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# Combined Sewer Overflows

## Guidance For Monitoring And Modeling

EPA/832-B-99-002
January 1999

# COMBINED SEWER OVERFLOWS

# GUIDANCE FOR MONITORING AND MODELING

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

**January 1999**

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

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OFFICE OF
WATER

MEMORANDUM

SUBJECT: Combined Sewer Overflows: Guidance for Monitoring and Modeling

FROM: Michael B. Cook, Director
Office of Wastewater Management (4203)

Michael B Cook

TO: Interested Parties

I am pleased to provide you with the Environmental Protection Agency's (EPA) guidance document on the monitoring and modeling of combined sewer overflows (CSO) and their impacts on receiving waters. This is the seventh in a series of guidance manuals that EPA prepared to support implementation of the 1994 Combined Sewer Overflow Control Policy.

This manual presents a set of guidelines that provide flexibility for a municipality to develop a site-specific strategy for characterizing its combined sewer system operations and impacts and for developing and implementing a long-term CSO control plan. It is **not** a "how-to" manual defining how many samples to collect or which flow metering technologies to use.

EPA used a peer-review process and solicited comments from CSO stakeholders and the general public. The EPA identified the Water Environment Research Foundation (WERF) and two technical experts to provide technical and scientific peer review. WERF convened a panel of its technical experts to review the document. The peer reviewers and the other reviewers submitted detailed comments and recommendations. EPA will make available to interested parties a "response-to-comments" document detailing how it addressed comments received during the peer review and the public comment period. I am very grateful to the peer reviewers and the other individuals and organizations who participated in preparation and review. I believe that this manual will assist municipalities as they develop and implement long-term CSO control plans to meet the requirements of the Clean Water Act and the objectives of the EPA's CSO Control Policy.

If you have any questions on the manual or its distribution, please contact Tim Dwyer in the Office of Wastewater Management at (202) 260-6064. Mr. Dwyer's e-mail address is *dwyer.tim@epa.gov.*

ACKNOWLEDGMENTS

The U.S. Environmental Protection Agency (EPA) wants to thank the Cities of Columbus, Georgia; South Bend, Indiana; and Indianapolis, Indiana for allowing EPA to use their experiences in monitoring and modeling as case studies for this manual. The experiences of these cities provide excellent examples of the monitoring and modeling process associated with developing and implementing combined sewer overflow (CSO) control programs. EPA believes that use of case studies greatly enhances the value of the document.

EPA also acknowledges the peer reviewers who kindly donated their time and knowledge to improving the technical and scientific discussions in this manual. The peer reviewers were David Dilks, Limno-Tech, Inc.; Raymond M. Wright, Ph.D., P.E., University of Rhode Island; and John Marr, Limno-Tech, Inc., who reviewed it on behalf of the Water Environment Research Foundation.

Finally, EPA thanks those individuals and organizations that took the time and energy to review and submit comments as part of the public review process. They are to be commended for their perseverance and dedication to a long and arduous task.

EPA believes that the peer review process and the public comments greatly improved the technical and scientific aspects of the manual. We hope that users will find the information in the manual useful as they develop and implement CSO control plans.

Assistance in developing this manual was provided to EPA under contract number 68-C4-0034.

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**Mention of trade names or commercial products in this document does not constitute an endorsement or recommendation for use.**

# LIST OF ACRONYMS

| | |
|---|---|
| BASINS | Better Assessment Science Integrating Point and Nonpoint Sources |
| BAT | Best Available Technology Economically Achievable |
| BCT | Best Conventional Pollutant Control Technology |
| BMP | Best Management Practice |
| BOD | Biochemical Oxygen Demand |
| BPJ | Best Professional Judgment |
| CAD | Computer Aided Design |
| COD | Chemical Oxygen Demand |
| CSO | Combined Sewer Overflow |
| CSS | Combined Sewer System |
| CWA | Clean Water Act |
| DO | Dissolved Oxygen |
| EMAP | Environmental Monitoring and Assessment Program |
| EMC | Event Mean Concentration |
| EPA | U.S. Environmental Protection Agency |
| GIS | Geographic Information System |
| IDF | Intensity Duration Frequency |
| I/I | Infiltration/Inflow |
| LA | Load Allocation |
| LTCP | Long-Term Control Plan |
| MPN | Most Probable Number |
| NCDC | National Climatic Data Center |
| NMC | Nine Minimum Controls |
| NOAA | National Oceanic and Atmospheric Administration |
| NPDES | National Pollutant Discharge Elimination System |
| NURP | Nationwide Urban Runoff Program |
| PDF | Probability Density Function |
| O&M | Operation and Maintenance |
| POTW | Publicly Owned Treatment Works |
| RBP | Rapid Bioassessment Protocol |
| QA | Quality Assurance |
| QC | Quality Control |
| SCS | Soil Conservation Service |
| SSES | Sewer System Evaluation Survey |
| STORET | Storage and Retrieval of U.S. Waterways Parametric Data |
| SWMM | Storm Water Management Model |
| TDS | Total Dissolved Solids |
| TMDL | Total Maximum Daily Load |
| TSS | Total Suspended Solids |
| UAA | Use Attainability Analysis |
| USGS | U.S. Geological Survey |
| VOC | Volatile Organic Compound |
| WLA | Wasteload Allocation |
| WQS | Water Quality Standard(s) |

# TABLE OF CONTENTS

## TABLE OF CONTENTS (Continued)

Page

## TABLE OF CONTENTS (Continued)

# TABLE OF CONTENTS (Continued)

**Page**

# TABLE OF CONTENTS (Continued)

Page

## LIST OF EXHIBITS

Page

## LIST OF EXHIBITS (Continued)



## LIST OF EXAMPLES

# CHAPTER 1

# INTRODUCTION

## 1.1 BACKGROUND

Combined sewer systems (CSSs) are 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 950 communities nationwide, most of them located in the Northeast and Great Lakes regions. During dry weather, CSSs convey domestic, commercial, and industrial wastewater to a publicly owned treatment works (POTW). In periods of rainfall or snowmelt, total wastewater flows can exceed the capacity of the CSS or the 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.

CSOs contain many types of contaminants, including pathogens, oxygen-demanding pollutants, suspended solids, nutrients, toxics, and floatable matter. Their presence in CSOs and the volume of the flows 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 is partly due to 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 950 communities served by CSSs to be approximately $45 billion based on results from the 1996 Clean Water Needs Survey.

To address these challenges, EPA 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 water quality, aquatic biota, and human health impacts of CSOs.

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

NMC = nine minimum controls
LTCP = long-term control plan
WQS = water quality standards

## 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 has developed the following guidance documents:

- *Combined Sewer Overflows - Guidancefor Long-Term Control Plan* (U.S. EPA, 1995a) (EPA 832-B-95-002)
- *Combined Sewer Overflows - Guidance for Nine Minimum Controls* (U.S. EPA, 1995b) (EPA 832-B-95-003)
- *Combined Sewer Overflows - Guidance for Screening and Ranking* (U.S. EPA, 1995c) (EPA 832-B-95-004)
- *Combined Sewer Overflows - Guidance for Funding Options* (U.S. EPA, 1995d) (EPA 832-B-95-007)
- *Combined Sewer Overflows - Guidance for Permit Writers* (U.S. EPA, 1995e) (EPA 832-B-95-008)
- *Combined Sewer Overflows - Guidance for Financial Capability Assessment and Schedule Development* (U.S. EPA, 1997) (EPA 832-B-97-004).

EPA has printed a limited number of copies of each guidance document and has made them available through several sources:

- EPA's Water Resource Center (202-260-7786)
- National Small Flows Clearinghouse (800-624-8301 or http://www.estd.wvu.edu/nsfc/)
- National Technical Information Service (NTIS) (800-553-6847 or http://www.ntis.gov)
- Educational Resources Information Center (ERIC) (800-276-0462 or http://www.aspensys.com/eric/catalog/)
- State environmental offices
- EPA Regional Offices.

Electronic copies of some of the guidance documents are also available on EPA's Office of Water Internet site (http://www.epa.gov/ow/).

## 1.5 PURPOSE OF GUIDANCE

This manual explains the role of monitoring and modeling in the development and implementation of a CSO control program. It expands discussions of monitoring and modeling introduced in the CSO Control Policy and presents examples of data collection and CSS simulation.

This manual is not a "how-to" manual defining how many samples to collect or which flow metering technologies to use. Rather, it is a *set of guidelines that provides flexibility for a municipality to develop a site-specific strategy for characterizing its CSS operation and impacts and for developing and implementing a comprehensive CSO controlplan. CSSs* vary greatly in their size, structure, operation, and receiving water impacts. A monitoring and modeling strategy appropriate for a large city such as New York or San Francisco would generally not apply to a small CSS with only one or two flow regulators and outfalls. In addition, communities have varying degrees of knowledge about how their CSSs react hydraulically to wet weather and how their CSOs affect receiving water quality. A municipality that does not know the location of its CSO outfalls has different information collection needs from a municipality that has already conducted CSS flow and water quality studies.

This manual provides guidance for communities of all sizes. It presents low-cost monitoring and modeling techniques, which should prove particularly helpful to small communities. However, communities with large CSSs should note that inexpensive techniques often prove useful in extending monitoring resources and in verifying the performance of more sophisticated techniques and equipment.

To use this manual, a municipality should already be familiar with the basic functioning of its CSS, basic monitoring procedures, and the general purpose of modeling. Since basic monitoring and modeling techniques are already covered extensively in other technical literature, this manual focuses mainly on the process of characterization as described in the CSO Control Policy, referring to other literature for more in-depth explanations of specific techniques or procedures.

## 1.6 MANUAL ORGANIZATION

This manual begins with an overview of monitoring and modeling under the CSO Control Policy, and then provides a detailed discussion of the monitoring and modeling activities that should be conducted for NMC implementation and LTCP development and implementation. These activities (and the chapters in which they are discussed) are as follows:

- Chapter 2 - Introduction To Monitoring and Modeling
- Chapter 3 - Initial System Characterization-Existing Data Analysis and Field Investigation
- Chapter 4 - Monitoring and Modeling Plan
- Chapter 5 - CSS Monitoring
- Chapter 6 - Receiving Water Monitoring
- Chapter 7 - CSS Modeling
- Chapter 8 - Receiving Water Modeling
- Chapter 9 - Assessing Receiving Water Impacts and Attainment of Water Quality Standards.

# CHAPTER 2

# INTRODUCTION TO MONITORING AND MODELING

Monitoring and modeling activities are central to implementation of the CSO Control Policy. Thoughtful development and implementation of a monitoring and modeling plan will support the selection and implementation of cost-effective CSO controls and an assessment of their improvements on receiving water quality.

This chapter describes general expectations for monitoring and modeling activities as part of a permittee's CSO control program. It also describes how monitoring and modeling efforts conducted as part of CSO control program implementation can be coordinated with other key EPA and State programs and efforts (e.g., watershed approach, other wet weather programs).

While this chapter will describe general expectations, EPA encourages the permittee to take advantage of the flexibility in the CSO Control Policy by developing a monitoring and modeling program that is cost-effective and tailored to local conditions, providing adequate but not duplicative or unnecessary information.

## 2.1 MONITORING AND MODELING FOR NINE MINIMUM CONTROLS AND LONG-TERM CONTROL PLAN

The CSO Control Policy urges permittees to develop a thorough understanding of the hydraulic responses of their combined sewer systems (CSSs) to wet weather events. Permittees may also need to estimate pollutant loadings from CSOs and the fate of pollutants in receiving water both for existing conditions and for various CSO control options. The CSO Control Policy states that permittees should immediately undertake a process to characterize their CSSs, demonstrate implementation of the nine minimum controls (NMC), and develop a long-term CSO control plan. Characterizing the CSS and its hydraulic response to wet weather events, implementing the NMC and producing related documentation, and developing a long-term control plan (LTCP) will involve gathering and reviewing existing data, and, in most cases, conducting some field inspections, monitoring, and modeling. Since flexibility is a key principle of the CSO Control Policy, these activities will be carried out to different degrees based on each permittee's situation. In particular, the type and complexity of necessary modeling will vary from permittee to permittee.

### 2.1.1 Nine Minimum Controls

The CSO Control Policy recommends that a Phase I permit require the permittee to immediately implement technology-based requirements, which at a minimum include the NMC, as determined on a best professional judgment (BPJ) basis by the NPDES permitting authority. The NMC are:

1. Proper operation and regular maintenance programs for the sewer system
2. Maximum use of the collection system for storage
3. Review and modification of pretreatment requirements to assure CSO impacts are minimized
4. Maximization of flow to the publicly owned treatment works (POTW) for treatment
5. Prohibition of CSOs during dry weather
6. Control of solid and floatable materials in CSOs
7. Pollution prevention
8. Public notification to ensure that the public receives adequate notification of CSO occurrences and CSO impacts
9. Monitoring to effectively characterize CSO impacts and the efficacy of CSO controls.

The NMC are technology-based controls, applied on a site-specific basis, to reduce the magnitude, frequency, and duration of CSOs and their impacts on receiving water bodies. NMC measures typically do not require significant engineering studies or major construction and thus implementation was expected by January 1, 1997. EPA's guidance document Combined Sewer *Overflows - Guidance for Nine Minimum Controls* (U.S. EPA, 1995b) provides a detailed description of the NMC, including example control measures and their advantages and limitations.

Monitoring is specifically included as the ninth minimum control. Implementation of this control would typically involve the following activities:

- Mapping the drainage area for the CSS, including the locations of all CSO outfalls and receiving waters
- Identifying, for each receiving water body, designated and existing uses, applicable water quality criteria, and whether water quality standards (WQS) are currently being attained for both wet weather and dry weather
- Developing a record of overflow occurrences (number, volume, frequency, and duration)
- Compiling existing information on water quality impacts associated with CSOs (e.g., beach closings, evidence of floatables wash-up, fish kills, sediment accumulation, and the frequency, duration, and magnitude of instream WQS violations).

Monitoring as part of the NMC is not intended to be extensive or costly. It should entail collection of existing information from relevant agencies about the CSS, CSOs, the receiving water body, and pollutant sources discharging to the same receiving waters, as well as preliminary investigation activities such as field inspections and simple measurements using chalk boards, bottle boards, and block tests. The collected information and data will be used to establish a baseline of existing conditions for evaluating the efficacy of the technology-based controls and to develop the LTCP (as described in Section 2.1.2).

Data analysis and field inspection activities also support implementation of several other NMC:

- ***Proper operation and regular maintenance programs for the sewer system-*** Characterization of the CSS will support the evaluation of the effectiveness of current operation and maintenance (O&M) programs and help identify areas within the CSS that need repair.
- ***Maximum use of the collection system for*** storage-Information gained during field inspections, such as the system topography (e.g., location of any steep slopes) and the need for regulator or pump adjustments, can assist in identifying locations where minor modifications to the CSS can increase in-system storage.

- ***Review and modification of pretreatment requirements to assure CSO impacts are*** minimized-Pretreatment program information and existing monitoring data will support assessment of the impacts of nondomestic discharges on CSOs and identify opportunities to mitigate the impacts of nondomestic discharges during wet weather.

- ***Control of solid andfloatable materials in*** CSOs-Existing information about receiving water impacts and observations made during field inspections of the CSS will help determine the extent of solid and floatable materials present and the effectiveness of any controls installed.

- ***Dry weather*** overflows-Field inspections will assess the presence of dry weather overflows, the conditions under which they occur, and the effectiveness of any control measures in place.

Because specific NMC implementation requirements will be embodied in a permit or other enforceable mechanism that is developed on a site-specific basis, the permittee should coordinate NMC implementation with the NPDES permitting authority on an ongoing basis.

### 2.1.2 Long-Term Control Plan Development

The CSO Control Policy recommends that a Phase I permit require the permittee to develop and submit an LTCP that, when implemented, will ultimately result in compliance with CWA requirements. The permittee should use either the presumption approach or the demonstration approach in developing an LTCP that will provide for WQS attainment. The two approaches are discussed in more detail below and in Chapters 7 through 9.

The permittee should evaluate the data and information obtained through the initial system characterization to determine which approach is more appropriate based on site-specific conditions. Generally, the demonstration approach would be selected when sufficient data are available, or can be collected, to “demonstrate” that a proposed LTCP is adequate to meet the water quality-based requirements of the CWA. If sufficient data are not available and cannot be developed to allow use of the demonstration approach, and the permitting authority believes it is likely that implementation of a control program that meets certain performance criteria will result in attainment of CWA requirements, the permittee would use the presumption approach.

**Demonstration Approach.** Under the demonstration approach, the permittee demonstrates the adequacy of its CSO control program to meet the water quality-based requirements of the CWA. As stated in the CSO Control Policy, the permittee should demonstrate each of the following:

"i. *The planned control program is adequate to meet WQS andprotect 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 and 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. "* (Section II.C.4.b of the CSO Control Policy)

Generally, monitoring and modeling activities will be integral to successfully demonstrating that these criteria have been met.

**Presumption Approach.** This approach is based on the presumption that WQS will be attained with implementation of an LTCP that meets certain performance-based criteria. For the presumption approach, the CSO Control Policy states that:

*"A program that meets any of the criteria listed below 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 described above. These criteria are provided because data and modeling of wet weather events often do not give a clear picture of the level of CSO controls necessary to protect WQS.*

i. *No more than an average of four overflow events per year...*

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...*

iii. *The elimination or removal of no less than the mass of pollutants, identified as causing water quality impairment..., for the volumes that would be eliminated or capturedfor treatment under paragraph ii... "* (Section II.C.4.a.)

Monitoring and modeling activities are also likely to be necessary in order to obtain the permitting authority's approval for using the presumption approach. Considerations for using both the presumption approach and the demonstration approach are discussed in *Combined Sewer Overflows - Guidance for Long Term Control Plan* (U.S. EPA, 1995a).

Whether the LTCP ultimately reflects the demonstration approach or the presumption approach, it should contain the same elements, as identified in the CSO Control Policy:

- Characterization, monitoring, and modeling of the CSS
- Public participation
- Consideration of sensitive areas
- Evaluation of alternatives
- Cost/performance considerations
- Operational plan
- Maximization of treatment at the POTW
- Implementation schedule
- Post-construction compliance monitoring program.

Of these elements, the first and last are directly linked to monitoring and modeling and are described below.

**Characterization, monitoring, and modeling of the CSS**

The first step in developing an LTCP involves characterization, monitoring, and modeling of the CSS. The CSO Control Policy states:

> *"In order to design a CSO control plan adequate to meet the requirements of the CWA, a permittee should have a thorough understanding of its sewer system, the response of the system to various precipitation events, the characteristics of the overflows, and the water quality impacts that result from CSOs. The permittee should adequately characterize through monitoring, modeling, and other means as appropriate, for a range of storm events, the response of its sewer system to wet weather events including the number, location and frequency of CSOs, volume, concentration and mass ofpollutants discharged and the impacts of the CSOs on the receiving waters and their designated uses. The permittee may need to consider information on the contribution and importance of other pollution sources in order to develop a final plan designed to meet water quality standards. 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."* (Section II.C.1)

Characterization, monitoring, and modeling of the CSS can be broken into the following elements:

1. Examination of existing data
2. Characterization of the CSS
3. Monitoring of CSOs and receiving water
4. Modeling of the CSS and receiving water.

Analysis of existing data should include an examination of rainfall records and available data on flow, capacity, and water quality for the collection system, treatment plant, and receiving water. This analysis, as well as information from field inspections and simple measurements, provides the basis for the preliminary system characterization. This initial characterization of the system (described in more detail in Chapter 3) should identify the number, location, and frequency of overflows and clarify their relationship to sensitive areas, pollution sources within the collection system (e.g., indirect discharges from nondomestic sources), other pollution sources discharging to the receiving water (e.g., direct industrial discharges, POTWs, storm water discharges), and background/upstream pollution sources (e.g., agricultural or other nonpoint source runoff).

Since some of these activities are also conducted as part of NMC implementation, the LTCP should be developed in coordination with NMC implementation efforts. Ultimately, because the LTCP is based on more detailed knowledge of the CSS and receiving waters than is necessary to implement the NMC, the extent of monitoring and modeling for LTCP development is expected to be more sophisticated.

Examination of existing data, field inspections and simple measurements, and other preliminary characterization activities will serve as the basis for the development of a cost-effective monitoring and modeling plan (discussed in Chapter 4). The monitoring and modeling plan should be designed to provide the information and data needed to develop and evaluate CSO control alternatives and to select cost-effective CSO controls.

Chapter 4 provides an overview of the development of a monitoring and modeling plan. Chapters 5 and 7 discuss CSS monitoring and modeling, and Chapters 6 and 8 discuss receiving water monitoring and modeling, respectively. It is important to remember that the monitoring and modeling plan should be based on the site-specific conditions of the CSS and receiving water. Therefore the permittee should, on an ongoing basis, consult and coordinate these efforts with the NPDES permitting authority.

Implementation of the monitoring and modeling plan should enable the permittee to predict the CSS's response to various wet weather events and evaluate CSO impacts on receiving waters for alternative control strategies. Evaluation of CSO control alternatives is discussed in *Combined Sewer Overflows - Guidance for Long Term Control Plan* (U.S. EPA, 1995a).

Based on the evaluation of control strategies, the permittee, in coordination with the public, the NPDES permitting authority, and the State WQS authority, should select the cost-effective CSO controls needed to provide for the attainment of WQS. Specific conditions relating to implementation of these CSO controls will be incorporated into the NPDES permit as described in Section 2.1.4.

**Post-construction compliance monitoring program**

Not only should the LTCP contain a characterization, monitoring, and modeling plan adequate to evaluate CSO controls, but it should also contain a post-construction compliance monitoring plan to ascertain the effectiveness of long-term CSO controls in achieving compliance with CWA requirements. Generally, post-construction compliance monitoring will not occur until after development and at least partial implementation of the LTCP. Nevertheless, the permittee should consider its needs for post-construction monitoring as its monitoring and modeling plan develops. The development of a post-construction compliance monitoring program is discussed in Section 2.1.4 and Chapter 4.

### 2.1.3 Monitoring and Modeling During Phase I

The CSO Control Policy recommends that the Phase I permit require permittees to:

- Immediately implement BAT/BCT (best available technology economically achievable/best conventional pollutant control technology), which at a minimum should include the NMC, as determined on a BPJ basis by the NPDES permitting authority

- Submit appropriate documentation on NMC implementation activities within two years of permit issuance/modification but no later than January 1, 1997

- Comply with applicable WQS expressed as narrative limitations

- Develop and submit an LTCP as soon as practicable, but generally within two years after permit issuance/modification.

The permittee should not view NMC implementation and LTCP development as independent activities, but rather as related components in the CSO control planning process. Implementation of the NMC establishes the baseline conditions upon which the LTCP will be developed.

In many cases, the LTCP will be developed concurrent with NMC implementation. As described in Sections 2.1.1 and 2.1.2, both efforts require the permittee to develop a thorough understanding of the CSS. For example, monitoring done as part of the NMC to *effectively characterize CSO impacts and the efficacy of CSO controls* should provide a base of information and data that the permittee can use in conducting more thorough characterization, monitoring, and modeling activities for LTCP implementation.

Therefore, the characterization activities needed to implement the NMC and develop the LTCP should be a single coordinated effort.

### 2.1.4 Monitoring and Modeling During Phase II

The CSO Control Policy recommends that a Phase II permit include:

- Requirements to implement technology-based controls including the NMC on a BPJ basis
- A narrative requirement that selected CSO controls be implemented, operated, and maintained as described in the LTCP
- Water quality-based effluent limits expressed in the form of numeric performance standards
- Requirements to implement the post-construction compliance monitoring program
- Requirements to reassess CSOs to sensitive areas
- Requirements for maximizing the treatment of wet weather flows at the treatment plant
- A reopener clause authorizing permit modifications if CSO controls fail to meet WQS or protect designated uses.

The post-construction compliance monitoring program should provide sufficient data to determine the effectiveness of CSO controls in attaining WQS. The frequency and type of monitoring in the program will be site-specific. In most cases, some monitoring will be conducted during the construction/implementation period to evaluate the effectiveness of the long-term CSO controls. In some cases, however, it may be appropriate to delay implementation of the post-construction monitoring program until construction is well underway or completed.

The post-construction compliance monitoring program may also include other appropriate measures for determining the success of the CSO control program. Measures of success, which are also discussed in Section 2.3, can address both CSO flow and quality issues. For example, flow-related measures could include the number of dry weather overflows or CSO outfalls eliminated, and reductions in the frequency and volume of CSOs. Quality-related measures could include decreases in loadings of conventional and toxic pollutants in CSOs. Environmental measures focus on human and ecosystem health trends such as reduced beach closures or fish kills, improved biological integrity indices, and the full support of designated uses in receiving water bodies.

## 2.2 MONITORING AND MODELING AND THE WATERSHED APPROACH

The watershed approach represents a holistic approach to understanding and addressing all surface water, ground water, and habitat stressors within a geographically defined area, instead of addressing individual pollutant sources in isolation. It serves as the basis for "place-based" solutions to ecosystem protection.

The watershed approach is based on a few main principles:

- ***Geographic*** Focus-Activities are focused on specific drainage areas
- ***Environmental Objectives and Strong Science/Data-Using*** strong scientific tools and sound data, the priority problems are characterized, environmental objectives are determined, action plans are developed and implemented, and effectiveness is evaluated

- ***Establishment of Partnerships-*** Management teams representing various interests (e.g., regulatory agencies, industry, concerned citizens) are formed to jointly evaluate watershed management decisions

- ***Coordinated Priority Setting and Integrated Solutions-*** Using a coordinated approach across relevant organizations, priorities can be set and integrated actions taken that consider all environmental issues in the context of various water programs and resource limitations.

Point and nonpoint source programs, the drinking water program, and other surface and ground water programs are all integrated into the watershed approach. Under the watershed approach, these programs address watershed problems in an effective and cooperative fashion. The CSO Control Policy encourages NPDES permitting authorities to evaluate CSO control needs on a watershed basis and coordinate CSO control program efforts with the efforts of other point and nonpoint source control activities within the watershed.

The application of the watershed approach to a CSO control program is particularly timely and appropriate since the ultimate goal of the CSO Control Policy is the development of long-term CSO controls that will provide for the attainment of WQS. Since pollution sources other than CSOs are likely to be discharging to the receiving water and affecting whether WQS are attained, the permittee needs to consider and understand these sources in developing its LTCP. The permittee should compile existing information and monitoring data on these sources from the NPDES permitting authority, State watershed personnel, or even other permittees or dischargers within the watershed. If other permittees within the watershed are also developing LTCPs, they may have an opportunity to pursue a coordinated and cooperative approach to CSO control planning.

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. A watershed-based approach to LTCP development allows for the site-specific determination of the relative impacts of CSOs and other pollution sources. The flows and loads from the pollutant sources are estimated using available site-specific data and modeling. In addition to locally available data, potential data sources include:

- ***BASINS (Better Assessment Science Integrating Point and Nonpoint Sources) -*** Combines a geographic information system (GIS), national watershed data, and environmental assessment and modeling tools to facilitate watershed and water quality analysis. Additional information is available at http://www.epa.gov/OST/BASINS/. (U.S. EPA, 1997a)

- ***EMAP (Environmental Monitoring and Assessment Program)*** - Contains data on a limited set of estuaries, surface waters, and coastal bays, as well as some information on landscape characteristics and land use. EPA's EMAP Internet site (http://www.epa.gov/emap/) also contains links to additional sources of environmental data.

- ***NAWQA (National Water-Quality Assessment) Program*** - Contains information on the status and trends in the quality of 60 U.S. river basins and aquifers. Information on the NAWQA Program can be obtained from the U.S. Geological Survey (703-648-5716) or from the USGS Internet site (http://wwwrvares.er.usgs.gov/nawqa/).

If the permittee determines during its LTCP development that WQS cannot be met because of other pollution sources within the watershed, a total maximum daily load (TMDL), including wasteload allocations for point sources and load allocations for nonpoint sources, may be necessary to apportion loads among dischargers. Several publications provide TMDL and wasteload allocation guidance (U.S. EPA, 1995g; U.S. EPA, 1991b; Mills et al., 1986; Mancini et al., 1983; Martin et al., 1990; Mills et al., 1985a,b). In many cases, a TMDL may not have been developed for the permittee's watershed. In these cases, the monitoring and modeling conducted as part of the development and implementation of long-term CSO controls will support an assessment of water quality and could support the development of a TMDL. BASINS (U.S. EPA, 1997a) also supports the development of 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* (U.S. EPA, 1994e). 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 *Clean Water Action Plan*, issued jointly by EPA and the U.S. Department of Agriculture, calls for States to issue unified watershed assessments by October, 1998 (U.S. EPA/USDA, 1998). Assessments identify degraded watersheds needing restoration, watersheds needing preventive action to sustain water quality, and pristine or sensitive watersheds on Federal lands needing additional protection. The *Clean Water Action Plan* identifies mechanisms for States and tribes to coordinate with Federal agencies to prioritize watershed restoration and protection efforts. Additional information is available at http://www.cleanwater.gov/.

Use of the comprehensive watershed approach during long-term CSO planning will promote a more cost-effective program for achieving WQS in a watershed. LTCP development using the watershed approach is discussed further in *Combined Sewer Overflows - Guidance for Long-Term Control Plan* (U.S. EPA, 1995a).

## 2.3 MEASURES OF SUCCESS

Before developing a monitoring plan for characterizing the CSS and determining post-construction compliance, the permittee should identify appropriate measures of success based on site-specific conditions. 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, such as the number of inspections

- ***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 receiving water body, such as trends in dissolved oxygen levels, sediment oxygen demand, and solids and fecal coliform concentrations

- ***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.

Measures of success for a CSO control program should typically 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. The permittee should choose measures of success that can be used to indicate reductions in the occurrence and effects of CSOs. Municipalities and NPDES permitting authorities should agree early in the planning stages on the data and information that will be used to measure success. These measures of success may need to be adapted as a municipality gains additional information during its system characterization. (Measures of success for the CSO program are discussed in *Combined Sewer Overflows-Guidance for Long-Term Control Plan* (U.S. EPA, 1995a) and *Performance Measures for the National CSO Control Program* (AMSA, 1996)). The permittee should consider these measures of success when determining which parameters to include in its monitoring plan.

## 2.4 COORDINATION WITH OTHER WET WEATHER MONITORING AND MODELING PROGRAMS

The permittee may be subject to monitoring requirements for other regulated wet weather discharges, such as storm water, in addition to CSOs. Due to the unpredictability of wet weather discharges, monitoring of such discharges presents challenges similar to those for monitoring CSOs. The permittee should coordinate all wet weather monitoring efforts. Developing one monitoring and modeling program for all wet weather programs will enable the permittee to establish a clear set of priorities for monitoring and modeling activities.

## 2.5 REVIEW AND REVISION OF WATER QUALITY STANDARDS

Section 301 of the CWA and NPDES regulations at 40 CFR 122.44 require the establishment of both technology-based and water quality-based effluent limitations:

- ***Technology-based requirements.*** Section 301 of the CWA requires effluent reductions based on various degrees of control technology for all discharges of pollutants. NPDES regulations at 40 CFR 122.44(a) require that technology-based effluent limitations be established for pollutants of concern discharged by point sources that will be regulated under an NPDES permit. Under the CSO Control Policy, permittees are expected to implement technology-based controls including, at a minimum, the NMC.

- ***Water quality-based requirements.*** Section 301(b)(1)(C) of the CWA and NPDES regulations at 40 CFR 122.44(d) require that NPDES permits contain water quality-based effluent limitations for all discharges that cause, contribute to, or have the potential to cause an exceedance of a numeric or narrative WQS. As described in the CSO Control Policy, Phase I permits should at least require that the permittee immediately comply with applicable narrative WQS, while sufficient data may not be available at this point to evaluate the need for numeric effluent limits. For Phase II permits, the CSO Control Policy recommends that permits contain water quality-based effluent limits expressed as numeric performance standards (e.g., number of overflow events per year) for the selected CSO controls. If sufficient data are available, numeric water quality-based effluent limitations should be developed and included in Phase II permits.

The development of permit limits and conditions for CSO permittees is described in greater detail in *Combined Sewer Overflows - Guidance for Permit Writers* (U.S. EPA, 1995e).

Since CSO controls must ultimately provide for the attainment of WQS, the analysis of CSO control alternatives should be tailored to the applicable WQS. A key principle of the CSO Control Policy is the review and revision, as appropriate, of WQS and their implementation procedures to reflect the site-specific wet weather impacts of CSOs. In identifying applicable WQS, the permittee and the permitting and WQS authorities should consider whether revisions to WQS are appropriate for wet weather conditions in the receiving water.

Review of WQS should be conducted concurrent with the development of the LTCP to ensure that the long-term CSO controls will be sufficient to provide for the attainment of applicable WQS. The information gained from LTCP development can then be used to support any efforts to revise WQS. (The identification of applicable WQS and methods for assessing attainment of WQS are discussed in Chapter 9).

The WQS program contains several types of mechanisms that could potentially be used to address site-specific factors such as wet weather conditions. These include the following:

- 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)
- Granting a temporary variance to a specific discharger in cases where maintaining existing standards for other dischargers is preferable to downgrading WQS.

These potential revisions are described in detail in the *Water Quality Standards Handbook, Second Edition* (U.S. EPA, 1994).

Reviewing and revising WQS requires the collection of information and data to support the proposed revision. In general, a use attainability analysis (UAA) is required to support a proposed WQS revision. The process for conducting UAAs for receiving waters has been described in various EPA publications (U.S. EPA, 1994; U.S. EPA, 1984a; U.S. EPA, 1984b; U.S. EPA, 1983b).

The information and data collected during LTCP development could potentially be used to support a UAA for a proposed revision to WQS to reflect wet weather conditions. Thus, it is important for the permittee, NPDES permitting authority, State WQS authority, and EPA Regional offices to agree on the data, information, and analyses that are necessary to support the development of long-term CSO controls as well as the review of applicable WQS and implementation procedures, if appropriate.

## 2.6 OTHER ENTITIES INVOLVED IN DEVELOPING AND IMPLEMENTING THE MONITORING AND MODELING PROGRAM

Development and implementation of a CSO monitoring and modeling program should not be solely the permittee's responsibility. Development of a successful and cost-effective monitoring and modeling program should reflect the coordinated efforts of a team that includes the NPDES permitting authority, State WQS authority, State watershed personnel, EPA or State monitoring personnel, and any other appropriate entities.

**NPDES Permitting Authority**

The NPDES permitting authority should:

- Develop appropriate system characterization, monitoring, and modeling requirements for NMC implementation and LTCP development (in a Phase I permit) and NMC and LTCP implementation (in a Phase II permit)
- Determine, in coordination with the permittee and appropriate State and Federal agencies, whether the permittee needs to consider any sensitive areas in developing a monitoring and modeling plan
- Coordinate with the permittee to ensure that the monitoring requirements in the permit are appropriately site-specific
- Assist in compiling relevant existing information, monitoring data, and studies at the State and/or EPA Regional level
- Decide if the presumption approach is applicable based on the data and analysis conducted in the characterization, monitoring, and modeling of the system and the consideration of any sensitive areas

- Coordinate the permittee's CSO monitoring and modeling efforts with monitoring and modeling efforts of other permittees within the watershed

- Coordinate the team review of the monitoring and modeling plan, monitoring and modeling data, and other components of the LTCP. To ensure team review of the monitoring and modeling plan, the permitting authority could recommend that the plan include a signature page for endorsement by all the team members after their review.

- Develop appropriate monitoring requirements for post-construction compliance monitoring to assess attainment of WQS and the effectiveness of CSO controls (in a Phase II permit and ongoing).

- Assist in the review and possible revision of WQS.

**State WQS Authority**

The State WQS authority should:

- Provide input on the review and possible revision of WQS, including conduct of a use attainability analysis where necessary

- Assist in compiling existing State information, monitoring data, and studies for the receiving water body

- Ensure that the permittee's monitoring and modeling efforts are coordinated and integrated with ongoing State monitoring programs

- Evaluate any special monitoring activities such as biological testing, sediment testing, and whole effluent toxicity testing.

**State Watershed Personnel**

State watershed personnel should:

- Ensure that the permittee's monitoring activities are coordinated with ongoing watershed monitoring programs

- Assist in compiling existing State information, monitoring data, and studies for the receiving water body

- Ensure the permittee's monitoring and modeling efforts are integrated with TMDL application or development.

**EPA/State Monitoring Personnel**

EPA and State monitoring personnel should:

- Provide technical support and reference material on monitoring techniques and equipment
- Assist in compiling relevant existing monitoring data and studies for the receiving water body
- Provide information on available models and the monitoring data needed as model inputs
- Assist in the evaluation and selection of appropriate models.

The public should also participate in development and implementation of the system characterization activities and the monitoring and modeling program. Throughout the LTCP development process, the public should have the opportunity to review and provide comments on the results of the system characterization, monitoring, and modeling activities that lead to the selection of long-term CSO controls. The public participation effort might involve public meetings at key points during the system characterization phase of LTCP development. 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 from 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 control CSOs.

# CHAPTER 3

# INITIAL SYSTEM CHARACTERIZATION - EXISTING DATA ANALYSIS AND FIELD INVESTIGATION

As explained in Chapter 2, the development of a long-term control plan (LTCP) requires a thorough characterization of the combined sewer system (CSS). Accurate information on CSS design, CSS responses to wet weather, pollutant characteristics of CSOs, and biological and chemical characteristics of receiving waters is critical in identifying CSO impacts and the projected efficacy of proposed CSO controls. Before in-depth monitoring and modeling efforts begin, however, the permittee should assemble as much information as possible from existing data sources and preliminary field investigations. Such preliminary activities will contribute to a baseline characterization of the CSS and its receiving waters and help focus the monitoring and modeling plan.

The primary objectives of the existing data analysis and field investigation are:

- To determine the current level of understanding and knowledge of the CSS and receiving water
- To assess the design and current operating condition of the CSS
- To identify any known CSO impacts on receiving waters
- To identify the data that still need to be collected through the monitoring and modeling program
- To assist in implementation and documentation of the nine minimum controls (NMC).

The activities required to meet these objectives will vary widely from system to system. Many permittees have already made significant progress in conducting initial system characterizations. Implementation of the NMC, which was expected by January, 1997, should have enabled permittees to compile a substantial amount of information on their CSSs. In addition, studies by EPA, State agencies, or other organizations may provide substantial information and data for the receiving water characterization.

This chapter describes the following activities in the initial system characterization:

- ***Physical Characterization of CSS-*** identification and description of all functional elements of the CSS and sources discharging into the CSS, delineation of the CSS drainage areas, analysis of rainfall data throughout the drainage area, identification of all CSO outfalls, and preliminary CSS hydraulic analyses.

- ***Characterization of Combined Sewage and CSOs-*** analysis of existing data to determine volume and pollutant characteristics of CSOs.

- ***Characterization of Receiving Waters-*** identification of the designated uses and current status of the receiving waters affected by CSOs, water quality assessment of those receiving waters, and identification of biological receptors potentially impacted by CSOs.

The permittee should consult with the NPDES permitting authority and the review team (see Section 2.6) when reviewing the results from the initial system characterization and in preparation for developing the monitoring and modeling plan (Chapter 4). Performing and documenting initial characterization activities may help satisfy certain requirements for NMC implementation and documentation. Thus, it is essential that the permittee coordinate with the NPDES permitting authority on an ongoing basis throughout the initial characterization process.

## 3.1 PHYSICAL CHARACTERIZATION OF CSS

### 3.1.1 Review Historical Information

For the first part of the physical characterization, the permittee should compile, catalogue, and review existing information on the design and construction of the CSS to evaluate how the CSS operates, particularly in response to wet weather events. The permittee should compile, for the entire CSS, information on the contributing drainage areas, the location and capacity of the POTW and interceptor network, the location and operation of flow regulating structures, the location of all known or suspected CSO outfalls, and the general hydraulic characteristics of the system (including existing flow data for both wet weather and dry weather). Historical information is often available from the following sources:

- ***Sewer Maps of Suitable Scale-*** Sewer maps define the pipe network of the sewer system and may indicate the drainage areas that contribute to each CSO outfall. Ideally, they should include the combined, separate sanitary, and separate storm sewer systems, manhole locations for monitoring access, catch basin locations, and pipe shapes and materials. Sewer maps may also show curb/surface drainage, roof connections, pipe age, and ongoing roadway construction projects and their influence on storm flow. Many cities have also used Geographic Information Systems (GIS) to develop maps of their sewer systems. Data provided from these maps, such as the invert elevations, can be used to calculate individual pipe capacities and to develop detailed hydraulic models. Sewer maps should be field checked because field conditions may differ significantly from the plans (see System Field Investigations, Section 3.1.3).

- ***Topographic Maps-*** The U.S. Geological Survey (USGS) provides topographic maps, usually with lo-foot contour intervals. The local municipality or planning agency may have prepared topographic maps with finer contour intervals, which may be more useful in identifying drainage areas contributing to CSOs.

- ***Aerial Photograph-When*** overlaid with sewer maps and topographic maps, aerial photos may aid in identifying land uses in the drainage areas. Local planning agencies, past land use studies, or State Departments of Transportation may have aerial photographs suitable for the initial characterization.

- ***Diversion Structure Drawings-*** Drawings of CSS structures, in plan and section view, indicate how the structures operate, how they should be monitored, and how they could be altered to facilitate monitoring or improve flow control.

- ***Rainfall Data-*** Rainfall data are one of the most important and useful types of data collected during the initial system characterization. Reliable rainfall data are necessary to understand the hydraulic response of the CSS and, where applicable, to model this response. Sources of data may include long-term precipitation data collected from a weather station within or outside the CSS drainage basin, or short-term, site-specific precipitation data from stations within the drainage basin or sub-basins. Wastewater treatment plants may also collect their own rainfall data or maintain records of rainfall data from a local weather station.

  Long-term rainfall data collected within the drainage basin provide the best record of precipitation within the system and hence have the greatest value in correlating historic overflow events with precipitation events and in predicting the likelihood of wet weather events of varying intensities. If such data are not available, however, both long-term regional and short-term local data may be used. For calibration and validation of hydraulic models (see Section 7.4), it is important to use rainfall data collected from within or in very close proximity to the drainage area.

National rainfall data are available from the National Weather Service, which operates thousands of weather monitoring stations throughout the country. Rainfall data for some areas are available on the Internet (the National Weather Service home page can be found at http://www.nws.noaa.gov/). The local municipality, airports, universities, or other State or Federal facilities can also provide rainfall data. The National Oceanic and Atmospheric Administration (NOAA), National Climatic Data Center (NCDC), Climate Services Branch is responsible for collecting precipitation data. Data on hourly, daily, and monthly precipitation for each monitoring station (with latitude and longitude) can be obtained on computer diskette, microfiche, or hard copy by calling (704) 259-0682, or by writing to NCDC, Climate Services Branch, The Federal Building, Asheville, NC 28071-2733. Some NCDC data are also available on the Internet (NCDC's home page can be found at http://www.ncdc.noaa.gov/). The NCDC also provides a computer program called SYNOP for data analysis.

Additionally, permittees with few or no rain gages located within the system drainage basin may want to install one or more gages early in the CSO control planning process. Collection and analysis of rainfall data are discussed in Chapters 4 and 5.

**Other Sources of Data**

A variety of other historical data sources may be used in completing the physical characterization of a CSS. As-built plans and documentation of system modifications can provide reliable information on structure location and dimensions. Similarly, any recent surveys and studies conducted on the system can verify or enhance sewer map information. Additional information may also be available from:

- GIS databases
- Treatment plant upgrade reports
- CSS flow records (for both dry weather and wet weather)
- Treatment plant and pump station flow and performance records
- Design specifications
- Infiltration/inflow (I/I) studies
- Sewer system evaluation surveys (SSES)
- Storm water master plans

- Storm water utility records and reports
- Section 208 areawide waste treatment plans
- Section 201 facility plans
- Local property taxation records
- Federal and State highway maps and plans
- County/city planning and zoning agencies.

The availability of these sources of information varies widely among permittees. Collection system operation and maintenance personnel can be invaluable in determining the existence and location of such data, as well as providing system knowledge and insight.

### 3.1.2 Study Area Mapping

Using the historical data, the permittee should develop a map of the CSS, including the drainage basin of combined sewer areas and separate storm sewer areas. Larger systems will find it useful to map sub-basins for each regulating structure and CSO. This map will be used for analyzing system flow directions and interconnections, analyzing land use and runoff parameters, locating monitoring networks, and developing model inputs. The map can also be a valuable planning tool in identifying areas of special concern in the CSS and planning further investigative efforts and logistics. The map should be modified as necessary to reflect additional CSS and receiving water information (such as the locations of other point source discharges to the receiving water, the location of sensitive areas, and planned or existing monitoring locations), when these become available.

The completed map should include the following information:

- Delineation of contributing CSS drainage areas (including topography)
- General land uses (e.g., residential, commercial, industrial) and degree of imperviousness
- POTW and interceptor network

- Trunk sewer and interceptor sewer locations and sizes
- Diversion structures (e.g., gates, weirs)
- CSO outfalls (including the presence of backflow gates)
- Access points (e.g., manholes safely accessible considering traffic and pipe depth; flat, open areas accessible for sampling)
- Pump stations
- River crossings
- Rain gages
- Existing monitoring locations (CSS, CSO, storm water, other point and nonpoint sources, and receiving water)
- USGS gage stations
- Receiving water bodies
- Soil types
- Ground water flow
- Outlying separate sanitary sewer areas draining to the CSS (where applicable)
- Other point source discharges such as industrial discharges and separate storm water system discharges
- Existing industrial and municipal treatment facilities
- Existing non-domestic discharges to the CSS.

It may be useful to generate two or more maps with different scales, such as a coarse-scale map (e.g., 7.5-minute USGS map) for land uses and other watershed scale information and a finer-scale map (e.g., 1" = 200' or 1" = 400') for sewer system details. In some cases, a Computer Aided Design (CAD) or GIS approach can be used. Some advanced sewer models can draw information directly from CAD tiles, eliminating the duplication of entering data into the model. A municipality's planning department may be a useful source for the hardware, software, and data needed for such mapping efforts.

### 3.1.3 System Field Investigation

Before developing a monitoring and modeling program, the permittee should supplement historical CSS information with field observations of the system to verify findings or fill data gaps. For example, visual inspection of regulator chambers and overflow structures during dry and wet weather verifies information included in drawings and provides data on current conditions. Further, it is necessary to verify that gates or flow diversion structures operate correctly so that ensuing monitoring programs collect information representative of the expected behavior of the system. Field inspections should address all areas of the CSS, including the pipe network, flow diversion structures, CSO outfalls, pump stations, manholes, and catch basins.

In general, field inspection activities may be used to:

- Verify the design and as-built drawings
- Locate and clarify portions of the system not shown on as-built drawings
- Identify dry weather overflows and possible causes of the overflows (e.g., diversion structures set too low)
- Identify locations of CSO outfalls (and whether they are submerged)
- Identify non-standard engineering or construction practices (e.g., irregularly-designed regulators, use of atypical materials)
- Examine the general conditions and operability of flow regulating equipment (e.g., weirs, gates)
- Identify areas in need of maintenance, repair, or replacement
- Identify areas that are curbed, areas where roof downspouts are directly connected to the CSS, and impervious areas.

Although generally beyond the scope of a small system characterization effort, in-line TV cameras can be used to survey the system, locate connections, and identify needed repairs. WPCF (1989) describes in-line inspection methods in detail and provides additional useful information for system evaluations.

The field investigation may also involve preliminary collection of both dry weather and wet weather flow and depth data, which can support the CSS flow monitoring and modeling activities later in the CSO control planning process. Preliminary CSS flow and depth estimates can begin to answer the following questions:

- How much rain causes an overflow at each outfall?
- How many dry weather overflows occur? How frequently and at which outfall(s)? How much flow is being discharged during dry weather?
- Do surcharging or backwater effects occur in intercepting devices or flow diversion structures?
- How deep are the maximum flows at the flow diversion structures? Would alteration of a diversion structure affect whether a CSO occurs?

A variety of simple flow measurement techniques can help answer these questions prior to development and implementation of a monitoring and modeling plan. These include:

- ***Chalk Board-*** A chalk board is a simple depth-measuring device, generally placed in a manhole. It is a vertical board with a vertical chalk line drawn on it. Sewer flow passing by the board washes away a portion of the chalk line, roughly indicating the maximum flow depth that occurred since the board was placed in the sewer.
- ***Chalk Spraying-*** A sprayer is used to blow chalk into a CSO structure. Passing sewer flow washes away the chalk, indicating approximate flow depth since spraying.
- ***Bottle Boards-A*** bottle board is a vertical board with a series of attached open bottles. As flow rises the bottles with openings below the maximum flow are filled. When the flow recedes the bottles remain full indicating the height of maximum flow (see Exhibit 5-6).

- ***Block*** Tests-Block tests do not measure depth, but are used to detect the presence of an overflow. A block of wood or other float is placed atop the overflow weir. If an overflow occurs, it is washed off the weir indicating that the event took place. The block can be tethered to the weir for retrieval.

These simple flow measurement techniques could be a useful component of the NMC for monitoring to characterize CSO impacts and the efficacy of CSO controls. The permittee should discuss this with the permitting authority. In some limited cases, automated continuous flow monitoring may be used. These techniques and other CSS monitoring techniques are discussed in Chapter 5.

### 3.1.4 Preliminary CSS Hydraulic Analysis

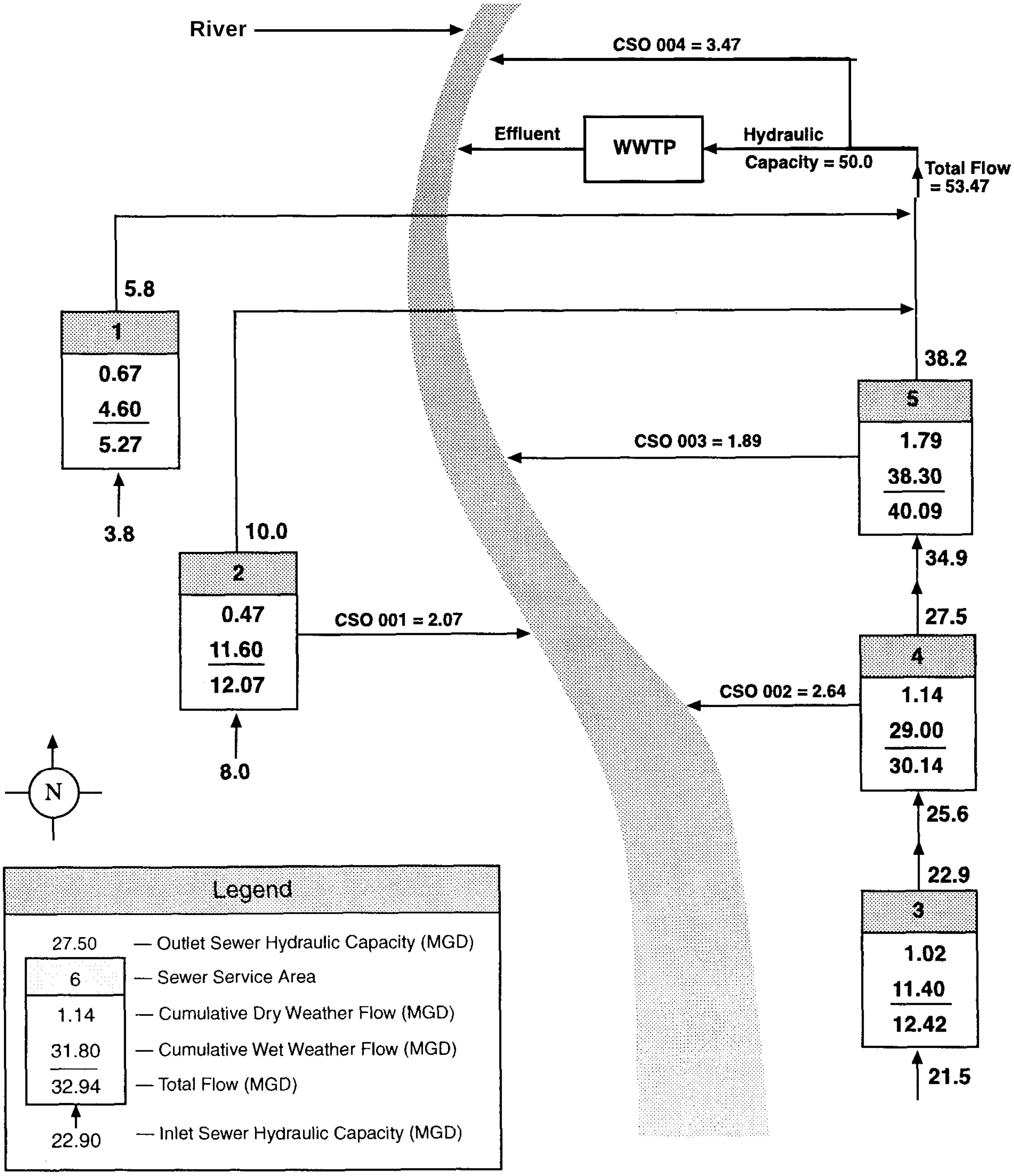
The physical characterization of the CSS should include a flow balance, using a schematic diagram of the collection system. Exhibit 3-1 provides an example of a basic flow balance diagram. It shows expected wet weather and dry weather flows through each service area, and the likely flows at each CSO based on sewer hydraulic capacities. The diagram can be expanded to include additional detail, such as breaking down the cumulative flows at each regulator to show schematically where the flows are entering the system. This can sometimes reveal local bottlenecks that may be resolved by relocating the connection to a downstream portion of the system where there is greater capacity.

The following steps can be used to develop a flow balance diagram or conduct a similar flow analysis:

- Section the collection system into a series of basins of small enough area to characterize the major collection system elements, differing land uses, receiving streams, and other characteristics that may become important during the development of a monitoring and modeling plan. These basins will likely be refined as work progresses.

- Establish the hydraulic capacity of each element of the system. For a preliminary analysis, this can be done using the unsurcharged capacity of the system, based on pipe size and slope, pump station capacity, and a knowledge of bottlenecks in the system.

**Exhibit 3-1. Basic Flow Balance Diagram**




* Cumulative flows = flows from the service area and service areas upstream in the collection system. Wet weather flow values are for the average of several sampled storm events.

- For each basin, develop a dry weather estimate of flow delivered to the system. This can be done in a preliminary way by using total dry weather flow to the treatment plant, disaggregated to each basin using population. Care should be taken where significant differences in infiltration are suspected.

- For each basin, develop an estimate of wet weather inflow and wet weather-induced infiltration. This estimate should be based on a consistent storm or return frequency in each basin. (Flow monitoring in the CSS, including rainfall and runoff assessment, is discussed in Chapter 5.)

- Display these data in a manner that aids data analysis, such as in a flow balance diagram (Exhibit 3-1).

The schematic diagram, together with the historical data review and supplemental field study, should enable the permittee to assign typical flows and maximum capacities to various interceptors for non-surcharged flow conditions. Flow capacities can be approximated from sewer maps or calculated from invert elevations. The resulting values provide a preliminary estimate of system flows at peak capacity. Calculations of flow within intercepting devices or flow diversion structures and flow records from the treatment plant help in locating sections of the CSS that limit the overall hydraulic capacity.

The preliminary hydraulic analysis, together with other physical characterization activities, will be useful in designing the CSS monitoring program and identifying areas that should receive greater attention in developing the monitoring and modeling plan. This preliminary analysis can help in identifying likely CSOs, the magnitude of rainfall that causes CSOs, estimated CSO volumes, and potential control points. A hydraulic model may be useful in conducting the analysis.

## 3.2 CHARACTERIZATION OF COMBINED SEWAGE AND CSOS

### 3.2.1 Historical Data Review

As part of the initial system characterization, the permittee should review existing data to determine the pollutant characteristics of combined sewage during both dry and wet weather conditions, and, if possible, CSO pollutant loadings to the receiving water. The purpose of this effort is to identify pollutants of concern in CSOs, their concentrations, and where possible, likely sources of such pollutants. Together, these assessments will support decisions on what pollutants should be monitored and where. This is discussed in detail in Chapter 4.

The POTW's records can provide influent pollutant and flow data for both dry weather and wet weather conditions. Such data can be analyzed to answer questions like:

- How do the influent volume, loads, and concentrations at the plant change during wet weather?
- What is the average concentration of parameters such as solids, BOD, and metals at the plant during wet weather flow?
- Which pollutants are discharged by industrial users, particularly significant industrial users?

For example, data analysis could include plotting a plant inflow time series by storm(s) and comparing it to a rainfall time series plot for the same storm(s). In some cases, the permittee may also be able to use POTW data to identify which portions of the CSS are contributing significant pollutant loadings.

Potential sources of information for this analysis include:

- General treatment plant operating data
- POTW discharge monitoring reports (DMRs)
- Treatment plant optimization studies
- Special studies done as part of an NPDES permit application
- Pretreatment program data
- Collection system data gathered during NMC implementation
- Existing wet weather CSS sampling and analyses
- Facilities plans and designs.

The permittee can potentially use national or regional storm water data (e.g., Nationwide Urban Runoff Program (NURP) data[1]) (US. EPA, 1983a) to supplement its available data, although more recent localized data are preferred. If approximate CSS flow volumes are known, approximate CSS pollutant loads can be estimated using POTW data, CSS flow volume, and assumed storm water concentration values. However, assumed constant or event mean concentration values for storm water concentrations, such as NURP data, should be used with some reservation for CSOs since concentrations vary during a storm and from storm to storm.

In order to obtain recent and reliable characterization data, the permittee may need to conduct limited sampling at locations within the CSS as well as at selected CSO outfalls as part of the initial system characterization. Since this limited sampling is usually less cost-effective than sampling done as part of the overall monitoring program, the permittee should fully evaluate the need for such data as part of the initial characterization. Chapter 5 provides details on CSS monitoring procedures.

### 3.2.2 Mapping

The permittee should plot existing pollutant characterization data on the study map for points within the CSS as well as for CSO outfalls. This will highlight areas where no data exist and areas with high concentrations of pollutants.

## 3.3 CHARACTERIZATION OF RECEIVING WATERS

### 3.3.1 Historical Data Review

The third part of the initial system characterization is to establish the status of each receiving water body impacted by CSOs. Using existing data and information and working with the NPDES and water quality standards (WQS) authorities, the permittee should attempt to answer the following types of questions:

[1] Some NURP data may no longer be useful due to changed conditions (e.g., lead data might not apply since control programs have been in place for many years). The permittee should contact the permitting authority to determine the applicability of NURP data.

- Does the receiving water body contain sensitive areas (as defined by the CSO Control Policy)?

- What are the applicable WQS? Is the receiving water body currently attaining WQS, including designated uses?

- Are there particular problems in the receiving water body attributable wholly or in part to CSOs?

- What are the hydraulic characteristics of the receiving water body (e.g., average flow, tidal characteristics, instream flow regulations for dams and withdrawals)?

- What other dry and wet weather sources of pollutants in the watershed are discharging to the receiving water body? What quantity of pollutants is being discharged by these sources?

- What is the receiving water quality upstream of the CSO outfalls?

- What are the ecologic and aesthetic conditions of the receiving water body?

The following types of receiving water data will help answer these questions:

- Applicable State WQS
- USGS and other flow data (including tide charts)
- Physiographic and bathymetric data
- Water quality data
- Sediment data
- Fisheries data
- Biomonitoring results
- Ecologic data (habitat, species diversity)
- Operational data (hydropower records).

The permittee may already have collected receiving water data as part of other programs or studies. For example, the NPDES permit may require sampling upstream and downstream of the treatment plant outfall or the permittee may have performed special receiving water studies as part of its NPDES permit reissuance process. Receiving water data may also be obtained through consultation with the NPDES permitting authority, EPA Regional staff, State WQS personnel, and State watershed personnel. The CWA requires States to generate and maintain data on certain water bodies within their jurisdictions.

The following reports may provide information useful for characterizing a receiving water body:

- ***State 303(d) Lists-*** Under CWA section 303(d), States and authorized Tribes identify, and establish total maximum daily loads (TMDLs) for, all waters that do not meet WQS even after implementation of technology-based effluent limitations and any more stringent effluent limitations or other pollution control requirements.[2]

- ***State 304(l) Lists-*** CWA section 304(l) required States to identify surface waters adversely affected by toxic and conventional pollutants from point and non-point sources, with priority given to waters adversely affected by point sources of toxic pollutants.[3] This one-time effort was completed in 1990. EPA recommends that the permittee discuss with the permitting authority data on toxic "hot spots" identified under this requirement.

- ***State 305(b) Reports-*** Under CWA section 305(b), States must submit a water quality assessment report to EPA every two years.

- ***Section 319 State Assessment Reports-*** Under CWA section 319, States were required to identify surface waters adversely affected by nonpoint sources of pollution, in a one-time effort following enactment of the 1987 CWA Amendments.

Generally, permittees may retrieve this information at EPA or State offices, EPA's Storage and Retrieval of U.S. Waterways Parametric Data (STORET) system, EPA's Water Quality System resident within STORET, or EPA's Water Body System (WBS). Since these data bases might not include the particular water bodies being evaluated, the permittee should contact State officials prior to seeking the data.

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[2] EPA recommends that the permittee discuss with the permitting authority the status of existing TMDL reports and the schedule for doing new TMDLs for the CSO-impacted receiving water bodies.

[3] These lists are not complete for some locations, so the lists should be discussed with State WQS staff before they are used extensively.

In addition, studies conducted under enforcement actions, new permitting actions, and special programs and initiatives may provide relevant data on receiving water flow, quality, and uses. BASINS (Better Assessment Science Integrating Point and Nonpoint Sources) contains water quality monitoring data and data on point sources and land use (US. EPA, 1997a). EPA's EMAP (Environmental Monitoring and Assessment Program) contains data on a limited number of receiving waters and the EMAP Internet site (http://www.epa.gov/emap/) provides links to other sources of environmental data (including STORET). EPA and State personnel may have information on studies conducted by other Federal organizations, such as the U.S. Fish and Wildlife Service, the U.S. Army Corps of Engineers, USGS, and the National Biological Service, and other organizations such as The Nature Conservancy and formalized volunteer groups. For example, USGS's National Water-Quality Assessment (NAWQA) Program contains water quality information on 60 U.S. river basins and aquifers.[4] The permittee may save considerable time and expense by consulting directly with these entities during the initial system characterization.

The receiving water characterization should also include an evaluation of whether CSOs discharge to sensitive areas, which are a high priority under the CSO Control Policy.[5] The LTCP should prohibit new or significantly increased overflows to sensitive areas and eliminate or relocate such overflows wherever physically possible and economically achievable. (This is discussed in more detail in *Combined Sewer Overflows - Guidance for Long-Term Control Plan,* U.S. EPA, 1995a). The permittee should work with the NPDES permitting authority, the U.S. Fish and Wildlife Service, and relevant State agencies to determine whether particular receiving water segments may be considered sensitive under the CSO Control Policy.

In addition to reviewing existing data, the permittee may wish to conduct an observational study of the receiving water body, noting differences in depth or width, tributaries, circulation (for

[4] Information on the NAWQA program is available from USGS (703-648-5716) and the USGS Internet site (http://wwwrvares.er.usgs.gov/nawqa/).

[5] Sensitive areas, as discussed in the CSO Policy, are defined by the NPDES authority but include Outstanding National Resource Waters, National Marine Sanctuaries, waters with threatened or endangered species and their habitat, waters with primary contact recreation, public drinking water intakes or their designated protection areas, and shellfish beds.

estuaries), point sources, suspected nonpoint sources, plant growth, riparian zones, and other noticeable features. This information can be used later to define segments for a receiving water model.

To supplement the observational study, the permittee may consider limited chemical or biological sampling of the receiving water. Biocriteria or indices may be used in States such as Ohio that have systems in place. Biocriteria describe the biological integrity of aquatic communities in unimpaired waters for a particular designated aquatic life use. Biocriteria can be numerical values or narrative conditions and serve as a reference point since biological communities in the unimpaired waters represent the best attainable conditions (U.S. EPA, 1991 a). A limitation of biocriteria is that they normally do not take into account wet weather conditions unique to urban streams, such as runoff from highly impervious areas.

### 3.3.2 Mapping

The permittee should plot existing receiving water characterization data on the study map. This will permit visual identification of areas for which no data exist, potential areas of concern, and potential monitoring locations. GIS mapping can be used as an aid in this process. In addition to the elements listed in Section 3.1.2 and 3.2.2, the map could include the following:

- WQS classifications for receiving waters at discharge locations and for upstream and downstream reaches, and an indication of whether receiving waters are tidal or non-tidal
- Location of sensitive areas such as downstream beaches, other public access areas, drinking water intakes, endangered species habitats, sensitive biological populations or habitats, and shellfishing areas
- Locations of structures, such as weirs and dams, that can affect pollutant concentrations in the receiving water
- Locations of access points, such as bridges, dams, and existing monitoring stations (such as USGS stations), that make convenient sampling sites.

## 3.4 IDENTIFY DATA GAPS

The final task in the initial system characterization is to identify gaps in information that is essential to a basic understanding of the CSS's response to rain events and the impact of CSOs on the receiving water. The following questions may help to identify data gaps that need to be addressed in the monitoring and modeling plan:

### Physical Characterization of CSS

- Have all CSO outfalls been identified? (Has the permittee taken all reasonable steps to identify outfalls-e.g., reviewing maps, conducting inspections, looking at citizen complaints?)
- Are the drainage sub-areas delineated for each CSO outfall?
- Is sufficient information on the location, size, and characteristics of the sewers available to support more complex analysis, including hydraulic modeling (as needed)?
- Is sufficient information on the location, operation, and condition of regulating structures available to construct at least a basic hydraulic simulation? (Even if a hydraulic computer model is not used, this level of knowledge is critical to understanding how the system works and for implementing the NMC.)
- Are the minimum amount of rainfall and minimum rainfall intensity that cause CSOs at various outfalls known?
- Are the areas of chronic surcharging in the CSS known?
- Have potential monitoring locations in the CSS been identified?
- Are there differences between POTW wet weather and dry weather operations? If so, are these clearly understood? (Improved wet weather operation can increase capture of CSS flows significantly.)

### Characterization of Combined Sewage and CSOs

- Are the flow and pollutant concentrations of CSOs for a range of storm conditions known?
- Are the sources of CSS pollutants known?

- Is sufficient information available on pollutant loadings from CSOs and other sources to support an evaluation of long-term CSO control alternatives?

**Characterization of Receiving Waters**

- Are the hydraulic characteristics of receiving waters known, such as the average/ maximum/minimum (7Q10) flow of rivers and streams or the freshwater component, circulation patterns, and mixing characteristics of estuaries?

- Are locations of sensitive areas and designated uses identified on a study map?

- Have existing monitoring locations in the receiving water been identified? Have potential monitoring locations (e.g., safe, accessible points) in the receiving water been identified for areas of concern and areas where no data exist?

- Are sufficient data available to assess existing water quality problems and the potential for future water quality problems, including information on:

  - Streambank erosion
  - Sediment accumulation
  - Dissolved oxygen levels
  - Bacterial problems, such as those leading to beach closures
  - Toxicity (metals)
  - Nuisance algal or aquatic plant growths
  - Damage to a fishery (e.g., shellfish beds)
  - Damage to a biological community (e.g., benthic organisms)
  - Floatables or other aesthetic concerns?

- Is sufficient information available on natural background conditions that may preclude the attainment of WQS? (For example, a stream segment with a high natural organic load may have a naturally low dissolved oxygen level.)

- Is sufficient information available on other pollutant sources (e.g., agricultural sources, other nonpoint sources, and municipal and industrial point sources, including those upstream) that may preclude the attainment of WQS?

The answers to these types of questions will support the development of goals and objectives for the monitoring plan, as described in Chapter 4.

# CHAPTER 4

# MONITORING AND MODELING PLAN

Under the CSO Control Policy, the permittee should begin immediately to characterize its combined sewer system (CSS), document implementation of the nine minimum controls (NMC), and develop a long-term control plan (LTCP). The NMC and the LTCP both contain elements that involve monitoring and modeling activities. The NMC include monitoring to characterize CSO impacts and the efficacy of CSO controls, while the LTCP includes elements for characterization, monitoring, and modeling of the CSS and receiving waters, evaluation and selection of CSO control alternatives, and development of a post-construction monitoring program. As discussed in Chapters 2 and 3, "monitoring" as part of the NMC involves gathering and analyzing existing data and performing field investigations, but does not generally involve sampling or the use of complex models. Thus the monitoring and modeling elements discussed in this chapter and subsequent chapters primarily pertain to LTCP development and implementation.

The NPDES permit is likely to contain requirements for monitoring necessary to develop and implement an LTCP. In many cases, the permit will first require the permittee to submit a monitoring and modeling plan. For example, the Phase I permit may require submission of a monitoring and modeling plan as an interim deliverable during LTCP development.

A well-developed monitoring and modeling plan is essential throughout the CSO planning process to provide useful monitoring data for system characterization, evaluation and selection of control alternatives, and post-construction compliance monitoring. Development of the plan is likely to be an iterative process, with changes made as more knowledge about the CSS and CSOs is gained. The permittee should aggressively seek to involve the NPDES permitting authority, as well as State water quality standards (WQS) personnel, State watershed personnel, and EPA Regional staff, throughout this process.

This chapter describes how the permittee can develop a monitoring and modeling plan that provides essential and accurate information about the CSS and CSOs, and the impact of CSOs on the receiving water. The chapter discusses the identification of monitoring and modeling goals and objectives and the development of a monitoring and modeling plan to achieve those goals and objectives. It provides detailed discussions and examples on identifying sampling locations, frequencies, and parameters to be assessed. In addition, it briefly discusses certain monitoring and modeling plan elements that are common to all system components being monitored. Readers should consult the appropriate EPA guidance documents (see References) for further information on topics such as chain-of-custody, sample handling, equipment, resources, and quality assurance/quality control (QA/QC) procedures.

## 4.1 DEVELOPMENT OF A MONITORING AND MODELING PLAN

A monitoring and modeling plan can be developed with the following steps:

***Step 1: Define the short- and long-term objectives*** - In order to identify wet weather impacts and make sound decisions on CSO controls, the permittee should first formulate the short- and long-term objectives of the monitoring and modeling effort. Every activity proposed in the plan should contribute to attaining those objectives. (Step 1 is discussed in Section 4.1.1.)

***Step 2: Decide whether to*** use ***a model*** - The permittee should decide whether to use a model during LTCP development (and, if so, which model to use). This decision should be based on site-specific considerations (e.g., CSS characteristics and complexity, type of receiving water) and the information compiled in the initial system characterization. If a permittee decides to use a model, the monitoring and modeling plan should include a modeling strategy. (Section 4.1.2)

***Step 3: Identify data needed*** - The permittee should identify the monitoring data needed to meet the goals and objectives. If modeling is planned, the monitoring plan should include any additional data needed for model inputs. (Section 4.1.3)

***Step 4: Identify sampling criteria (e.g., locations, frequency)*** - The permittee should identify monitoring locations within the CSS, which CSOs to monitor, and sampling points within the receiving water body. The permittee must also determine the frequency and duration of sampling, parameters to be sampled, appropriate sample types to be collected (e.g., grab, composite), and proper sample handling and preservation procedures. If a model will be used, the monitoring plan should include any additional sampling locations, sample types, and parameters necessary to adequately support the proposed model. If this is not feasible, the permittee may need to reevaluate the model choice and select a different or less-complex model. (Sections 4.2 to 4.7)

***Step 5: Develop data management and analysis procedures*** - A monitoring and modeling plan also needs to specify QA/QC procedures and a data management program to facilitate storage, use, and analysis of the data. (Section 4.8)

***Step 6: Address implementation issues*** - Finally, the monitoring and modeling plan should address implementation issues, such as record keeping and reporting, responsible personnel, scheduling, and the equipment and resources necessary to accomplish the monitoring and modeling. (Section 4.9)

These steps are described in detail in the remainder of this chapter.

### 4.1.1 Goals and Objectives

The ultimate goal of a CSO control program is to implement cost-effective controls to reduce water quality impacts from CSOs and provide for compliance with CWA requirements, including attainment of WQS. Monitoring and modeling will foster attainment of this goal by generating data to support decisions for selecting CSO controls. The monitoring and modeling plan should identify how data will be collected and used to meet the following goals:

- Define the CSS's hydraulic response to rainfall.
  - What level of rainfall causes CSOs?
  - Where do the CSOs occur?
  - How long do CSOs last?
  - Which structures or facilities limit the hydraulic capacity of the CSS?

- Determine CSO flows and pollutant concentrations/loadings.

  - What volume of flow is discharged?
  - What pollutants are discharged?
  - Do the flows and concentrations of pollutants vary greatly from event to event and outfall to outfall?
  - How do pollutant concentrations and loadings vary within a storm event?

- Evaluate the impacts of CSOs on receiving water quality.

  - What is the baseline quality of the receiving water?
  - What are the upstream background pollutant concentrations?
  - What are the impacts of CSOs? Are applicable WQS being met?
  - What is the contribution of pollutant loadings from other sources?
  - Is biological, sediment, or whole effluent toxicity testing necessary?

- Support model input, calibration, and verification.

- Support the review and revision, as appropriate, of WQS.

  - What data are needed to support a use attainability analysis?
  - What data are needed to support potential revision of WQS to reflect wet weather conditions?

- Evaluate the effectiveness of the NMC.

  - Have any dry weather overflows been eliminated?
  - Has wet weather flow to the POTW increased (if additional plant capacity was available)?
  - Has the level of rainfall needed to cause CSOs increased?

- Evaluate and select long-term CSO control alternatives.

  - What improvements in water quality will result from proposed CSO control alternatives in the LTCP?
  - How will the CSS hydraulics and CSO frequency and duration change under various control alternatives?
  - What is the best combination of control technologies across the system?
  - Can CSO flows to sensitive areas be eliminated? If not, can they be relocated to less sensitive areas?

In addition to selecting and implementing long-term CSO controls, the permittee will also be required to develop and implement a post-construction compliance monitoring program. For this type of monitoring program, the goal will typically be to:

- Evaluate the effectiveness of the long-term CSO controls.
  - Are applicable WQS being met?
  - How much water quality improvement do environmental indicators show?
  - Do the measures of success (see Section 2.3) indicate reductions in CSOs and their effects?

Besides the broad goals, a municipality may have some site-specific objectives for its monitoring program. For example, a permittee that is considering sewer separation as a CSO control alternative may wish to assess the likely impacts of increased storm water loads on receiving waters.

The permittee should distinguish between short-term and long-term monitoring objectives. Determining the length of short-term and long-term planning horizons will depend in part on how much CSO control is already in place.

### 4.1.2 Modeling Strategy

In developing a monitoring and modeling plan, the permittee should consider up front whether to use modeling. If a permittee has a relatively simple system with a limited number of outfalls, the use of flow balance diagrams and similar analyses may be sufficient and modeling may not be necessary. For more complex systems, modeling can help characterize and predict:

- Sewer system response to wet weather
- Pollutant loading to receiving waters
- Impacts within the receiving waters
- Relative impacts attributable to CSOs and other pollutant sources.

Modeling also assists in formulating and testing the cause-effect relationships between wet weather events and receiving water impacts. This knowledge can help the permittee evaluate control alternatives and formulate an acceptable LTCP. Modeling enables the permittee to predict the effectiveness of a range of potential control alternatives. By assessing the expected outcomes of control alternatives before their implementation, the permittee can make more cost-effective decisions. Modeling results may also be relevant to reviewing and revising State WQS. Since the use of a model and its level of complexity affect the need for monitoring data, the permittee should determine early on whether modeling is needed to provide sufficient information for making CSO control decisions.

Once a model is calibrated and verified, it can be used to:

- Predict CSO occurrence, volume, and in some cases, pollutant characteristics, for rain events other than those that occurred during the monitoring phase. These can include a storm event of large magnitude (with a long recurrence period) or numerous storm events over an extended period of time.

- Predict the wet weather performance of portions of the CSS that have not been monitored extensively.

- Develop CSO statistics such as annual number of CSOs and percent of combined sewage captured (particularly useful for municipalities pursuing the presumption approach under the CSO Control Policy).

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

- Evaluate and optimize control alternatives, from simple controls described under the NMC (such as raising weir heights to increase in-line storage) to more complex controls proposed in the LTCP. The model can be used to evaluate the resulting reductions in CSO volume and frequency.

- To predict the number and duration of WQS exceedances in areas of interest (such as beaches or other sensitive areas).

- To evaluate water quality improvements likely to result from implementation of different CSO controls or combinations of CSO controls.

If the permittee decides to model, the monitoring and modeling plan should include a modeling strategy. There are several considerations in developing an appropriate modeling strategy:

- ***Meeting the expectations of the CSO Policy-*** The focus of modeling depends in part on whether the permittee adopts the presumption or demonstration approach under the CSO Policy. For some communities, the demonstration approach can necessitate detailed simulation of receiving water impacts to show that CWA requirements will be met under selected CSO control measures. The presumption approach may not involve as much receiving water modeling since it presumes that CWA requirements are met based on certain performance criteria, such as the maximum number of CSO events or the percent capture of flows entering the system during a wet weather event.

- ***Successfully simulating the physical characteristics of the CSS, pollutants, and receiving waters under study-*** Models should be chosen to simulate the physical and hydraulic characteristics of the CSS and the receiving water body, characteristics of the pollutants of concern, and the time and distance scales necessary to evaluate attainment of WQS. Receiving waters should be modeled whenever there is significant uncertainty over the importance of CSO loads as compared to other sources. A model's governing equations and boundary conditions should match the characteristics of the CSS, receiving water body, and pollutant fate and transport processes under study. A model does not necessarily need to describe the system completely in order to analyze CSO events satisfactorily. Different modeling strategies will be necessary for the different physical domains being modeled: overland storm flow, pollutant buildup/washoff, and transport to the collection system; transport within the CSS to the POTW, storage facility, or CSO; and dilution and transport in receiving waters. In most cases, simulation models appropriate for the sewer system also address pollutant buildup/washoff and overland flow. Receiving water models are typically separate from the storm water/sewer models, although in some cases compatible interfaces are available.

- ***Meeting information needs at optimal cost-*** The modeling strategy should identify modeling activities that provide answers as detailed and accurate as needed at the lowest corresponding expense and effort. Since more detailed, accurate models are more difficult and expensive to use, the permittee needs to identify the point at which an increased modeling effort would provide diminishing returns. The permittee may use an incremental approach, initially using simple screening models with limited data. These results may then lead to refinements in the monitoring and modeling plan so that the appropriate data are generated for more detailed modeling. Another option is to use a simpler CSS model for the whole system and selectively apply a more complex sewer model to portions of the system to answer specific design questions.

More detailed discussions on modeling, including model selection, development, and application, are included in Chapters 7 (CSS Modeling) and 8 (Receiving Water Modeling).

### 4.1.3 Monitoring Data Needs

The monitoring effort necessary to address each goal will depend on a number of factors: the layout of the collection system; the quantity, quality, and variability of the existing historical data and the necessary additional data; whether modeling will be done and, if so, the complexity of the selected model; and the available budget. In some cases, the initial characterization will yield sufficient historical data so that only limited additional monitoring will be necessary. In other cases, considerable effort may be necessary to fully investigate the characteristics of the CSS, CSOs, and receiving waters. Some municipalities may choose to allocate a relatively large portion of the available budget to monitoring, while others may allocate less. Because data needs may change as additional knowledge is obtained, the monitoring program must be a dynamic program that evolves to reflect any changes in data needs.

In identifying goals and objectives, developing a modeling strategy, and identifying monitoring data needs, the permittee should work with the team that will be reviewing NMC implementation and LTCP development and implementation (e.g., NPDES permitting authorities, State WQS authorities, and State watershed personnel). This coordination should begin in the initial planning stages so that appropriate goals and objectives are identified and effective monitoring and modeling approaches to meet these goals and objectives are developed. Concurrence among the review team participants during the planning stages should ensure design of a monitoring and modeling plan that will support sound CSO control program decisions. The proposed plan should be submitted to the review team and modified as necessary. The permittee should also coordinate the monitoring and modeling plan with other Federal and State agencies, and with other point source dischargers, especially for effects on watersheds and ambient receiving waters.

## 4.2 ELEMENTS OF A MONITORING AND MODELING PLAN

In addition to identifying the goals and objectives, the monitoring and modeling plan should generally contain the following major elements:

- Review of Existing Data and Information (discussed in Chapter 3)
  - Summary of existing data and information
  - Determination of how existing data meet goals and objectives
  - Identification of data gaps and deficiencies
- Development of Sampling Program to Address Data Needs (discussed in Chapters 4-6)
  - Duration of monitoring program
  - Monitoring locations
  - Frequency of sampling and number of wet weather events to be sampled
  - Criteria for when the samples will be taken (e.g., greater than x days between events, rainfall events greater than 0.4 inches to be sampled)
  - Strategy for determining when to initiate wet weather monitoring
  - Sampling protocols (e.g., sample types, sample containers, preservation methods)
  - Flow measurement protocols
  - Pollutants or parameters to be analyzed and/or recorded
  - Sampling and safety equipment and personnel
  - QA/QC procedures for sampling and analysis
  - Procedures for validating, tracking, and reporting sampling results
- Discussion of Methods for Data Management and Analyses (discussed in Chapters 4-9)
  - Data management (e.g., type of data base)
  - Statistical methods for data analysis
  - Modeling strategy, including model(s) selected (discussed in Chapters 7 and 8)
  - Use of data to support NMC implementation and LTCP development
- Implementation Plan (discussed in Section 4.9, and Chapters 5 and 6)
  - Recordkeeping and reporting
  - Personnel responsible for implementation
  - Scheduling
  - Resources (funding, personnel, and equipment)
  - Health and safety issues.

The checklists in Appendix A, Tables A-l and A-2 list items that should be addressed in formulating a monitoring program. Elements in the first checklist should be part of any monitoring program and cover seven major areas: sample and field data collection, laboratory analysis, data management, data analysis, reporting, information use, and general. The second checklist applies specifically to CSO monitoring and covers three areas: mapping of the CSS and identification of monitoring locations, monitoring of CSO volume, and monitoring of CSO quality.

As noted earlier, development of a monitoring and modeling plan is generally an iterative process. The permittee should update the plan as a result of feedback from the NPDES permitting authority and the rest of the CSO planning team, and as more knowledge about the CSS and CSOs is gained.

Because each permittee's CSS, CSOs, and receiving water body are unique, it is not possible to recommend a generic, "one-size-fits-all" monitoring and modeling plan in this document. Rather, each permittee should design a cost-effective monitoring and modeling plan tailored to local conditions and reflecting the size of the CSS, the impacts of CSOs, and whether modeling will be performed. It should balance the costs of monitoring against the amount of data and information needed to develop, implement, and verify the effectiveness of CSO controls.

While a monitoring and modeling budget may initially seem large, it is often a small percentage of the total cost of CSO control. Each municipality should balance the cost of monitoring and modeling against the risk of developing ineffective or unnecessary CSO controls based on insufficient or inaccurate data. The information obtained from additional monitoring and modeling may very well be offset by the reduction in total CSO costs.

### 4.2.1 Duration of Monitoring Program

The duration of the monitoring program will vary from location to location and reflect the number of storm events needed to provide the data for calibrating and validating the CSS hydraulic model (if a model is used), and evaluating CSO control alternatives and receiving water impacts.

During that period (which generally may be a season or several months), the permittee should monitor storms of varying intensity, antecedent dry days, and total volume to ensure that calculations and models represent the range of conditions experienced by the CSS.

The monitoring program should span enough storm events to enable the permittee to fully understand the pollutant loads from CSOs, including the means and variations of pollutant concentrations and the resulting effects on receiving water quality. If the permittee monitors only a few storm events, the analysis should include appropriately conservative assumptions because of the uncertainty associated with small sample sizes. For example, if monitoring data are collected from a few storms during spring, when CSOs are generally larger and more frequent, mean pollutant concentrations may be lower due to dilution from snowmelt and heavier rainfall and diminished first-flush effects. When monitoring data are collected for additional storms, including those in the summer and fall when CSOs are less frequent, the mean pollution concentrations may increase significantly. Additional samples should reduce the level of uncertainty and allow the use of a smaller margin of safety in the analysis.

The value of additional monitoring diminishes when additional data would result in a limited change in the estimated mean and variance of a data set. The permittee should assess the value of additional data as they are collected by reviewing how the estimated mean and variance of contaminant concentrations changes over time. If estimated values stabilize (i.e., the mean and variance show almost no change as additional monitoring results are added to the data set), the need for additional data should be reassessed.

Pollutant loadings vary according to the number of days since the last storm and the intensity of previous rainfalls. Therefore, to better represent the variability of actual conditions, the monitoring program should be designed to sample storms with a variety of pre-storm conditions.

### 4.2.2 Sampling Protocols and Analytical Methods

The monitoring and modeling plan should describe the sampling and analytical procedures that will be used. Sample types depend on the parameter, site conditions, and the intended use of the data. Flow-weighted composites may be most appropriate for determining average loadings of pollutants to the receiving stream. Grab samples may suffice if only approximate pollutant levels are needed or if worst-case conditions (e.g., first 15 or 30 minutes of overflow) are being assessed. In addition, grab samples should be collected for pollutant parameters that cannot be cornposited, such as oil and grease, pH, and bacteria. The monitoring plan should follow the sampling and analytical procedures in 40 CFR Part 136, including the use of appropriate sample containers, sample preservation methods, maximum allowable holding times, and analytical methods referencing one or more of the following:

- Approved methods referenced in 40 CFR 136.3, Tables 1A through 1E
- Test methods in Appendix A to 40 CFR Part 136 (Methods for Organic Chemical Analysis of Municipal and Industrial Wastewater)
- Standard Methods for the Analysis of Water and Wastewater (use the most current, EPA-approved edition)
- Methods for the Chemical Analysis of Water and Wastes (U.S. EPA, 1979. EPA 600/4-79-020).

In some cases, other well-documented analytical protocols may be more appropriate for assessing in-stream parameters. For example, in estuarine areas, a protocol from NOAA's Status and Trends Program may provide better accuracy and precision if it reduces saltwater interferences.

These issues are discussed in further detail in Section 5.4.1.

## 4.3 CSS AND CSO MONITORING

To satisfy the objectives of the CSO Control Policy, the monitoring and modeling plan should specify how the CSS and CSOs will be monitored, including monitoring locations, frequencies, and pollutant parameters. The plan should be coordinated with other concurrent sampling efforts (e.g., ongoing State water quality monitoring programs) to reduce sampling and monitoring costs and maximize use of available resources. Careful selection of monitoring locations can minimize the number of monitors and monitoring stations needed.

### 4.3.1 CSS and CSO Monitoring Locations

The monitoring and modeling plan should specify how rainfall data, flow data, and pollutant data will be collected to define the CSS's hydraulic response to wet weather events and to measure CSO flows and pollutant loadings. The monitoring program should also provide background data on conditions in the CSS during dry weather conditions, if this information is not already available (see Chapter 3). Dry weather monitoring of the CSS may help identify pollutants of concern in CSOs during wet weather.

**Rainfall Gage Locations**

The permittee should ascertain whether additional rainfall data are necessary to supplement existing data. In general, rainfall should be monitored if CSO flow and quality are being measured since areas often do not have routine rainfall monitoring data of sufficient detail. In such cases the monitoring and modeling plan should identify where rain gages will be placed to provide data representative of the entire CSS drainage area. Gages should be spaced closely enough that location variation in storm tracking and storm intensity does not result in large errors in estimation of the rainfall within the CSS area.

Recommended spacing is the subject of a variety of research papers. The *CSO Pollution Abatement Manual of Practice* (WPCF, 1989) provides the following summary of recommendations on rain gage spacing:

> *"In Canada, rainfall and collection system modelers recommend one gauge every 1 or 2 kilometers. In Britain, the Water Research Center has recommended only half that density, or one gauge every 2 to 5 kilometers. In the United States current spacing recommendations are related to thunderstorm size. The average thunderstorm is 6 to 8 kilometers in diameter,.. Therefore rain gauges are frequently spaced every 6 to 8 kilometers . . . "*

For small watersheds, rain gages may need to be placed more closely than every 6 to 8 kilometers so that sufficient data are available for analysis and model calibration. The monitoring and modeling plan should document the rationale for rain gage spacing. Additional gages can provide valuable information for CSS analysis and modeling and are usually a relatively inexpensive investment.

**CSS Monitoring Locations**

The monitoring and modeling plan will need to identify where in the collection system flow and pollutant loading data will be collected. To predict the likelihood and locations of CSOs during wet weather, it is necessary to assess general flow patterns and volume in the CSS and identify which structures tend to limit the hydraulic capacity. This may require sampling along various trunk lines of the collection system. Flow data from existing monitors and operating records for hydraulic controls such as pump stations and POTW headworks can also be used. Some calculations may be necessary to obtain flow data. For example, pump station operating records may consist of pump run times and capacities, which can be used to calculate flow.

To obtain complete flow and pollutant loading data, the plan should also target portions of the collection system that are likely to receive significant pollutant loadings. The plan should identify locations where industrial users discharge into the collection system, and specify any additional monitoring that will be conducted to supplement data collected through the industrial pretreatment program. The plan should give special consideration to these areas when they are located near CSO outfalls. Section 4.3.3 discusses the types of pollutants to be monitored.

**CSO Monitoring Locations**

The monitoring and modeling plan should provide for flow and pollutant monitoring for a representative range of land uses and basin sizes and at as many CSO outfalls as possible. Small systems may be able to monitor all outfalls for each storm event studied, but large systems may need a tiered approach in which only outfalls with higher flows or pollutant loadings receive the full range of measurements. Discharges to sensitive areas would warrant continuous flow monitoring and the use of composite samples for chemical analyses. Lower-priority outfalls, meanwhile, would be monitored with simpler techniques such as visual observation, block tests, depth measurement, overflow timers, or chalk boards (discussed in section 3.1.3) and limited chemical analyses. When several outfalls are located along the same interceptor, flow monitoring of selected outfalls and at one or two locations in the interceptor should suffice.

Even if a monitoring program accounts for most of the total land area or estimated runoff, monitoring other outfall locations, even with simple techniques, can provide information about problem areas. For example, at an overflow point with only 10 percent of the contributing drainage area, a malfunctioning regulator may result in discharges during dry weather or during small storms when the interceptor has remaining capacity. As a result, this overflow point may become a major contributor of flows. A simple technique such as a block test could identify this problem.

Alternatively, flow measurement equipment can be rotated between locations so that some locations are monitored for a subset of the storms studied. For example, during one storm the permittee could monitor critical outfalls with automated flow monitoring equipment, two less-important outfalls with portable flow meters, and the others using chalk boards. During a second storm, the permittee could still monitor critical outfalls with automated flow equipment but rotate the portable flow meters to two other outfalls of secondary importance. However, since variability is usually greater from storm to storm than from site to site, it is generally preferable to measure more storms at a set of representative sampling sites than to rotate between all CSO locations.

If it is not feasible to monitor all outfalls, the permittee should identify a specific percentage of the outfalls to be monitored based on the size of the collection system, the total number of outfalls, the number of different receiving water bodies, and potential and known impacts. The selected locations should represent the system as a whole or represent the worst-case scenario (for example, where overflows occur most frequently, have the largest pollutant loading or flow volume, or discharge to sensitive areas). If a representative set of CSO locations is selected for monitoring, the results can be more easily extrapolated to non-monitored areas in the system.

In general, monitoring locations should be distributed to achieve optimal coverage of actual overflows with a minimum number of stations. The initial system characterization should have already provided information useful in selecting and prioritizing monitoring locations, such as:

- ***Drainage Area Flow Contribution-*** The relative flow contributions from different drainage areas can be used to prioritize flow and pollutant monitoring efforts. There are several methods for estimating relative flow contributions. The land area of each outfall's sub-basin provides only an approximate estimate of the relative flow contribution because regulator operation and land use characteristics affect overflow volume. Other estimation methods, such as the rational method[1], account for the runoff characteristics of the upstream land area and produce relative peak flows of individual drainage areas. Flow estimation using Manning's equation (see Section 5.3.1) may produce a better estimate of the relative flow contribution by drainage area.

- ***Land Use-*** During the initial sampling effort, the permittee should estimate the relative contribution of pollutant loadings from individual drainage areas. Maps developed during the initial system characterization should provide land use information that can be used to derive pollutant concentrations for the different land uses from localized data bases (based on measurements in the CSS). If local data are not available, the permittee may use regional land use-based National Urban Runoff Program (NURP) studies, although NURP data reflect only storm water and must be adjusted for the presence of sanitary sewage flows and industrial wastewater. Pollutant concentration and drainage area flow data can then be used to estimate loadings. Since pollutant concentrations can vary greatly for different land uses, monitoring locations should represent subdivisions of the drainage area with differing land uses.

[1] The rational method is described in Schwab, et al., 1981.

- ***Location of Sensitive Areas-*** Since the LTCP should give the highest priority to controlling overflows to sensitive areas, the monitoring and modeling plan should identify locations where CSOs to sensitive areas, and their impacts, will be monitored.

- ***Feasibility and Safety of Using the Location-*** After using the above criteria to identify which outfalls will provide the most useful data, the permittee should determine whether the locations are safe and accessible and identify which safety precautions are necessary. If it is not feasible or practical to monitor at the point of discharge, the permittee should select the closest upstream or downstream location that is still representative of the overflow.

Example 4-1 illustrates one approach to selecting discharge monitoring sites for a hypothetical CSS with ten outfalls. The selected outfalls-1, 4, 5, 7, and 9- discharge flow from more than 60 percent of the total drainage area and 70 percent of the industrial area. Outfalls 1 and 5 are adjacent to sensitive areas. These five outfalls should provide sufficient in-depth coverage for the city's monitoring program. Simplified flow and modeling techniques at outfalls 2, 3,6, 8, and 10 can supplement the collected monitoring data and allow estimation of total CSS flow.

*Combined Sewer Overflows - Guidance for Screening and Ranking* (U.S. EPA, 1995c) provides additional guidance on prioritizing monitoring locations. Although generally intended for ranking CSSs with respect to one another, the techniques in this reference may prove useful for ranking outfalls within a single system.

### 4.3.2 Monitoring Frequency

The permittee should monitor a sufficient number of storms to accurately predict the CSS's response to rainfall events and the characteristics of resulting CSOs. The frequency of monitoring should be based on site-specific considerations such as CSO frequency and duration, which depend on the rainfall pattern, antecedent dry period, type of receiving water and circulation pattern or flow, ambient tide or stage of river or stream, and diurnal flow to the treatment plant.

**Example 4-1. One Approach to Selecting Discharge Monitoring Sites for a Hypothetical CSS with 10 Outfalls**

A municipality has a combined sewer area with 4,800 acres and 10 outfalls discharging into a large river. Exhibit 4-1 shows the characteristics of the discharge points that are potentially useful in choosing which intercepting devices to monitor. Investigators used sewer and topographic maps to determine the size of the drainage areas. Aerial photographs and information from a previous study indicated land use. Sewer maps, spot checked in the field, verified the type of regulating structure. The sewer map and discussions with CSS personnel provided information about safety and ease of access.

Outfalls 7 and 9 account for 33 percent of the total drainage area, and monitoring at outfall 7 would provide data on commercial and industrial land uses that may have relatively higher pollutant loadings. These sites pose no safety/accessibility concerns, making them desirable sampling locations.

Outfall 5 discharges in an area that is predominantly residential and includes one of the largest parks in the municipality. This park has many recreational uses, including swimming during the warmer months. Since areas used for primary contact recreation are considered sensitive areas, they are given highest priority in the permittee's LTCP under the CSO Control Policy. This outfall, which accounts for about 10 percent of the drainage area, should be monitored.

Outfall 4, which is served by a pump station, accounts for 8 percent of the discharge area and includes commercial areas. At this outfall, a counter or timer on the pump contacts or the use of full pipe flow measurement devices usually provides an accurate measure of flow.

Outfall 1 discharges near the north edge of town, just before the river curves at its entrance to the municipality. This outfall is located near a portion of the river that serves as a threatened species habitat and therefore is considered a sensitive area. Since sensitive areas should be given the highest priority, this outfall will be monitored. Monitoring this outfall also accounts for 13 percent of the total drainage area and a significant portion of the area with commercial land uses.

In total, these five outfalls account for approximately 64 percent of the drainage area and more than 70 percent of the industrial land use.

The remaining sites pose practical problems for monitoring. Outfall 3 is difficult to access and poses safety concerns. Outfalls 2, 6, 8, and 10 all have backwater effects, and access/safety concerns further limit monitoring opportunities.

- *Outfall 2*- Backwater effects, difficult access rating and safety concerns
- *Outfall 3*- Residential drainage area similar to Outfall 5, but difficult access rating and safety concerns
- *Outfall 6*- Large residential drainage area but backwater effects and access/safety concerns limit monitoring opportunities
- *Outfall 8*- Drainage area small, but includes industrial and commercial land uses. Backwater effects and access/safety concerns limit monitoring opportunities
- *Outfall 10*- Backwater and difficult access limit monitoring opportunities.

## Exhibit 4-1. Data for Example 4-1

| Outfall # | Drainage Area (acres) | Land Use | | | | Flow Regulation Device | | | | Access/ Safety Concerns | Sensitive Area | Potential Monitoring Location |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Residential | Industrial | Commercial | Open/Park | Weir Gravity | Weir Backflow | Orifice Backwater | Pump Station | | | |
| 1 | 695 | 80% | | 20% | | ✓ | | | | | ✓ | Yes |
| 2 | 150 | 50% | 20% | 30% | | | | ✓ | | ✓ | | No |
| 3 | 560 | 75% | | 5% | 20% | ✓ | | | | | | Yes |
| 4 | 430 | 60% | 10% | 30% | | | | | ✓ | | | Yes |
| 5 | 500 | 90% | | | 10% | ✓ | | | | | ✓ | Yes |
| 6 | 800 | 90% | | 10% | | | ✓ | | | ✓ | | No |
| 7 | 690 | 20% | 60% | 20% | | ✓ | | | | | | Yes |
| 8 | 120 | 40% | 50% | 10% | | | ✓ | | | ✓ | | No |
| 9 | 1,060 | 80% | | | 20% | ✓ | | | | | | Yes |
| 10 | 300 | 90% | | | 10% | | | ✓ | | ✓ | | No |
| Total | 5,305 | 71% | 10% | 11% | 8% | | | | | | | |

Monitoring frequency may be targeted to such factors as:

- Wet weather events that result in overflows
- A certain number of precipitation events (e.g., monitor until five storms are sampled-each storm may need to meet a certain minimum size)
- A certain size precipitation event (e.g., 3-month, 24-hour).

A range of storm sizes should be sampled, if possible, to characterize the CSS response for the variety of storm conditions that can occur. These data can be useful for long-term simulations. Section 4.6 discusses a strategy for determining whether to monitor a particular wet weather event. Overall, more frequency monitoring is warranted where:

- CSOs discharge to sensitive or high-quality areas, such as waters with drinking water intakes or swimming, boating, and other recreational activities
- CSO flow volumes per inch of rainfall vary significantly from storm event to storm event.

The number of samples collected will also reflect the type of sample collected. Where possible, the permittee should collect flow-weighted composite samples to determine the average pollutant concentration over a storm event (also known as the event mean concentration or EMC). This approach decreases the analytical cost of a program based on discrete samples. Certain parameters, such as oil and grease and bacteria, however, have limited holding times and must be collected by grab sample (see discussion in Section 5.4.1). Also, when the permittee needs to determine whether a pattern of pollutant concentration, such as a first-flush phenomenon, occurs during storms, the monitoring program should collect several samples from the same locations throughout a storm.

permittee should carefully consider the tradeoffs involved in committing resources to a sampling program. A small number of samples may necessitate more conservative assumptions or result in more uncertain assumptions because of high sample variability. A larger data set might better determine pollutant concentrations and result in a more detailed analysis, enabling the permittee to optimize any investment in long-term CSO controls. On the other hand, a permittee should avoid spending large sums of money on monitoring when the additional data will not significantly enhance the permittee's understanding of CSOs, CSO impacts, and design of CSO controls. The permittee should work closely with the NPDES permitting authority and the review team to design a monitoring program that will adequately characterize the CSS, CSO impacts on the receiving water body, and effectiveness of proposed CSO control alternatives.

### 4.3.3 Combined Sewage and CSO Pollutant Parameters

The monitoring and modeling plan should state how the permittee will determine the concentrations of pollutants carried in the combined sewage and the variability of these concentrations during a storm, from outfall to outfall, and from storm to storm. Pollutant concentration data should be 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 monitoring and modeling plan should identify which parameters will be monitored. These should include pollutants with water quality criteria for the specific designated use(s) of the receiving water. The NPDES permitting authority may have specific guidance regarding parameters for CSO monitoring. Parameters of concern may include:

- Flow (volume and flow rate)
- Indicator bacteria[2]
- Total suspended solids (TSS)

[2] Concentrations of bacteria in CSOs may be fairly consistent over time (around $10^6$ MPN/100 ml for fecal coliform). If sampling yields consistent results over time, the permittee may find that additional bacteria sampling is not informative. Concentration data could be combined with flow data to determine bacteria loadings.

- Biochemical oxygen demand (BOD) and dissolved oxygen (DO)
- pH
- Settleable solids
- Nutrients
- Toxic pollutants reasonably expected to be present in the CSO based on an industrial survey or tributary land use, including metals typically present in storm water, such as zinc, lead, copper, and arsenic (U.S. EPA, 1983a).[3]

The monitoring and modeling plan should also include monitoring for any other pollutants for which water quality criteria are being exceeded, as well as pollutants suspected to be present in the combined sewage and those discharged in significant quantities by industrial users. For example, if the water quality criterion for zinc is being exceeded in the receiving water, zinc should be monitored in the portions of the CSS where industrial users discharge zinc to the collection system. POTW monitoring data and industrial pretreatment program data on nondomestic discharges can help identify other pollutants that should be monitored. In coastal systems, measurements of sodium, chloride, total dissolved solids, or conductivity can be used to detect the presence of sea water in the CSS, which may be the result of intrusion through failed tide gates.

Not all pollutants need to be analyzed for each location sampled. For example:

- A larger list of pollutants should be analyzed for an industrial area suspected to have contaminated storm water or a large load of pollutants in its sanitary sewer.
- Bacteria should be analyzed in a CSO upstream of a beach or drinking water supply with past bacteriological problems, while it may not be necessary to analyze for metals or other toxics.

[3] The permittee should consider sampling both dissolved and total recoverable metals. The dissolved portion is more immediately bioavailable, but does not account for metals that are held in solids. Since CSOs generally contain elevated levels of suspended solids, which can release metals over time, sampling for total metals is important for evaluating CSOs and their impacts.

The permittee should also ensure that monitored parameters correspond to the downstream problem as well as the water quality criteria that apply in the receiving water body at the discharge pipe. For example, the downstream beach may have an *Enterococcus* standard while the water quality criterion at the discharge point might be expressed in fecal coliforms. In this case, samples should be analyzed for both parameters.

The permittee should consider collecting composite data for certain parameters on as many overflows as possible during the monitoring program. This can help establish mean pollutant concentrations for computing pollutant loads. For instance, TSS concentrations are generally important both because of potential habitat impacts and because they are associated with adsorbed toxics. Collecting some discrete TSS samples can also be useful, particularly for evaluating the existence of first flush.

The permittee should consider initial screening-level sampling for a wide range of pollutants if sufficient information is not available to initially identify the parameters of concern. The permittee can then analyze subsequent samples only for the subset of pollutants identified in the screening. However, because pollutant concentrations in CSO discharges are highly variable, the permittee should exercise caution in removing pollutants from the analysis list.

## 4.4 SEPARATE STORM SEWERS

If separate storm sewers are significant contributors to the same receiving water as CSOs,[4] the permittee should determine pollutant loads from storm sewers as well as CSOs. This information is needed to define the loadings from different wet weather sources and target CSO and storm water controls appropriately. If sufficient storm water data are not available, the permittee may need to sample separate storm sewers and the monitoring and modeling plan should include storm water sampling for the pollutants being sampled in the CSS. Storm water discharges from areas suspected of having high loadings, such as high-density commercial areas or industrial parks, should have priority. Storm water discharges from highways can be another major source of pollutants,

[4] The potential significance of storm water discharges can often be assessed by looking at land uses and the relative sizes of discharges.

particularly solids, oil and grease, and trace metals. For guidance on characterizing and monitoring urban runoff, permittees can refer to EPA's *NPDES Storm Water Sampling Guidance Document* (U.S. EPA, 1992) and the *Guide for Collection, Analysis, and Use of Urban Storm Water Data* (Alley, 1977).

The monitoring and modeling plan should reflect storm water and other sampling programs occurring concurrently and provide for coordination with them. This will ensure that wet weather discharges and their impacts are monitored and addressed in a cost-effective, targeted manner. Many communities operate their storm water programs under a different department or authority from their sewer program. Whenever possible, similar activities within these different organizations should be coordinated on a watershed basis.

## 4.5 RECEIVING WATER MONITORING

The goals of receiving water monitoring should include the following:

- Assess attainment of WQS (including designated uses)
- Define the baseline conditions in the receiving water (chemical, biological, and physical parameters)
- Assess the relative 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, as appropriate, of WQS.

The monitoring program should also provide background data on conditions in the receiving waters during dry weather conditions, if this information is not already available (see Chapter 3). Dry weather monitoring of the receiving water body helps define the background water quality and will determine whether water quality criteria are being met or exceeded during dry weather.

Where a permittee intends to eliminate CSOs entirely (i.e., separate its system), only limited or short-term receiving water monitoring may be necessary (depending on how long elimination of

CSOs will take). It may be useful, however, to collect samples before separation to establish the baseline as well as after separation to evaluate the impacts of CSO elimination.

The permittee should coordinate monitoring activities closely with the NPDES permitting authority. In many cases, it may be appropriate to use a phased approach in which the receiving water monitoring program focuses initially on determining the pollutant loads from CSOs and identifying short-term water quality impacts. The information obtained from the first phase can then be used to identify additional data and analytical needs in an efficient manner. Monitoring efforts can be expanded as circumstances dictate to provide additional levels of detail, including evaluation of downstream effects and longer term effects.

The scope of the receiving water monitoring program will depend on several factors, such as the identity of the pollutants of concern, whether the receiving water will be modeled, and the relative size of the CSO. For example:

- To study dissolved oxygen (DO) dynamics, depth and flow velocity data must be collected well downstream of the CSO outfalls. DO modeling may require data on the plant and algae community, the temperature, the sediment oxygen demand, and the shading of the river. Therefore, DO monitoring locations would likely span a larger area than for some other pollutants of concern.

- When the volume of the overflow is small relative to the receiving water body, as in the case of a small CSO into a large, well mixed river, the overflow may have little impact.[5] Such a situation generally would not require extensive downstream sampling.

In developing the monitoring and modeling plan, the permittee should consider the location and impacts of other sources of pollutant loadings. As mentioned in Chapter 3, information on these sources is generally compiled and reviewed during the initial system characterization. To evaluate the impacts of CSOs on the receiving water body, the permittee should try to select monitoring locations that have limited or known effects from these other sources, If the initial system

[5] In areas where the receiving water is used for swimming, the dilution needs to be at least 10,000 to 1 for bacteria.

characterization did not provide sufficient information to adequately determine the location of these sources, the permittee may need to conduct some monitoring to better characterize them.

### 4.5.1 Monitoring Locations

In planning where to sample, it is important to understand land uses in the drainage basin (which affect what pollutants are likely to be present) and characteristics of the receiving water body such as:

- Pollutants of concern (e.g., bacteria, dissolved oxygen, metals)
- Locations of sensitive areas
- Size of the water body
- Horizontal and vertical variability in the water body
- Degree of resolution necessary to assess attainment of WQS.

Individual monitoring stations may be located to characterize:

- Flow patterns
- Pollutant concentrations and loadings from individual sources
- Concentrations and impacts at specific locations, including sensitive areas such as shellfishing zones and recreational areas
- Differences in concentrations between upstream and downstream sampling sites for rivers, or between inflows and outflows for lakes, reservoirs, or estuaries
- Changing conditions at individual sampling stations before, during, and after storm events
- Differences between baseline and current conditions in receiving water bodies
- Locations of point and nonpoint pollution sources.

In selecting monitoring locations, the permittee needs to consider physical logistics (e.g., whether the water is navigable, if bridges are available from which to sample) and crew safety.

Exhibit 4-2 illustrates how sampling locations might be distributed in a watershed to assess the effect of other sources of pollution. If monitoring is conducted at the potential sampling locations (labeled 1-6 in Exhibit 4-2), the results from the different locations could be compared to provide a relative measure of the pollutant contributions from each source.

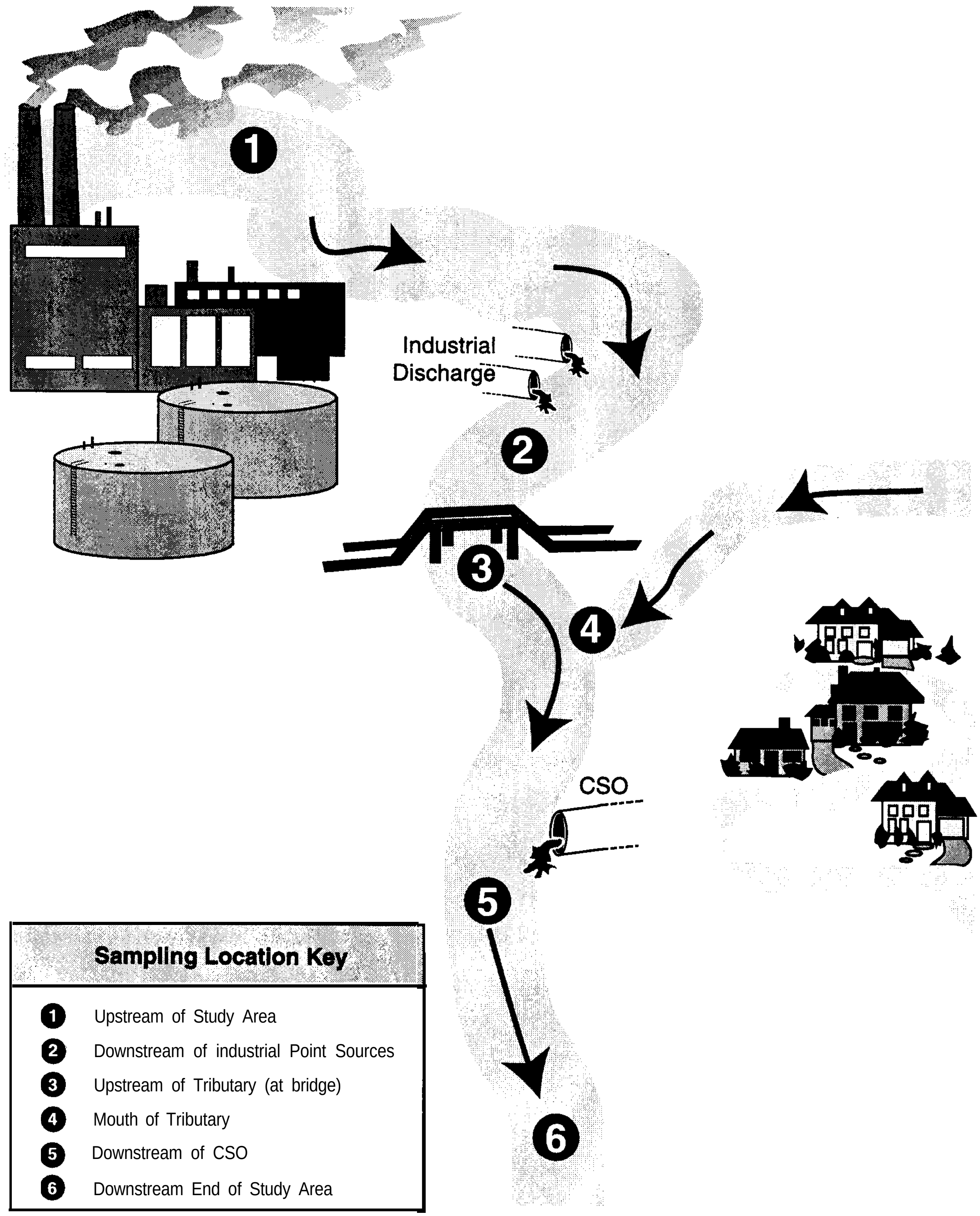
The permittee should also consider making cooperative sampling arrangements when pollutants from multiple sources enter a receiving water or when several agencies share the cost of the collection system and the POTW. The identification of new monitoring locations should account for sites that may already be part of an existing monitoring system used by local or State government agencies or research organizations.

### 4.5.2 Monitoring Frequency, Duration, and Timing

In general, the monitoring and modeling plan should target receiving water monitoring to those seasons, flow regimes, and other critical conditions where CSOs have the greatest potential for impacts, as identified in an initial system characterization (see Chapter 3). It should specify additional monitoring as necessary to fill data gaps and to support receiving water modeling and analysis (see Tables B-2 through B-5 in Appendix B for potential modeling parameters), or to determine the relative contribution of other sources to water quality impairment.

In establishing the frequency, duration, and timing of receiving water monitoring in the monitoring and modeling plan, the permittee should consider seasonal variations to determine whether measurable and significant changes occur in the receiving water body and uses during

**Exhibit 4-2. Receiving Water Monitoring Location Example**



different times of year. The monitoring and modeling plan should also enable the permittee to address issues regarding attainment of WQS, such as:

- Assessing attainment of WQS for recreation: This may require determination of a maximum or geometric mean coliform concentration at the point of discharge into a river or mixing zone boundary. This requires grab samples during and immediately after discharge events in sufficient number (possibly specified in the WQS) to reasonably approximate actual in-stream conditions.

- Assessing attainment of WQS for nutrients: This may call for samples collected throughout the water body and timed to examine long-term average conditions over the growing season.

- Assessing attainment of WQS for aquatic life support: This may call for biological assessment in potentially affected locations and a comparison of the data to reference sites.

Receiving water sampling designs include the following:

- ***Point-in-time*** single-event samples to obtain estimates where variation in time is not a large concern.

- ***Short-term*** intensive sampling for a predetermined period of time in order to detail patterns of change during particular events, such as CSOs. Sample collections for such studies may occur at intervals such as five minutes, one hour, or daily.

- ***Long-term*** less-intensive samples collected at regular intervals-such as weekly, monthly, quarterly, or annually-to establish ambient or background conditions or to assess seasonal patterns or general trends occurring over years.

- ***Reference site*** samples collected at separate locations for comparison with the CSO study site to determine relative changes between the locations.

- ***Near-field*** studies to sample and assess receiving waters within the immediate mixing zone of CSOs. These studies can examine possible short-term toxicity impacts or long-term habitat alterations near the CSO.

- ***Far-field*** studies to sample and assess receiving waters outside the immediate vicinity of the CSO. These studies typically examine delayed impacts, including oxygen demand, nutrient-induced eutrophication, and changes in macroinvertebrate assemblages.

Section 4.6 discusses a strategy for determining whether to initiate monitoring for a particular wet weather event.

### 4.5.3 Pollutant Parameters

The monitoring and modeling plan should identify parameters of concern in the receiving water, including pollutants with water quality criteria for the designated use(s) of the receiving water. The NPDES authority may have specific requirements or guidance regarding parameters for CSO-related receiving water monitoring. These parameters may include the ones previously identified for combined sewage (see Section 4.3.3):

- Indicator bacteria
- TSS
- BOD and DO
- pH
- Settleable solids
- Nutrients
- Metals (dissolved and total recoverable) and other toxics.

In addition, the permittee should consider the following types of monitoring prior to or concurrently with the other analyses:

- Flow monitoring
- Biological assessment (including habitat assessment)
- Sediment monitoring (including metals and other toxics)
- Monitoring other pollutants known or expected to be present.

Monitoring should focus on the parameters of concern. In many cases, the principal concern will be pathogens, represented by fecal coliform.

Depending on the complexity of the receiving water and the analyses to be performed, the monitoring and modeling plan may need to reflect a larger list of parameters. Measuring temperature, flow, depth, and velocity, and more complex parameters such as solar radiation, light extinction, and sediment oxygen demand, can enable investigators to simulate the dynamics of the receiving water that affect basic parameters such as bacteria, BOD, and TSS.[6] Table B-1 in Appendix B lists the data needed to perform the calculations for several dissolved oxygen, ammonia, and algal studies. Indirect indicators, such as beach closings, fish advisories, stream bank erosion, and the appearance of floatables, may also provide a relative measure of the impacts of CSOs.

## 4.6 CRITERIA FOR INITIATING MONITORING OF WET WEATHER EVENTS

The monitoring program should include enough storm events to enable the permittee to predict the CSS's response to rainfall events, the characteristics of resulting CSOs, and the extent of impacts on receiving waters (as discussed in Sections 4.2.1, 4.3.2, and 4.5.2). By developing a strategy for determining which storm events are most appropriate for wet weather monitoring, the permittee can collect the needed data while limiting the number of times the sampling crew is mobilized and the number of sampling events. This can result in significant savings in personnel, equipment, and laboratory costs.

The following list (ORSANCO, 1998) contains key elements to consider in determining whether to initiate monitoring for a wet weather event:

- Identifying local site conditions
  - Establish the amount and intensity of precipitation needed to initiate CSOs
  - Characterize seasonal stream conditions (flow, stage, and velocity)
  - Characterize historical climatic patterns
- Setting criteria for monitoring activities
  - Establish minimum amount of precipitation and duration to trigger event monitoring
  - Focus on frontal storms instead of thunderstorms

[6] For example, a Streeter-Phelps DO analysis requires temperature, flow rate, reach length, and sediment oxygen demand.

  - Identify time periods contained within the monitoring schedule that may not be representative of the system (holiday weekends) and avoid monitoring during those periods

- Identify local rain gage networks

  - Airports
  - Municipalities

- Identify monitoring contact personnel

  - Laboratory managers
  - Consultant crew leaders
  - Municipality crew leaders

- Identify weather sources

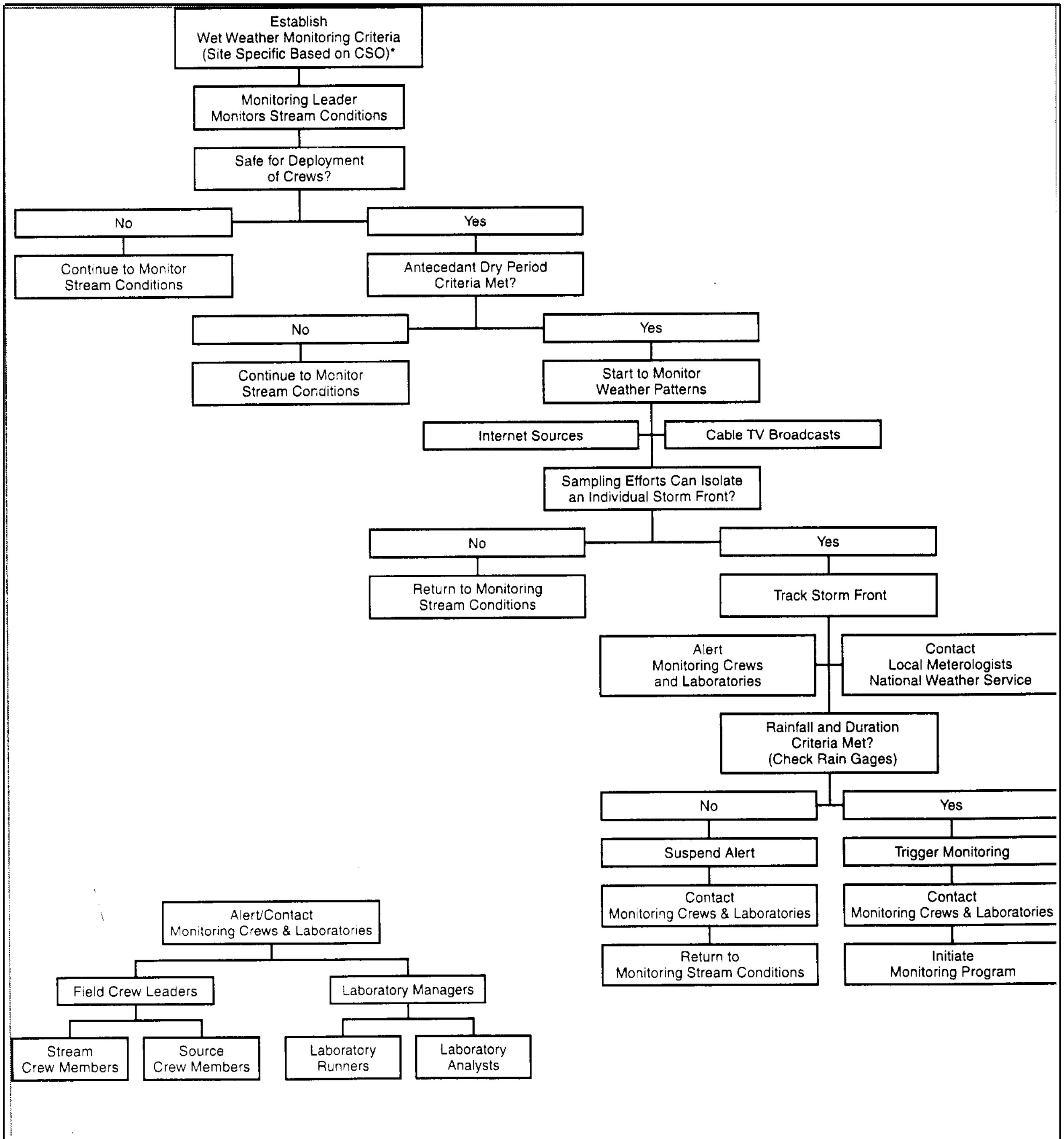
  - Local meteorologist
  - National Weather Service
    - Contact at regional forecast office
    - NOAA weather radio broadcast
  - Cable TV broadcasts
    - Local radar
    - Weather Channel
  - Internet sites
    - Local television network sites
    - National weather information sites

- Storm tracking

  - The monitoring leader tracks weather conditions and stream conditions
  - The monitoring leader notifies all monitoring contact personnel of potential events when:
    - Stream conditions are acceptable
    - Monitoring criteria may be met
  - The monitoring leader initiates monitoring following the flowchart.

The flowchart in Exhibit 4-3 provides an example of how to apply these elements (ORSANCO, 1998).

**Exhibit 4-3. Decision Flowchart for Initiating a Wet Weather Monitoring Event**




* Since the amount and intensity of precipitation needed to initiate an overflow and the physical conditions may vary significantly from CSO to CSO, the permittee may need to establish different monitoring criteria for different CSOs.

## 4.7 CASE STUDY

The case study in Example 4-2 outlines the monitoring aspects of a comprehensive effort to determine CSO impacts on a river and evaluate possible control alternatives. The city of South Bend, Indiana developed and implemented a monitoring program to characterize flows and pollutant loads in the CSOs and receiving water. The city then used a model to evaluate possible control alternatives.

In developing its monitoring plan, South Bend carefully selected monitoring locations that included roughly 74 percent of the area within the CSS and represented the most characteristic land uses. The city conducted its complete monitoring program at 6 of the 42 CSO outfalls and performed simpler chalking measurements at the remaining outfalls to give some basic information on the occurrence of CSOs across the system. By using existing flow monitoring stations in the CSS, the city was able to limit the need to establish new monitoring stations.

## 4.8 DATA MANAGEMENT AND ANALYSIS

### 4.8.1 Quality Assurance Programs

Since inaccurate or unreliable data may lead to faulty decisions in evaluating, selecting, and implementing CSO controls, the monitoring and modeling plan must provide for quality assurance and quality control to ensure that the data collected have the required precision and accuracy. Quality assurance and quality control (QA/QC) procedures are necessary both in the field (during sampling) and in the laboratory to ensure that data collected in environmental monitoring programs are of known quality, useful, and reliable. The implementation of a vigorous QA/QC program can also reduce monitoring expenses. For example, a QA/QC program for flow monitoring may help prevent the need for resampling due to meter fouling or loss of calibration.

## Example 4-2. Monitoring Case Study

**South Bend, Indiana**

The City of South Bend, population of 109,000, has 42 combined sewer service areas covering over 14,000 acres.

**Monitoring Goals**

The ultimate goal of the CSO control effort was to reduce or eliminate impacts on uses of the receiving water, the St. Joseph River. The more immediate goal consisted of quantifying CSO impacts to the St. Joseph River and evaluating alternatives for cost-effective CSO control. To achieve these goals, the City reviewed its existing data to determine what additionaldata were needed to characterize CSO impacts. The City then developed and implemented a sampling and flow monitoring plan to fill in these data gaps. Objectives of the monitoring plan included quantifying overflow volumes and pollutant loads in the overflows and flows and pollutant loads in the receiving water. After evaluating various analytical and modeling tools, the City decided to use the SWMM model to assist in predicting the benefits of alternative control strategies and defining problems caused by CSOs.

**Monitoring Plan Design and Implementation**

The monitoring plan was designed to focus on the 6 largest drainage areas, which were most characteristic of land uses within the CSS area and included 74 percent of that area, Monitoring all 42 outfalls was judged to be unnecessarily costly. The monitoring plan specified 8 temporary and 9 permanent flow monitoring locations along the main interceptor and in the influent and outfall structures of the 6 largest CSOs. The interior surface of each non-monitored CSO diversion structure was chalked to determine which storms caused overflows; after each storm, the depth to which the chalk disappeared was recorded. Although the plan included monitoring only 14 percent of the outfalls, it measured flow and water quality for most of the CSS area and covered a representative range of land uses and basins. Flow monitoring data were used to calibrate the SWMM model.

The monitoring plan described water quality sampling procedures for both dry weather and wet weather periods. The plan specified sample collection from four CSO structures during at least five storm events representing a range of storm sizes. For the CSOs, monitored water quality parameters included nine metals, total suspended solids (TSS), BOD, CBOD (carbonaceous biochemical oxygen demand), total Kjeldahl nitrogen (TKN), ammonia, total phosphorus, total and fecal coliform bacteria, conductivity, and hardness. Periodic dry-weather grab sample collections at the interceptors were also planned.

During storm events, water quality samples were collected using 24-bottle automatic samplers at the four CSO points. To quantify “fist-flush” concentrations, the automatic samplers began collecting samples at the start of an overflow event and continued collecting samples every five minutes for the first two hours of the monitored events. A two-person crew drove between sites during each monitored event to check equipment operation and the adequacy of sample collection.

River samples were taken from eight bridges along the St. Joseph River during and after three storms. Six bridges are located within South Bend, and two are located just downstream in Michigan. River samples were analyzed to determine the impacts of CSOs on the St. Joseph River and to calibrate and verify the river model for dissolved oxygen, E. coli, and fecal coliform.

**Example 4-2. Monitoring; Case Study (Continued)**

River samples were collected concurrently from the eight bridges every four hours. Four people sampled the eight bridges. One person collected samples from two adjacent bridges within 30 minutes, Samples were collected at the center of each bridge at the same location where the City collects its monthly river samples. At least two sets of samples were collected before the storm to establish the baseline condition and the river was sampled for at least 48 hours after onset of the storm to allow the river to return to its baseline condition.

Hourly rainfall data were collected from a network of five rain gages located in the drainage basins.

**Results of the Sampling and Flow Monitoring Program**

Results from the sampling and monitoring program for three storms during summer and early fall of 1991 indicated little or no impact on dissolved oxygen in the St. Joseph River, Large pulses in river bacteria counts (E. coli and fecal coliform) were observed during the storms. Bacteria counts returned to baseline values within 48 hours after the onset of each storm, Wet weather CSO sampling results showed a "first flush" effect in three of the four sampled CSO structures. The fourth structure did not exhibit a "first flush" effect, probably because of a high biochemical oxygen demand (BOD) loading at the upstream end of the trunk sewer to the structure. Wet weather CSO sampling results also showed that the soluble metal concentrations were much lower than the particulate metal concentrations.

The objective of the CSO control program is to solve real pollution problems and improve the river water quality for specific uses. Based on the results of the monitoring program, bacteria reduction in the river during wet weather has been the primary focus; A cost-performance curve was developed, using bacteria reduction as the performance measure; to select the most cost-effective alternative and level of CSO control.

For an additional case study on CSO and receiving water monitoring, see Chapter 2 of *Combined Sewer Overflows - Guidance for Long-Term Control Plan* (EPA, 1995a).

Quality assurance refers to programmatic efforts to ensure the quality of monitoring and measurement data. QA programs increase confidence in the validity of the reported analytical data. Quality control, which is a subset of quality assurance, refers to the application of procedures designed to obtain prescribed standards of performance in monitoring and measurement. For

QC.

QA/QC procedures can be divided into two categories:

procedures. Both types of QA/QC are described in the following subsections.

**Field QA/QC.** QA programs for sampling equipment and for field measurement procedures (for such parameters as temperature, dissolved oxygen, and pH) are necessary to ensure data are of the appropriate quality. A field QA program should contain the following documented elements:

- The sampling and analytical method; special sample handling procedures; and the precision, accuracy, and detection limits of all analytical methods used.
- The basis for selection of sampling and analytical methods. Where methods do not exist, the QA plan should state how the new method will be documented, justified, and approved for use.
- Sample tracking procedures (labeling, transport, and chain of custody).
- Procedures for calibration and maintenance of field instruments and automatic samplers during both dry and wet weather flows.
- The organization structure, including assignment of decision-making and other responsibilities for field operations.
- Training of all personnel involved in any function affecting data quality.
- A performance evaluation system assessing the performance of field sampling personnel in the following areas:
    - Qualifications of field personnel for a particular sampling situation
    - Determination of the best representative sampling site
    - Sampling technique including monitoring locations, the choice of grab or composite sampling, the type of automatic sampler, special handling procedures, sample preservation, and sample identification and tracking procedures
    - Flow measurement
    - Completeness of data, data recording, processing, and reporting
    - Calibration and maintenance of field instruments and equipment
    - The use of QC samples such as duplicate, split, or spiked samples and blanks as appropriate to assess the validity of data.

- Procedures for recording, processing, and reporting data; procedures for use of non-detects/results-below-detection in averaging or other statistical summaries (e.g., substituting one-half the detection level for results of non-detect at the lowest standard used); procedures for review of data and invalidation of data based upon QC results.

- The amount of analyses for QC, expressed as a percentage of overall analyses, to assess the validity of data.

Sampling QC includes calibration and preventative maintenance procedures for sampling equipment, training of sampling personnel, and collection and analysis of QC samples. QC samples are used to determine the performance of sample collection techniques and the homogeneity of the water and should be collected when the other sampling is performed. The following sample types should be part of field QC:

- ***Duplicate Samples (Field)*** - Duplicate field samples collected at selected locations provide a check for precision in sampling equipment and techniques.

- ***Equipment Blank -*** An aliquot of distilled water which is taken to and opened in the field, its contents poured over or through the sample collection device, collected in a sample container, and returned to the laboratory for analysis to check sampling device cleanliness.

- ***Trip Blank -*** An aliquout of deionized/distilled water or solvent that is brought to the field in a sealed container and transported back to the laboratory with the sample containers for analysis in order to check for contamination from transport, shipping, or site conditions.

- ***Preservation Blank*** - Adding a known amount of preservative to an aliquot of deionized/distilled water and analyzing the substance to determine whether the preservative is contaminated.

The permittee should also consider analyzing a sample of blank water to ensure that the water is free of contaminants.

**Laboratory QA/QC.** Laboratory QA/QC procedures ensure analyses of known and documented quality through instrument calibration and the processing of samples. **Precision** of laboratory findings refers to the reproducibility of results. In a laboratory QC program, a sample is independently analyzed more than once, using the same methods and set of conditions. The precision is estimated by the variability between repeated measurements. **Accuracy** refers to the degree of difference between observed values and known or true values. The accuracy of a method may be determined by analyzing samples to which known amounts of reference standards have been added.

The following techniques are useful in determining confidence in the validity of analytical data:

- ***Duplicate Samples (Laboratory)*** - Samples received by the laboratory and divided into two or more portions at the laboratory, with each portion then separately and identically prepared and analyzed. These samples assess precision and evaluate sampling techniques and equipment.
- ***Split Samples (Field)*** - Single samples split in the field and analyzed separately check for variation in laboratory method or between laboratories. Samples can be split and submitted to a single laboratory or to several laboratories.
- ***Spiked Samples (Laboratory)*** - Introducing a known quantity of a substance into separate aliquots of the sample or into a volume of distilled water and analyzing for that substance provides a check of the accuracy of laboratory and analytic procedures.
- ***Reagent Blanks*** **-** Preserving and analyzing a quantity of laboratory blank water in the same manner as environmental water samples can indicate contamination caused by sampling and laboratory procedures.

QA/QC programs are discussed in greater detail in *EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations* (U.S. EPA, 1994d) and *Industrial User Inspection And Sampling Manual For POTWs* (U.S. EPA 1994c).

### 4.8.2 Data Management

Although a permittee may collect accurate and representative data through its monitoring efforts and verify the reliability of the data through QA/QC procedures, these data are of limited usefulness if they are not stored in an organized manner and analyzed properly. The permittee should develop a data management program to provide ready access to data, prevent data loss, prevent introduction of data errors, and facilitate data review and analysis. Even if a permittee intends to use a "complex" model to evaluate the impacts of CSOs and proposed CSO control alternatives, the model still requires appropriate data for input parameters, as a basis for assumptions made in the modeling process, and for model calibration and verification. Thus, the permittee needs to properly manage monitoring data and perform some review and analysis of the data regardless of the analytical tools selected.

All monitoring data should be organized and stored in a form that allows for ready access. Effective data management is necessary because the voluminous and diverse nature of the data, and the variety of individuals who can be involved in collecting, recording and entering data, can easily lead to data loss or error and severely damage the quality of monitoring programs.

Data management systems must address both managerial and technical issues. The managerial issues include data storage, data validation and verification, and data access. First, the permittee should determine if a computerized data management system will be used. The permittee should consider factors such as the volume of monitoring data (number of sampling stations, samples taken at each station, and pollutant parameters), complexity of data analysis, resources available (personnel, computer equipment, and software), and whether modeling will be performed. To enable efficient and accurate data analysis, a computerized system may be necessary for effective data management in all but the smallest watersheds. Computerized data management systems may also facilitate modeling if the data can be uploaded directly into the model rather than being reentered. Thus, when modeling will be performed, the permittee should consider compatibility with the model when selecting any computerized data management system. Technical issues related to data management systems involve the selection of appropriate computer equipment and software and the design of the data system, including data definition, data standardization, and a data dictionary.

Data quality must be rigidly controlled from the point of collection to the point of entry into the data management system. Field and laboratory personnel must carefully enter data into proper spaces on data sheets and avoid transposing numbers. To avoid transcription errors when using a computerized data management system, entries into a preliminary data base should be made from original data sheets or photocopies. As a preliminary screen for data quality, the data base/spreadsheet design should include automatic range-checking of all parameters, where values outside defined ranges are flagged and either immediately corrected or included in a follow-up review. For some parameters, it might be appropriate to include automatic checks to disallow duplicate values. Preliminary data base/spreadsheet files should be printed and verified against the original data to identify errors.

Additional data validation can include expert review of the verified data to identify possible suspicious values. In some cases, consultation with the individuals responsible for collecting or entering original data may be necessary to resolve problems. After all data are verified and validated, they can be merged into the monitoring program’s master data files. For computerized systems, to prevent loss of data from computer failure at least one set of duplicate (backup) data files should be maintained.

Data analysis is discussed in Chapters 5 (CSS Monitoring) and 6 (Receiving Water Monitoring). The use of models for more complex data analysis and simulation is discussed in Chapters 7 (CSS Modeling) and 8 (Receiving Water Modeling).

## 4.9 IMPLEMENTATION OF MONITORING AND MODELING PLAN

During development of the monitoring and modeling plan, the permittee needs to consider implementation issues such as recordkeeping and reporting requirements, personnel responsible for carrying out each element of the plan, scheduling, and resources. Although some implementation issues cannot be fully addressed in the monitoring and modeling plan until other plan elements have evolved, they should be considered on a preliminary basis in order to ensure that the resulting plan will satisfy reporting requirements and be feasible with available resources.

### 4.9.1 Recordkeeping and Reporting

The monitoring and modeling plan includes a recordkeeping and reporting plan, since future permits will contain recordkeeping and reporting requirements such as progress reports on NMC and LTCP implementation and submittal of monitoring and modeling results. The recordkeeping and reporting plan addresses the post-compliance monitoring program the permittee will develop as part of the LTCP.

### 4.9.2 Personnel Responsible for Implementation

The monitoring and modeling plan identities the personnel that will implement the plan. In some cases, particularly in a city with a small CSS, the appropriately trained personnel available for performing the tasks specified in the monitoring and modeling plan may be very limited. By reviewing personnel and assigning tasks, the permittee will be prepared to develop an implementation schedule that will be attainable and will be able to identify resource limitations and needs (including training) early in the process.

### 4.9.3 Scheduling

The monitoring and modeling plan has a tentative implementation schedule to ensure that elements of the plan are implemented continuously and efficiently. The schedule can be revised as necessary to reflect the review team’s assessment of the plan and the evaluation of monitoring and modeling results. The schedule should address:

- Reporting and compliance dates included in the NPDES permit
- Monitoring frequencies
- Seasonal sampling schedules and dependency on rainfall patterns
- Implementation schedule for the NMC
- Coordination with other ongoing sampling programs
- Availability of resources (equipment and personnel).

### 4.9.4 Resources

The monitoring and modeling plan identifies equipment, personnel, and other resource needs. If modeling will be conducted, resource needs include a copy of the model and the equipment and technical expertise to use the model. The plan may need to be modified after assessing the availability of these resources. For example, if the monitoring and modeling plan identifies complex modeling strategies, resource limitations may require the permittee to consider modeling techniques that have more moderate data requirements. Alternatively, if the permittee does not have the resources to purchase the hardware or software needed to run a detailed model, the permittee may be able to make arrangements to use the equipment at another facility (e.g., another municipality developing a CSO control program) or at a State or Federal agency. However, if such arrangements are not possible, the permittee may need to choose a less detailed model which could lead to reduced monitoring costs.

Through a review of resources, the permittee may identify monitoring equipment needed to implement the monitoring and modeling plan. By obtaining needed equipment such as automatic samplers, flow measuring equipment, rain gages, and safety equipment before the date when monitoring is scheduled to begin, the permittee can prevent some potential delays.