	◒	◒	◓	◒	◒	◒
	Coarse Screening	◒	◓	◓	◓	⊙	⊙	⊙	◒	◒	◓	◒	◒	◒
	Primary Sedimentation	◒	◓	◓	◓	◓	◓	⊙	⊙	◒	◒	◒	◒	⊙
	Flocculation/Sedimentation	◒	◓	◓	◓	◒	◒	⊙	⊙	◒	◒	◒	◒	⊙
	Dissolved Air Flotation (DAF)	◒	◓	◓	◒	⊗	⊙	⊙	◒	◒	◒	◒	◒	⊙
	DAF with Polymer Addition	◒	◓	◓	◒	⊗	⊙	⊙	◒	◒	◒	◒	◒	◒
	High Rate Filtration (HRF)	◒	◓	◓	◒	⊙	⊙	⊙	◒	◒	◒	◒	◒	◒
	Flocculation/HRF	◒	◓	◓	◓	⊙	◒	⊙	◒	◒	◒	◒	◒	◒
Biological Treatment	Columbia Boulevard WWTP					◓	●	◓	●	◓	◓	◒	◓	●
	Wetlands Treatment					◓	◓	⊙	◒	◓	◒	◒	●	◒

● Excellent ◓ Very Good ◒ Good ⊙ Poor ⊗ Adverse

SOURCE: CH2MHILL, 1993

Exhibit 3-10. Control Technologies Screening Summary

CSO Control Technology	Consider for Widespread Use	Consider for Localized Use	Consider for Interim Use	Eliminate from Further Consideration
Source Controls				
Street Sweeping			X	
Construction Site Erosion			X	
Catch Basin Cleaning			X	
Industrial Pretreatment		X	X	
Garbage Disposal Ban				X
Onsite Domestic Wastewater				X
Combined Sewer Flushing			X	
Sewer System Optimization				
Static Flow Control	X		X	
Variable Flow Control	X			
Real-Time Flow Control	X			
Inflow Reduction Techniques				
Upland Storm Water Storage		X		
Storm Water Sumps		X		
Sewer Separation	X	X		
Stream Diversion		X		
Storage				
Earthen Basins				X
Open Concrete Tanks				X
Closed Concrete Tanks	X			
Storage Conduits	X			
Storage Tunnels	X			
Physical/Chemical				
Swirl Concentrator				X
Vortex Separator		X	X	
Coarse Screening				X
Primary Sedimentation	X			
Flocculation/Sedimentation				X
Dissolved Air Flotation (DAF)				X
DAF with Polymer Addition				X
High Rate Filtration (HRF)				X
Flocculation/HRF				X
Chlorination/Dechlorination	X			
Biological Treatment				
Columbia Boulevard WWTP				X
Wetlands		X		

Source: CH2MHILL, 1993

EVALUATION OF ALTERNATIVES FOR CSO CONTROL

SWMMs were developed for each of the 43 combined sewer basins and for the major interceptors, and calibrated and verified based on extensive rainfall and flow data. Both long-term (15 years) and single-storm simulations were performed using the calibrated models. In addition to the CSS hydraulic modeling, CSS pollutant and receiving water quality models were developed to assess CSO impacts to the Willamette River.

The first step in the CSO control approach for Portland was to focus on technically simpler and lower cost methods that could be implemented on a neighborhood scale to reduce the size of the CSO problem. It is anticipated that the following projects, called Cornerstone Projects, will reduce the annual average volume of overflow by 47 percent (AMSA, 1994):

- **Storm Water Sump Construction**—Much of the combined sewer area has highly permeable soils with a high hydraulic capacity. Street inlets are currently being disconnected from the CSS and connected to sumps, which are designed to infiltrate the storm water into the ground. The sumps are designed to settle suspended solids and reduce pollutant loads.

- **Roof Drain Disconnections**—Most of the roof drains in the combined sewer service area are connected to the CSS. A program is currently underway to disconnect these roof drains from the CSS and dispose of the drainage on site. Roof drain disconnection is particularly effective in areas to be sumped, because any roof drainage leaving the property would be kept out of the CSS.

- **Street Diversion**—As Portland grew, several streams in Portland were channelized and routed into pipes to allow property development in the downtown area. These streams discharge into the CSS and reduce the collection system capacity available for sewage. The city will be disconnecting these streams from the CSS.

- **Local Sewer Separation Projects**—Sewer separation is planned in areas where the CSS is undersized, in remote basins where conveyance costs are high, and where the outfalls discharge to sensitive areas, such as parks. Several of these separation projects are being designed and built.

The next step was to analyze the amount of remaining overflow that would occur in the Columbia Slough. The Slough is shallow and slow moving and can be dominated by CSOs during large storm events. It has been identified as water quality limited for bacteria, pH, aesthetics, and some toxics. The facility plan concluded that the presumption approach identified in the CSO Control Policy would not provide adequate treatment for the Slough. The recommended control plan is to capture overflows to the Slough to the once in 10-year summer storm and the once in 5-year winter storm. All combined sewage flow resulting from storms smaller than these design storms will be conveyed to a wet weather treatment facility at the Columbia Boulevard Treatment Plant Site. It is anticipated that CSOs from storms larger than these design storms will continue to overflow without treatment. This represents a 99.6-percent capture of the existing CSO volume to the Columbia Slough.

The final step was to analyze the amount of remaining overflow that would occur in the Willamette River. Because of the swifter-flowing nature of the river, the large volume of water it contains, and the river's own ecology, the facility plan examined options to protect the beneficial uses of the Willamette River with facilities that capture and treat less CSO volume than required by the SFO. The approach was to compare the methods, benefits, and costs of alternative levels of control ranging between the two key benchmarks—the SFO and the CSO Control Policy. The resulting recommended plan is to capture overflows to the Willamette to the one in 3-year summer storm and the three in 1-year winter storm. All combined sewage overflow resulting from storms smaller than these design storms will be conveyed to a wet weather facility located on the Willamette River. A fallback option determined to be technically feasible but more costly is to convey the Willamette River overflows to the Columbia Boulevard Wastewater Treatment Plant. Overflows from storms larger than these design storms will continue to overflow without treatment. This represents a 94-percent capture of the existing overflow volume to the Willamette River.

To capture and treat the overflow, the city will rely on a combination of storage and wet weather treatment. A number of storage and treatment options were considered in the facilities plan for their ability to cost effectively store and treat overflows, for their operational simplicity, for their implementability within Portland, and for their ability to protect water quality and beneficial uses. Wet weather storage will be provided by oversizing the tunnels that convey overflows to the new wet weather treatment plants. This will provide in-line storage. Off-line storage will not be a major component of the CSO solution for Portland. Wet weather treatment will include screening, sedimentation basins, and disinfection. The planning assumption was that disinfection will be accomplished with hypochlorite injection followed by dechlorination. It is anticipated that the discharges from the treatment plants will allow in-stream WQS to be met at the edge of the mixing zone.

CHAPTER 4

SELECTION AND IMPLEMENTATION OF THE LONG-TERM PLAN

This chapter recommends procedures for selecting, adopting, and implementing combined sewer overflow (CSO) controls under the long-term control plan (LTCP). The procedures include the role of public participation and agency interaction, selection and development of a recommended plan, adoption, financing, implementation scheduling, preparation of an operational plan, post-construction compliance monitoring, and re-evaluation and update of the LTCP.

4.1 PUBLIC PARTICIPATION AND AGENCY INTERACTION

After detailed evaluation, but prior to the selection of specific CSO controls under the LTCP, the public should be informed about each alternative. The detailed evaluation and ranking of alternatives is typically compiled in a draft report. Because long-term CSO abatement planning usually involves a significant amount of data collection and analysis, it is often prudent to summarize the results of the evaluation in an executive summary. Copies of the draft report should be distributed to the repositories established at the initiation of the public participation program. Control plan alternatives can include control alternatives involving both the construction of facilities and the adoption of new management practices. The extent to which each type of control measure is utilized within each alternative can be based on public input. The implementation schedule and method of financing can also be selected or modified based on public input.

Informing the public about potential alternatives is one part of the public participation process. The extent of the public participation program generally depends on the amount of resources available and the size of the municipality. Exhibit 4-1 presents component programs and their elements for a comprehensive public education and involvement process in Portland, Oregon.

Exhibit 4-1. Example of Public Participation Program for Portland, Oregon, CSO Management Program

Component Programs	Program Elements
River Alert Program	Placement of informational and warning signs Media advisories
Public Education	Media coverage Speaker's bureau *Clean River Review* newsletter *CSO Update* newsletter Direct mailers Billing inserts Videotape production Issue and choices booklet Educational theater presentations Interactive educational software
Public Involvement	Public meetings Creative Alternatives Workshop Clean River Funding task force Clean River committee Community leader interviews General public telephone survey Focus groups

Source: CH2MHILL, 1993

Typically, public meetings are the forum for describing and explaining alternatives. The municipality and its agents should discuss each alternative thoroughly. Technical solutions should be presented in a simple, concise manner, understandable to diverse groups. The discussion should include, to the greatest level of detail possible, background on the project, a description of proposed facilities, the level of control to be achieved, temporary and permanent impacts, possible mitigating measures, and cost and financial information. Graphics can be used to compare each alternative with regard to site layouts, resource requirements, and cost. The benefits of each alternative should be articulated clearly so that public support can be generated.

Public hearings are usually formal proceedings in which the agenda, including comments, questions, and responses, are recorded. One or more public hearings are generally held so that public interest groups, business and civic organizations, and members of the general public can officially comment and/or pose questions to the municipality. The municipality should consult with local, State, and Federal regulatory agencies to identify any public participation requirements. In some cases, municipalities might consult the public participation conditions and program elements set forth in 40 CFR Part 25. These regulations provide for:

- Well-publicized notice of the hearing mailed to interested and affected parties at least 45 days prior to the date of the hearing
- Location and time of the hearing chosen to facilitate attendance by the public
- Presentations scheduled in advance to ensure maximum participation
- Conduct of the hearing in a manner that allows for informing the audience and soliciting information from the public
- Record of the hearing procedures prepared and made available by transcript or recording.

To improve communications at public meetings or hearings held during this phase, the municipality can summarize technical information that will be presented at meetings. The municipality should also generally designate an agent to attend the meetings, take notes, and distribute and collect public comment sheets so that participants' views are recorded. If the municipality has retained a consultant to prepare the plan, the consultant will typically present the findings and recommendations of the alternative evaluations. In larger municipalities, an experienced public participation consultant can be used as a facilitator or moderator. A number of public meetings (held prior to formal public hearings) might be necessary for larger municipalities; however, smaller municipalities should consider at least two meetings prior to a formal public hearing.

Presentations to the public should explain the benefits of CSO control. For example, improvements in water quality can significantly improve aesthetics, recreational areas, opportunities for increased use of beaches, or fishing and shellfishing. These benefits might offset construction, environmental, and financial impacts associated with each alternative and, therefore, should be communicated in order to reach a consensus. A key objective of the public education process is to build support for increases in user charges and taxes that might be required to finance CSO control projects. By demonstrating the importance of improved water quality and the cost-effectiveness of proposed control alternatives, rate payers and taxpayers will be assured that environmental protection is being provided at the lowest reasonable cost.

In order to proceed with adoption of an LTCP, the regulatory community should be part of the consensus. Presumably, Federal, State, county, and other regulatory groups will have been involved throughout the long-term CSO control planning process. Early and consistent coordination with the regulatory authorities during the development and implementation of the LTCP and WQS review provides "*...greater assurance that the long-term control plan selected and the limits and requirements included in the NPDES permit will be sufficient to meet WQS and to comply with Sections 301(b)(1)(C) and 402(a)(2) of the CWA*" (III.A). Typically, the municipality submits to the regulatory authority technical memoranda, interim reports, minutes of public meetings, and responsiveness summaries. The regulatory agencies then submit their comments to the municipality. The municipality is responsible for responding to each agency.

4.2 FINAL SELECTION AND DEVELOPMENT OF RECOMMENDED PLAN

After appropriate public input (e.g., one or more public hearings) and receipt of comments from interested parties, the municipality should proceed to selecting and adopting an LTCP. If the public information program has been strong and continual during the course of the planning effort, the highest-ranked alternative from the alternatives evaluation will probably be adopted. If a consensus to select a different alternative has developed as a result of the final public meetings, public hearings, and comments, however, a different option might be selected. The responsible legal entity takes action to select and officially adopt the LTCP. For example, a large metropolitan water management authority would adopt the plan by a vote of its board of directors. Cities might require a vote by the city council or, in smaller communities, its counterpart.

In some cases, multiple agencies or jurisdictions might have to adopt the plan. If more than one entity is responsible, intermunicipal agreements might be necessary. The final published plan should incorporate adopted resolutions of plan acceptance and proposed or executed intermunicipal agreements.

The municipality should develop the LTCP to enable implementation by the CSO program team. The information obtained through the earlier tasks of assessing existing baseline conditions and alternatives evaluation can be used as a basis for fully developing the selected plan.

The first part of the LTCP should describe the controls selected for implementation. This includes both management and operational controls, as well as controls that require constructed facilities. For controls that do not include the construction of facilities, the selected plan should identify the frequency of conducting each practice, where the practice takes place, a schedule of activities, the necessary staffing, and the cost. Initial program start-up costs can include training staff and purchasing equipment. Ongoing costs typically include labor for maintenance efforts. A record system should also be designed to track activities and pertinent data.

Controls that require constructed facilities eventually necessitate engineering design and construction. At this stage of plan development, the LTCP should include a description and diagrams, concept sketches, or architectural renderings of each facility. Design information, including assumptions and design criteria, should be tabulated. Site-specific information such as known site conditions, including existing structures, topography, and use, as well as soil conditions, utility locations, and wetlands and other resource areas, should be documented. Final detailed design plans and specifications should be prepared in accordance with the implementation schedule.

For each selected control, the municipality should develop a cost estimate. Although the cost is initially estimated during the alternatives development step, it can be refined for the implementation plan. Accuracy is important because the cost estimates might provide a basis for fund allocation. Project cost estimates should include costs for engineering, construction, site acquisition, and legal and financing fees. Because uncertainty still exists at this stage (site survey and engineering work is still normally necessary), contingencies should be included in the estimate, and a range of values might be appropriate. Operation and maintenance (O&M) costs can also be refined at this stage to assess the impact on user fees or tax rates. Cost estimates can be tied to an applicable cost index, such as the ENR/CCI for construction costs or the PPI (Producer Price Index) and the CPI (Consumer Price Index) for O&M costs. Using these indices, costs can be adjusted in the future to account for inflation.

Because proper O&M is particularly important to the long-term functioning of constructed controls, it is necessary to ensure that maintenance requirements are included in the selected plan. Specifically, the implementation plan can identify the number of and time period that additional staff might be needed or reassigned. A more detailed review of resource inputs, such as chemical deliveries, can be included.

4.3 FINANCING PLAN

The key element for implementation of an LTCP is the ability to obtain funding for the selected controls. Most LTCPs include construction of abatement facilities. For some municipalities, the LTCP includes relatively costly, capital-intensive projects, such as deep tunnel storage. Chapter 3 describes the importance of cost-effectiveness in alternatives selection. The financial capability of the municipality is a major factor in determining the implementation schedule. The financing method is also important. The CSO Control Policy states that each municipality "*...is ultimately responsible for aggressively pursuing financial arrangements*" (I.E) for implementation. For this reason, some municipalities might engage a financial consultant familiar with municipal finance as part of the planning and/or implementation team. The municipality should review and select both a capital funding approach and a method of collecting annual funding needs.

4.3.1 Capital Funding Options

Capital funding options include bonds, loans, grants, and privatization (EPA, 1995f).

4.3.1.1 Bonds

Bonds are promissory notes issued (sold) by local governments to raise funds to pay for projects that require a large amount of capital. A bond has a fixed payment schedule that is often 20 years for municipal or local utility bonds. Revenue bonds, sometimes referred to as water/sewer bonds, are generally backed by user fees or service charges paid by system users. General obligation (GO) bonds are issued by a municipal or county government to fund capital projects of the jurisdiction. GO bonds are secured by the general taxing power of the local jurisdiction. GO bonds are viewed as the most secure type of local debt. Many municipalities require voter approval to issue these bonds. Statutory limits can apply to the amount of GO debt.

4.3.1.2 Loans

Loans from private, State, and Federal sources can be used to finance CSO control projects. The loan interest rates vary, depending on the program. The ability of a municipality to secure a loan depends, in part, on its "creditworthiness," or ability to repay the funds borrowed. Loans are available from a variety of sources, including State Revolving Fund (SRF) programs, other State loan programs, the Rural Development Administration, CoBank (the National Bank of Cooperatives), and commercial lending institutions. Each source has different requirements, advantages, and limitations.

4.3.1.3 Grants

Many municipalities have experience with wastewater construction grants. Grants are expected to play only a limited role in future CSO program funding, however. Direct Federal grants have been replaced with SRFs and other local funding options. Individual States might have different SRF program elements. For example, some might include partial grants and subsidized loans, while others have only subsidized loans. EPA offers a variety of State and local grants for program research and development, administration, demonstration, and planning. These grants can provide funding for CSO-related activities indirectly. The availability of grant funds usually varies annually, reflecting congressional mandates and EPA policies. Also, for small and economically disadvantaged communities, the Rural Development Administration offers up to 75-percent grants for the construction of environmental infrastructure facilities. The Economic Development Administration (EDA), U.S. Department of Commerce, also awards grants to economically disadvantaged communities for construction of public works.

4.3.1.4 Privatization

Private investment in wastewater treatment facilities can provide an additional option for funding CSO facilities. In response to a recent Executive Order, EPA is developing policy and regulatory changes to encourage private investment in EPA-funded municipal wastewater treatment facilities. The final outcome of these changes is unknown at this time, but for some municipalities, privatization might be a viable option.

4.3.1.5 Other Capital Funding Options

Other options include special reserves, special assessments, and "pay-as-you-go." Special reserves are usually funds established by municipalities to fund capital equipment repair or replacement. In some cases, these reserves can be used to fund CSO controls. Special assessments are used to provide and fund projects for a specific geographical area. Special assessment districts provide the legal arrangement to charge those receiving the service for the capital and/or operating cost of the project. For smaller, less expensive projects that are more common to smaller municipalities, a "pay-as-you-go" approach can be used where projects are funded with annual tax and other revenues.

4.3.2 Annual Funding Options

Annual CSO costs include:

- O&M costs for CSO controls
- Annual loan payments for SRF or other loans used to fund CSO controls
- Debt service on local bonds used to fund CSO controls
- Reserves for future equipment replacement.

Annual funding options include different types of fees and taxes. Both the Federal construction grant program and the SRF program require sewer user fee systems. Federal law requires such systems only on SRF loans and aid from the Federal Government to the SRF. Loans made from State funds in the SRF do not require user fee systems except pursuant to State law. User fees are widely accepted as an equitable source of revenues for water pollution control. Some municipalities have implemented storm water utilities that assess user fees based on impervious area or runoff. In general, sales, property, or income taxes cannot be used to pay annual operating costs of projects funded under EPA construction grant funding or SRF funding but can be used to repay bonds used for capital outlays. A number of communities use an ad valorem (i.e., general property) tax levy to collect operating costs. These exceptions require EPA approval.

4.3.3 Selection of Financing Method

The method of financing will be determined by several factors, including:

- The availability of each option. For example, some municipalities might have difficulty in obtaining long-term bond financing. Some States might have applicable grant or loan assistance programs, while other States might not.
- The advantages and limitations of a specific type of financing.

The LTCP should identify a specific capital and annual cost funding approach. EPA's guidance on funding options presents a detailed description of financing options and their benefits and limitations, as well as case studies sharing different approaches municipalities took to fund CSO control projects (EPA, 1995f). Most municipalities will continue to depend on local revenue bonds or SRF loans for capital to fund CSO controls. Annual costs will most likely be paid for by user fees.

4.4 IMPLEMENTATION SCHEDULE

A common characteristic of an LTCP is that CSO controls will be implemented over a long time period. The municipality is expected to consider a number of factors in preparing a schedule of activities. According to the CSO Control Policy, the nine minimum controls (NMC) should be implemented prior to adoption of the LTCP.

The CSO Control Policy recommends a phased implementation schedule based on the relative importance of adverse impacts upon water quality standards (WQS) and designated uses. The municipality is expected to consider eliminating overflows that discharge to sensitive areas and cause use impairment.

In addition, the CSO Policy recommends consideration of financial capability in developing the implementation schedule. As described in Section 3.5, the financial capability assessment should include an evaluation of the following:

- Median household income
- Total annual wastewater and CSO control costs per household as a percent of median household income
- Overall net debt as a percent of full market property value
- Property tax revenues as a percent of full market property value
- Property tax collection rate
- Unemployment
- Bond rating.

In addition to financial capability, the CSO Control Policy recommends that the municipality consider sources of funding in determining the phasing of construction projects. The municipality can consider the availability of grants and loans; previous and current residential, commercial, and industrial sewer user fees and rate structures; and other viable funding mechanisms.

Other considerations include the need for pilot-scale testing, time necessary for obtaining necessary permits, and the need to observe timing constraints for obtaining funding (e.g., SRF grant/loan application deadlines, local referenda). These considerations are incorporated into a schedule with start and finish dates for major tasks and milestones. The schedule should also include interim dates for reporting CSO control results and monitoring program results.

Depending on the size of the LTCP, the schedule could be shown by means of a simple bar chart or a more complex Critical Path Method (CPM) system using project scheduling/ management computer software. The decision on the type of schedule to develop should be determined by the level of program complexity. This can be assessed by the number of tasks and subtasks (activities) required, the number of entities involved, the length of time over which the LTCP will extend, and the available management resources. Tasks associated with financing should be included in the implementation schedule.

Implicit in developing an implementation schedule is the need to set priorities. The CSO program team should review the recommended CSO controls and determine an order of implementation (or phasing), taking into account extenuating circumstances in any particular case. If funding is a major issue, for example, the least expensive controls can be implemented early in the process. Individual projects should be phased in accordance with available funding. In general, priorities and, thus, the schedule of program implementation, should be tailored to each situation.

If the development of public support for the LTCP is a critical issue, the CSO program team should consider addressing first any control with the potential for significant pollution reduction. In this case, controls that could improve the water quality of widely used water bodies should be implemented, if possible, before other steps are taken. These decisions should be reflected in the implementation schedule.

Exhibit 4-2 provides an example of a phased implementation. After implementation of the NMC and development of the LTCP, this particular municipality will proceed with six construction projects. The first three construction contracts—contracts 1, 2, and 3—will address sensitive areas by protecting a designated National Marine Sanctuary, eliminating beach closings, preventing fish kills, and opening shellfish beds. They will address overflows that include

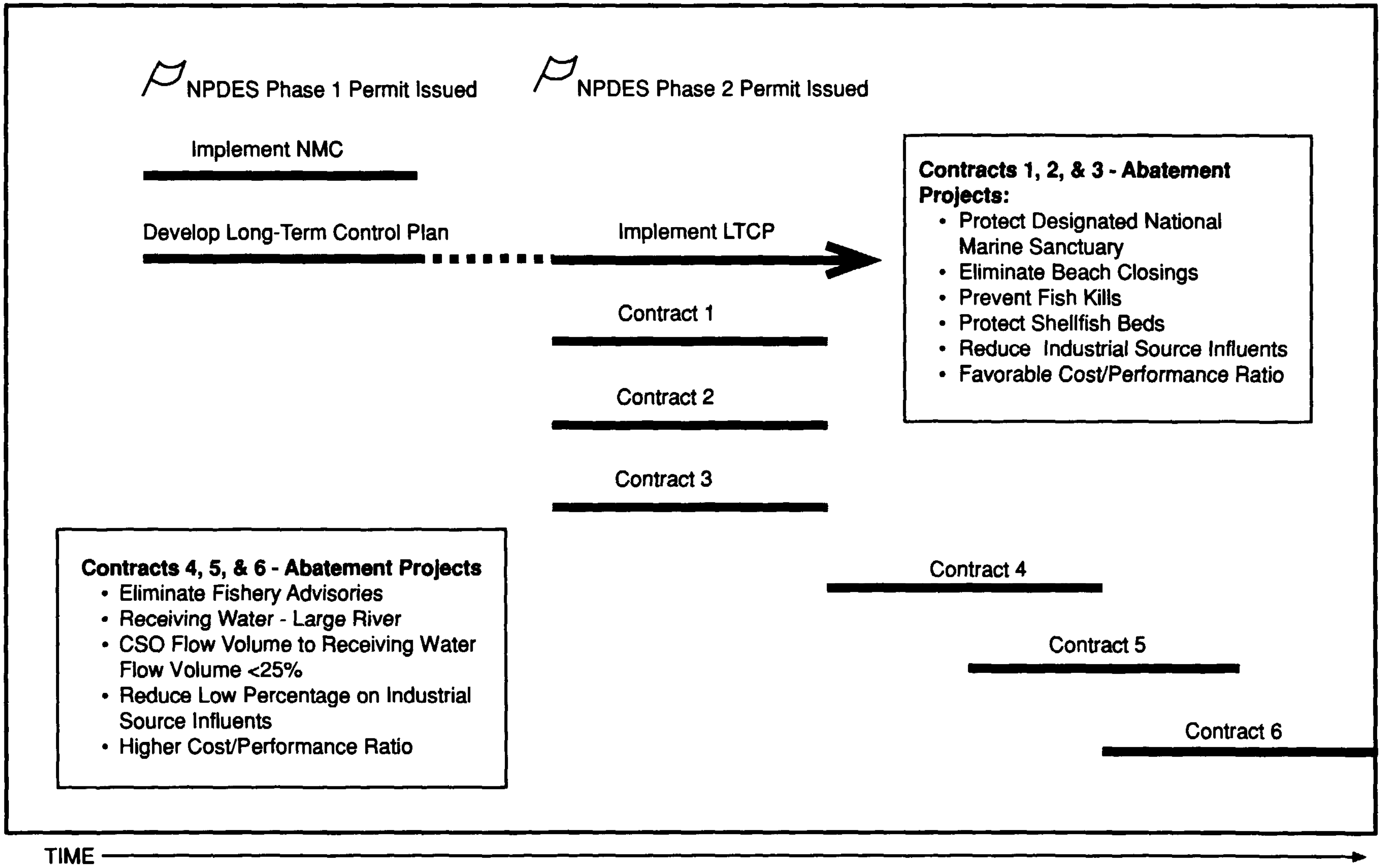


Exhibit 4-2. Example of Phased Implementation Approach

significant discharges from industrial sources with potentially toxic materials. The projects also have favorable cost/performance ratios, and the financial impact on the municipality will not be excessive. The subsequent three projects, Contracts 4 through 6, address overflows to a less sensitive area, a large river. They have a relatively low flow volume compared to the flow of the receiving water and have little influent contributed by industrial sources. Their cost/performance ratio is not as favorable as the initial three projects. As shown on the schedule, the three contracts are staggered to allow for funding availability in successive years.

It is important that the individuals and entities responsible for implementing each aspect of the program be identified in the LTCP. Much of the effort for implementing plans should come from either local or regional governments. At the State and Federal levels, enforcement and oversight probably will occur, and technical and financial assistance might be available. To develop a plan, municipal officials should coordinate and initiate activities, as well as motivate others in the municipality or other agencies to get involved. Firm commitments from these agencies prior to program implementation is important to the final success of the program. Exhibit 4-3 identifies groups, agencies, and individuals that can support aspects of the management plan, including monitoring, design, permitting, regulations, public education, maintenance, and enforcement.

4.5 OPERATIONAL PLAN

As part of the implementation of the NMC, municipalities should be required to develop and document programs for operating and maintaining the components of their CSSs. Once an LTCP has been approved, however, the municipality's O&M program should be modified to incorporate the facilities and operating strategies associated with the LTCP controls.

Typically, each facility constructed as part of the LTCP will have its own O&M manual detailing the equipment and features of the facility, including operating instructions, troubleshooting guides, and safety considerations. If the LTCP features multiple facilities, however, a master operating strategy should be developed to optimize the operation of the various LTCP components. Optimization might involve coordination of pump back timing,

Exhibit 4-3. Potential Implementation Responsibilities

Program Component	Responsible Organization	Other Potentially Involved Parties
Monitoring	Local Water Pollution Control Agency Local Boards of Health State Water Pollution Control Agency State Marine Fisheries Department	Local Environmental Groups University Students Volunteer Organizations Environmental Consultants
Engineering Design	Local Water Pollution Control Agency Local Engineering Department State Department of Public Works	University Engineering Departments Engineering Consultants
Permitting and Regulatory Controls	Local Water Pollution Control Agency Local Boards of Health Local Conservation Office Local Planning Board EPA State Water Resources Agency Federal Coastal Zone Management Office U.S. Army Corps of Engineers	Local Environmental Groups Environmental Consultants
Public Education	Local Water Pollution Control Agency Regional Environmental Agency Local Environmental Groups Watershed Associations State Environmental Agency EPA	Local Environmental Groups Local Civic Groups Private Organizations Cable TV/Newspapers Public Participation Consultants
Maintenance	Local Water Pollution Control Agency Local Department of Public Works	Contract Maintenance Providers
Enforcement	Local Conservation Agency Local Board of Health Planning Board Local Code Enforcement Officer Coastal Zone Management U.S. Army Corps of Engineers State Environmental Agency EPA	Local Environmental (watchdog) Groups

dynamic regulator operation, or other real-time operating strategies. Interim operating strategies might be required for phased projects and for construction-period operations and flow transitions. Maintenance programs should consider the unique operating conditions of CSO facilities, particularly with regard to schedules for inspecting and exercising idle equipment. Aspects of the post-construction monitoring program might also be incorporated into the operational plan, as regular schedules for sampling and maintaining sampling equipment are developed.

If not addressed in the individual facility O&M manuals, the operational plan should identify staffing needs for CSO control facilities, both in terms of numbers of staff and specific positions necessary, with appropriate descriptions of responsibilities and minimum qualifications.

4.6 POST-CONSTRUCTION COMPLIANCE MONITORING

The municipality should conduct a monitoring program during and after LTCP implementation to help determine the effectiveness of the overall program in meeting CWA requirements and achieving local water quality goals. Monitoring during LTCP implementation should include data collection to measure the overall effects of the program on water quality and to determine the effectiveness of CSO controls. Because existing water quality conditions should have been determined during the planning process, receiving water quality will probably be well understood before LTCP implementation. A monitoring plan to assess water quality conditions during and after program implementation will allow evaluation of the improvements through comparison to baseline conditions.

Sampling data can also be used to educate the public on the effects of CSOs on receiving water quality and the need for CSO control. To increase public awareness, information that identifies the effects of CSO abatement can be disseminated in newsletters, at public meetings, or by other means. Trend analyses are helpful in understanding the changes in receiving water quality and can provide important feedback to assessments of the success of CSO controls. Long-term data can be used to demonstrate the influence of control plan activities on water quality.

Overall plan effectiveness can usually be determined more easily than the effectiveness of individual controls. The long-term monitoring plan should be designed to measure effectiveness and provide accountability. The plan should use existing monitoring stations (both those used in previous studies and those used for collecting data during system characterization, as outlined in Chapter 2) to collect long-term data for comparisons. Using this approach, program progress in addressing pollution problems and preventing further water quality degradation can be determined. Monitoring plan components (e.g., a map of monitoring stations, a record of the frequency of sampling at each station, a parameter list, a QA/QC project work plan) should be identified in a work plan similar to that outlined for sampling in Chapter 2.

Collecting sufficient data to clearly define the effectiveness of CSO controls is challenging sometimes for various reasons, including the variability of rainfall and CSOs and the difficulty in specifically identifying the effect of a particular control on a receiving water. This type of monitoring program should be developed with caution because of the importance associated with demonstrating the effectiveness of CSO controls on receiving water quality.

4.7 RE-EVALUATION AND UPDATE

The post-construction compliance monitoring program is intended to "*...verify compliance with water quality standards and protection of designated uses as well as to ascertain the effectiveness of CSO controls*" (II.C.9). The CSO Control Policy provides that "*...the selected controls should be designed to allow cost effective expansion or cost effective retrofitting if additional controls are subsequently determined to be necessary to meet WQS, including existing and designated uses*" (II.C). If the implemented controls do not result in attainment of WQS, including designated use, a municipality should evaluate the current system's operating practices before considering structural modifications. If correct operating practices are confirmed, the re-evaluation might indicate that a different operating strategy should be considered, such as bypassing flow at a different flow rate. In some cases, real-time control system operating software might have to be modified or weir elevations changed.

If post-construction compliance monitoring indicates that existing WQS are not being met, the data generated can be used to identify the additional CSO controls necessary to achieve WQS. This can include a repeat of the WQS review conducted earlier in the planning process. The CSO Control Policy provides that "*...if adequately supported with data and analyses,* *Agency regulations and guidance provide states with the flexibility to adapt their WQS, and implementation procedures to reflect site-specific conditions including those related to CSOs....In addition, the regulations...specify when and how a designated use may be modified"* (III.B). In accordance with the CSO Control Policy, however, expansion or retrofitting of a CSO control facility might ultimately be required.

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GLOSSARY[1]

BOD_5	Five-day biochemical oxygen demand; a standard measure of the organic content of wastewater, expressed in mg/l.
catch basin	A chamber usually built at the curbline of a street, which admits surface water for discharge into a storm drain.
collector sewer	The first element of a wastewater collection system used to collect and carry wastewater from one or more building sewers to a main sewer. Also called a lateral sewer.
combined sewage	Wastewater and storm drainage carried in the same pipe.
combined sewer	A sewer designed to carry wastewater and stormwater runoff.
combined sewer overflow (CSO)	1) The portion of flow from a combined sewer system (CSS) which discharges into a water body from an outfall located upstream of the headworks of a POTW, usually during a rainfall event. 2) The outfall pipe which carries this discharge.
designated use	Use specified in WQS for each water body or segment whether or not it is being attained.
infiltration	Water other than wastewater that enters a wastewater system and building sewers from the ground through such means as defective pipes, pipe joints, connections, or manholes. (Infiltration does not include inflow.)
infiltration/inflow (I/I)	The total quantity of water from both infiltration and inflow.
inflow	Water other than wastewater that enters a wastewater system and building sewer from sources such as roof leaders, cellar drains, yard drains, area drains, foundation drains, drains from springs and swampy areas, manhole covers, cross connections between storm drains and sanitary sewers, catch basins, cooling towers, stormwaters, surface runoff, street wash waters, or drainage. (Inflow does not include infiltration.)

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[1] These definitions were developed solely for the purposes of this guidance document.

interceptor sewer	A sewer without building sewer connections which is used to collect and carry flows from main and trunk sewers to a central point for treatment and discharge.
load allocation (LA)	The portion of a receiving water's loading capacity that is attributed to one of its existing or future nonpoint sources of pollution, or to natural background sources.
overflow rate	Detention basin release rate divided by the surface area of the basin. It can be thought of as an average flow rate through the basin. Generally expressed as gallons per day per sq. ft. (gpd/sq.ft.)
peak flow	The maximum flow that occurs over a specific length of time (e.g., daily, hourly, instantaneous).
rainfall duration	The length of time of a rainfall event.
rainfall intensity	The amount of rainfall occurring in a unit of time, usually expressed in inches per hour.
regulator	A device in combined sewer systems for diverting wet weather flows which exceed downstream capacity to an overflow.
TSS	Total suspended solids; a standard measure of the concentration of particulate matter in wastewater, expressed in mg/l.
wasteload allocation(WLA)	The portion of a receiving water's loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs can be the basis for water quality-based effluent limitations.
wet weather flow	Dry weather flow combined with stormwater introduced into a combined sewer, and dry weather flow combined with inflow in a separate sewer.

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