CHAPTER 6

RECEIVING WATER MONITORING

This chapter discusses techniques and equipment for receiving water monitoring, including hydraulic, water quality, sediment, and biological sampling procedures. The techniques vary in applicability and complexity, but all are generally applicable to CSO-impacted receiving waters. In collecting and analyzing receiving water monitoring data, the permittee needs to implement a quality assurance and quality control (QA/QC) program to ensure that accurate and reliable data are used for CSO planning decisions (see Section 4.8.1). For purposes of the post-construction compliance monitoring program, all sampling and analysis needs to be done in accordance with EPA regulations.

6.1 THE CSO CONTROL POLICY AND RECEIVING WATER MONITORING

The CSO Control Policy discusses characterization and monitoring of receiving water impacts as follows:

- *In order to design a CS0 controlplan 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...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 permittee should develop a comprehensive, representative monitoring program that ... assesses the impact of the CSOs on the receiving waters. The monitoring program should include necessary CSO effluent and ambient in-stream monitoring and, where appropriate, other monitoring protocols such as biological assessment, toxicity testing and sediment sampling. Monitoring parameters should include, for example, oxygen demanding pollutants, nutrients, toxic pollutants, sediment contaminants, pathogens, bacteriological indicators (e.g., Enterococcus, E. Coli), and toxicity. A representative sample of overflow points can be selected that is sufficient to allow characterization of*

CSO discharges and their water quality impacts and to facilitate evaluation of control plan alternatives. (Section II.C.1)

As discussed in Chapter 2, the CSO Policy intends for the permittee to use either the presumption approach or the demonstration approach in identifying controls that will provide for attainment of water quality standards (WQS). Under the demonstration approach, the permittee demonstrates the adequacy of its proposed CSO control program to attain WQS. Generally, permittees selecting the demonstration approach will need to monitor receiving waters to show that their control programs are adequate.

The presumption approach is so named because it is based on the presumption that WQS will be attained when certain performance-based criteria identified in the CSO Policy are achieved, as shown by the permittee in its long-term control plan (LTCP). The regulatory agency is likely to request some validation of the presumption, such as receiving water quality sampling or end-of-pipe sampling of overflows combined with flow information and dilution calculations. Chapters 7 (CSS Modeling) and 8 (Receiving Water Modeling) discuss the different modeling considerations related to the demonstration and presumption approaches.

6.2 RECEIVING WATER HYDRAULIC MONITORING

When a CSO enters a receiving water body, it is subject to fate and transport processes that modify pollutant concentrations in the receiving water body. The impact of CSOs on receiving waters is largely determined by the hydraulics of the receiving water body and the relative magnitude of the CSO loading. Assessing receiving water hydraulics is an important first step in a receiving water study, since an understanding of how CSOs are transported and diluted is essential to characterizing their impacts on receiving waters. Awareness of large-scale and small-scale hydrodynamics can help the permittee determine where to sample in the receiving water for the effects of CSOs. Large-scale water movement largely determines the overall transport and transformation of pollutants. Small-scale hydraulics, such as water movement near a discharge point (often called near-field), determine the initial dilution and mixing of the discharge, For example, a discharge into a wide, fast-flowing river might not mix across the river for a long distance since it will quickly be transported downstream.

6.2.1 Hydraulic Monitoring

Hydraulic monitoring involves measuring the depth and velocity of the receiving water body and its other physical characteristics (e.g., elevation, bathymetry, cross section) in order to assess transport and dilution characteristics. This may include temporary or permanent installation of gages to determine depth and velocity variations during wet weather events. In all cases, the permittee will need to use existing mapping information or perform a new survey of the physical characteristics of the receiving water in order to interpret the hydraulic data and understand the hydraulic dynamics of the receiving water. (Section 4.5 discusses receiving water sampling designs and the selection of monitoring locations.)

Identifying a suitable hydraulic monitoring method depends largely on the type and characteristics of receiving water.

Rivers and Streams

In rivers and streams, flow rate is generally a factor of the depth, width, cross-sectional area, and hydraulic geometry of the river or stream channel. Flow in rivers and streams is usually determined by measuring the stage (elevation of water above a certain base level) and relating stage to discharge with a rating curve. This relationship is developed by measuring flow velocity in the stream or river at different stages, and using velocity and the area of the stream or river channel to determine the total discharge for each stage (Bedient and Huber, 1992). For large rivers and streams, long-term flow and geometry data are often available for specific gaging stations from USGS and the U.S. Army Corps of Engineers.

For a CSO outfall located near a USGS gage, the monitoring team can use the nearest USGS gage watershed areas to estimate flow at the discharge site.[1] Flow information may also be available from stage measurements at bridge crossings and dams, and from studies performed by other State and Federal agencies. In the absence of such flow data, the permittee may need to install stage indicators or use current meters to collect stream flow measurements. Some of the CSO flow monitoring devices described in Exhibit 5-5 of Chapter 5 also may be used to measure open channel flow in rivers and streams. The USGS (1982) and USDI (1984) have published detailed manuals on stream gaging and measurement techniques.

Estuaries

Estuaries connect rivers and oceans and thus represent a complex system of tides, salinity, and upstream drainage. Tidal variations and density effects from the varying levels of salinity need to be defined to determine how pollutants from CSOs are transported.

Tidal variations affect estuarine circulation patterns which, along with salinity patterns, determine how pollutant loadings entering the estuary are dispersed. Based on velocity and salinity patterns, estuaries can be classified as one of the following types:

- ***Stratified estuaries*** have a large fresh water inflow over a more dense salt water layer. Tidal currents are not sufficient to mix the separate layers. Transport of pollutants is largely dependent on the difference in the densities of the pollutants and the receiving water.

- ***Well-mixed estuaries*** have a tidal flow much greater than the river outflow, with mixing and flow reversal sufficient to create a well-mixed water column at all depths. Pollutants tend to move with the motion of the tides and are slowly carried seaward.

- ***Partially-mixed estuaries*** have flow and stratification characteristics between the other two types and have tide-related flows much greater than river flows. Pollutant transport depends somewhat on density, but also involves significant vertical mixing.

[1] For example, the 5,000-square mile Merrimack River watershed in New Hampshire and Massachusetts has 46 USGS gages that monitor most of the larger tributaries and the main stem in several locations. Using flow data from the one or two gages closest to a CSO outfall, flow at the outfall can be estimated based on the relative watershed areas between the gages and the outfall.

Classification depends on the river outflow. Rivers with large flows generally lead to more stratified estuaries (U.S. EPA, 1985b).

Tidal height data and current predictions, published annually by NOAA, may provide sufficient information, or it may be necessary to install a new tide gage (stage monitor) to develop data closer to the CSO-impacted area. Due to the variation of tides and winds, estuarine and coastal currents often change rapidly. It is necessary, therefore, to measure tides and currents simultaneously using continuously recording depth and velocity meters. Tidal currents can be measured with meters similar to those used for measurement of river currents, but the direction of the currents must also be recorded. Information on monitoring methods for such areas may also be found in USGS (1982) and USDI (1984).

Lakes

The hydraulic characteristics of lakes depend on several factors, including the depth, length, width, surface area, volume, basin material, surrounding ground cover, typical wind patterns, and surface inflows (including CSOs) and outflows. Lakes tend to have relatively low flow-through velocities and significant vertical temperature gradients, and thus are usually not well-mixed (Thomann and Mueller, 1987). To determine how quickly pollutants are likely to be removed from a lake, it is necessary to define the flushing rate. The flushing rate depends on water inputs (inflows and precipitation) and outputs (outflows, evaporation, transpiration, and withdrawal), pollutants and their characteristics, and the degree of mixing in the lake. Mixing in lakes is primarily due to wind, temperature changes, and atmospheric pressure.

Analysis of pollutant fate and transport in lakes is often complex and generally requires the use of detailed simulation models. (Some less-complex analysis can be done, however, when simplifying assumptions, such as complete mixing in the lake, are made.) Pollutant fate and transport analysis requires definition of parameters such as lake volume, surface area, mean depth, and mean outflow and inflow rates. Analytical and modeling methods for lakes and the data necessary to use the methods are discussed in greater detail in Section 8.3.2 and in Thomann and Mueller (1987) and Viessman, et al. (1977).

6.2.2 Analysis of Hydraulic Data

Receiving water hydraulic data can be analyzed to characterize the relationship between depth, velocity, and flow in the receiving water. This analysis may involve:

- Developing stage-discharge, area-depth, or volume-depth curves for specific monitoring locations, using measured velocities to calibrate the stage-discharge relationship[2]
- Pre-processing the data for input into hydraulic models
- Plotting and review of the hydraulic data
- Evaluating the data to define hydraulic characteristics, such as initial dilution, mixing, travel time, and residence time.

Plotting programs such as spreadsheets and graphics programs are useful for presenting hydraulic data. A data base and a plotting and statistical analysis package will typically be necessary to analyze the data and generate such information as:

- Plots of depth, velocity, and flow vs. time
- Plots of depth, velocity, and flow vs. distance from the outfall
- Frequency distributions of velocities and flows
- Vector components of velocities and flows
- Means, standard deviations, and other important statistical measures for depth, velocity, and flow data.

[2] Stage-discharge curves, also referred to as rating curves, are plots of water level (stage) vs. discharge. Development of these curves is discussed in Bedient and Huber (1992). USGS (1982) and USDI (1984)) discuss methods for developing hydraulic curves for various types of flow monitoring stations.

As presented later in Chapter 8, receiving water models need physical system and hydraulic data as input. Processing of input data is specific to each model. In general, however, the physical characteristics of the receiving water (slopes, locations, and temperatures) are used to develop the model computational grid. The measured hydraulic data (depths, velocities, and flows) are compared with model calculations in order to validate the model.

6.3 RECEIVING WATER QUALITY MONITORING

Collection and analysis of receiving water quality data is necessary when available data are not sufficient to describe water quality impacts from CSOs. This section discusses some approaches for conducting receiving water sampling and for analyzing the collected samples. (Chapters 3 and 4 discuss how to identify sampling locations, sampling parameters, and sampling frequency. Section 6.4 discusses biological and sediment sampling and analysis.)

6.3.1 Water Quality Monitoring

Receiving water monitoring involves many techniques similar to CSS monitoring (see Section 5.4.1) and many of the same decisions, such as whether to collect grab or composite samples and whether to use manual or automated methods. Receiving water quality monitoring involves the parameters discussed in Section 4.5.3 as well as field measurement of parameters such as temperature and conductivity.

Sample Program Organization

Sampling receiving waters, especially large water bodies, requires careful planning and a sizable resource commitment. For example, a dye study of a large river requires careful planning regarding travel time, placement of sampling crews, points of access, safety concerns, and use of boats. Sampling during wet weather events is typically more complicated than sampling during dry weather, since it often requires rapid mobilization of several sampling teams on short notice, sampling throughout the night, and sampling in rainy conditions with higher-than-normal flows in the receiving water body. Time of travel between the various sampling stations may necessitate the use of additional crews when sample collection must occur at predetermined times.

Wet weather sampling requires specific and accurate weather information. Local offices of the American Meteorological Society can provide a list of Certified Consulting Meteorologists who can provide forecasting services specific to the needs of a sampling program. Many weather services also have Internet sites that provide real-time radar updates across the U.S. Radar coverage can also be arranged in some areas for real-time observation of rainfall conditions. These efforts represent an additional cost to the program, but they can be invaluable for planning wet weather surveys and can result in significant savings in costs associated with false starts and unnecessary laboratory charges. Section 4.6 discusses a strategy for determining whether to initiate monitoring for a particular wet weather event.

The rainfall, darkness, and cold temperatures that often accompany wet weather field investigations can make even small tasks difficult and sometimes unsafe. Contingency planning and extensive preparation can, however, minimize mishaps and help ensure safety. Prior to field sampling, the permittee should ensure that:

- Sampling personnel are well trained and familiar with their responsibilities, as defined in the sampling plan
- Personnel use appropriate safety procedures and equipment
- A health and safety plan identifies the necessary emergency procedures, safety equipment, and nearby rescue organizations and emergency medical services
- Sample containers are assembled and bottle labels are filled out to the extent possible
- All necessary equipment is inventoried, field monitoring equipment is calibrated and tested, and equipment such as boats, motors, automobiles, and batteries are checked
- Boat crews are used when landside and bridge sampling are infeasible or unsafe.

Sample Preparation and Handling

As discussed in Section 5.4.1, sample collection, preparation and handling, preservation, and storage should minimize changes in the condition of sample constituents. The standard procedures for collecting, preserving, and storing receiving water samples are the same as those for combined sewage samples and are described in 40 CFR Part 136. Procedures for cleaning sample bottles, preserving water quality samples, and analyzing for appropriate chemicals are detailed in various methods manuals, including APHA (1992) and U.S. EPA (1979). NOAA's Status and Trends Program also provides information on standard protocols for sampling and analysis. Collection and analytical methods depend on the constituents in the receiving water (e.g., salinity, suspended sediments, ionic strength) as well as the required precision and accuracy. Samples should be labeled with unique identifying information and should have chain-of-custody forms documenting the changes of possession between time of collection and time of analysis (discussed in Section 5.4.1). The use of sample bar code labels and recorders can be particularly helpful during wet weather sampling when paper records are often infeasible.

6.3.2 Analysis of Water Quality Data

As was the case for hydraulic data, water quality data for receiving waters are analyzed by plotting and reviewing the raw data to define water quality characteristics and by processing the data for input to water quality models. Data can be analyzed and displayed using spreadsheets, databases, graphics software, and statistical packages, such as Statistical Analysis Software (SAS) and Statistical Package for Social Sciences (SPSS).[3]

Simple receiving water analyses could include:

- Comparing receiving water quality with applicable water quality criteria to determine whether criteria are being exceeded
- Comparing sampling results from before, during, and after a wet weather event to assess whether water quality problems are attributable to CSOs and other wet weather events[4]

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[3] Use of these statistical packages generally requires solid statistical capabilities, so they should be used cautiously by someone who is not experienced in statistical data evaluations and survey design. For information on SAS, contact: SAS Institute, Inc., SAS Campus Drive, Cary, NC 27513 or (919) 677-8000. For information on SPSS, contact: SPSS Incorporated, 444 N. Michigan Avenue, Chicago, IL 60611 or (800) 543-2185.

[4] An alternative approach is to stratify the analysis by those samples that time travel analyses (e.g., Lagrangian analysis) indicate are impacted by CSO discharges. Many instream samples collected during a wet weather event represent times either before or after the CSO "slug" has passed.

- Comparing data from downstream of CSOs to data collected upstream of CSOs (or to a reference point) to distinguish CSO impacts.

Since CSO controls must ultimately provide for attainment of WQS, receiving water analyses should be tailored to the applicable WQS. If the WQS for a pollutant contain numeric criteria specifying frequency, magnitude, and duration, receiving water analyses should use the same frequency, magnitude, and duration (see Sections 4.5, 9.1, and 9.2 for additional discussion.)

Water quality data are also used to calibrate receiving water models (see Chapter 8). This is generally facilitated by plotting the data vs. time and/or distance to compare with model simulations. Special studies may be required to determine rate constants, such as decay rates, bacteria die-off rates, or suspended solids settling rates, if these values are used in the model.

6.4 RECEIVING WATER SEDIMENT AND BIOLOGICAL MONITORING

It is often difficult and expensive to identify CSO impacts during wet weather using only hydraulic and water quality sampling. Sediment and biological monitoring may be cost-effective supplements or, in limited cases, alternatives to water quality sampling. Since sediment and biological monitoring do not address public health risks, they can only be used as alternatives when bacterial contamination is not a CSO concern. The following sections discuss sediment and biological sampling techniques and data analysis.

6.4.1 Sediment Sampling Techniques

Sediments are sinks for a wide variety of materials. Nutrients, metals, and organic compounds bind to suspended solids and settle to the bottom of a water body when flow velocity is insufficient to keep them in suspension. Once re-suspended through flood scouring, bioturbation, desorption, or biological uptake, free contaminants can dissolve in the water column, enter sediment-dwelling organisms, or accumulate or concentrate in fish and other aquatic organisms and subsequently be ingested by humans and other terrestrial animals.

Typically, CSOs contain suspended material that can settle out in slower-moving sections of receiving waters. Sediments can release accumulated contaminants for years after overflows have been eliminated.

Sediment samples are collected using hand or winch-operated dredges as follows:

- The sampling device is lowered through the water column by a hand line or a winch
- The device is then activated either by the attached line or by a weighted messenger sent down the line
- The scoops or jaws of the device close either by weight or spring action
- The device is brought back to the surface.

Ideally, dredging should disturb the bottom as little as possible and collect all fine particles.[5]

In cases where sediments are physically amendable to coring, core samples can be collected to determine how pollutant types, concentrations, and accumulation rates have varied over time.

To avoid sample contamination, sediments should be removed from the dredge or core sampler by scraping back layers in contact with the device and extracting sediments from the central mass of the sample. In many cases the upper-most layer of sediment will be the most contaminated and, therefore, of most interest. Sediment samples for toxicological and chemical examination should be collected following Method E 1391 detailed in *Standard Guide for Conducting Sediment Toxicity Tests with Freshwater Invertebrates* (ASTM, 1991).

[5] Commonly used sediment samplers include the Ponar, Eckman, Peterson, Orange-peel, and Van Veen dredges. *Macroinvertebrate Field and Laboratory Methods for Evaluating the Biological Integrity of Surface Waters* (Klemm, 1990) has detailed descriptions of such devices.

6.4.2 Analysis of Sediment Data

CSO investigations will benefit from analysis of a range of sediment characteristics, including physical characteristics (grain size distribution, type of sediment), chemical composition (toxics, metals, total solids), and benthic makeup (discussed in Section 6.4.3). Sediment sampling locations for CSO investigations should include the depositional zone below the outfall. The same sediment characteristics should also be evaluated in sediments from upstream reference stations and sediments from non-CSO sources to facilitate comparison with sediments near the CSO outfall. In comparing the chemical composition and biological communities of multiple sites, it is important to select sites that have similar physical characteristics.

Sediment data are typically analyzed by developing grain size distributions and plotting concentrations of chemicals vs. distance. If the area of interest is two-dimensional horizontally, isopleths can be plotted showing contours of constant concentration from the CSO outfall. If vertical variations from core samples are available, concentration contours can also be plotted vs. depth. Sediment chemistry data may be statistically analyzed to compare areas that are affected by CSOs, non-CSO sources, and unaffected (background) areas. These analyses can give a longer-term view of CSO impacts than water quality monitoring.

Additional information on sediment monitoring is available in EPA's *Guidance for Sampling of and Analyzingfor Organic Contaminants in Sediments* (U.S. EPA, 1987).

6.4.3 Biological Sampling Techniques

Evaluation of aquatic organisms is another way to obtain information on cumulative impacts of CSOs, since resident communities of aquatic organisms integrate over time all the environmental changes that affect them. Biological sampling should be accompanied by habitat assessment since it is necessary to separate out the effects of habitat condition when determining the presence and degree of biological impairment due to CSOs. It may be difficult to trace any impacts to CSOs unless there are no other significant pollutant sources present. Biological sampling results may be more useful for determining the overall impacts from all pollution sources on the biological health of the receiving water.

Collection and Handling of Biological Samples

This section describes collection techniques for fish, phytoplankton, zooplankton, and benthic macroinvertebrates. Additional information on sampling methods for these species, as well as for riparian and aquatic macrophytes, is in Exhibit 6-1.

Fish. Although other aquatic organisms may be more sensitive to pollutants, fish generate the greatest public concern. Observable adverse effects from pollutants include declines of populations and tumor growth on individuals. Fish monitoring programs can identify the relative and absolute numbers of individuals of each species; the size distributions within species; growth rates; reproduction or recruitment success; the incidence of disease, parasitism, and tumors; changes in behavior; and the bioaccumulation of toxic constituents.

Common fish sampling methods include angling, seines, gill and trap nets, and electrofishing. The references in Exhibit 6-1 provide guidance on methods used for collection, measurement, preservation, and analysis of fish samples.’

Phytoplankton. Phytoplankton are free-floating, one-celled algae. They are useful in monitoring receiving water quality because many species are highly sensitive to specific chemicals. Because phytoplankton have relatively rapid rates of growth and population turnover (approximately 3 to 5 days during the summer season), only short-term CSO impacts can be analyzed. Laboratory analyses can provide information on the abundance of each taxon, the presence of, or changes in, populations of indicator species, and the total biomass of phytoplankton present. Lowe (1974) and

[6] Two reference works published by the American Fisheries Society are especially informative. *Fisheries Techniques* (Nielsen and Johnson, 1983) focuses mainly on field work considerations, discussing most of the sampling techniques currently practiced. The companion volume, *Methods for Fish Biology* (Schreck and Moyle, 1990) focuses primarily on methods used to analyze and assess collected fish samples. It includes material on fish growth, stress and acclimation, reproduction, behavior, population ecology, and community ecology.

Exhibit 6-1. Overview of Field Biological Sampling Methods

Sample Parameter	Information Gained	Method of Collection	References
Fish	• Community structure • Distributions (depth & basin wide) • Biomass • Density • Bioconcentration • Fecundity	• Electroshocking • Seines • Gill nets • Trawls • Angling • Traps	APHA, 1992; ASTM, 1991; Everhart et al., 1975; Nielsen and Johnson, 1983; Plafkin et al., 1989; Schreck and Moyle, 1990; Ricker, 1975; Weber et al., 1989
Limitations:	Each method is biased to some degree as to the kind and size of fish collected. Some methods are designed for use in relatively shallow water.		
Phytoplankton Algae)	• Chlorophyll a • Community structure • Primary productivity • Biomass • Density	• Plankton buckets attached to vertical or horizontal tow net (e.g., Wisconsin style net) • Discreet depth samples using VanDorn or Kemmer bottles • Periphytometer	American Public Health Association-(APHA), 1992; American Society for Testing and Materials-(ASTM), 1991; Lind, 1985; Vollenweider, 1969; Weber et al., 1989; Wetzel and Likens, 1979
Limitations:	Small organisms can pass through the net, and periphytometers can only be used for algae that attach to a substrate.		
Zooplankton	• Community structure • Distributions • Biomass • Sensitivity • Density	• Plankton buckets attached to vertical or horizontal tow net (e.g., Wisconsin style net) • Discreet depth samples using VanDorn or Kemmer bottles	APHA, 1992; ASTM, 1991; Lind, 1985; Pennak, 1989; Weber et al., 1989; Wetzel and Likens, 1979
Limitations:	Small organisms can pass through the net; some zooplankton migrate vertically in the water column, so it is possible to miss some species.		
Benthic invertebrates	• Community structure • Biomass • Density • Distributions • Tissue analysis	• Ponar grab sampler • Eckman dredge sampler • Surber sampler • Hess sampler • Kick net or D-ring net • Artificial substrates	APHA, 1992; ASTM, 1991; Lind, 1985; Merritt and Cummins, 1984; Pennak, 1989; Weber et al., 1989; Klemm, 1990; Wetzel and Likens, 1979; Plafkin et al., 1989
Limitations:	Some methods are time-consuming and labor-intensive; some methods can only be used in shallow waters.		
Riparian and aquatic macrophytes	• Community structure • Distributions (depth & basin wide) • Biomass • Density • Tissue analysis	• Usually qualitative visual assessments • Quantitative assessments using quadrant or line point methods	APHA, 1992; ASTM, 1991; Dennis and Isom, 1984; Vollenweider, 1969; Weber et al., 1989; Wetzel and Likens, 1979; Plafkin et al., 1989
Limitations:	Limited to the growing season for many species.		

VanLandingham (1982) provide useful guides to the environmental requirements and pollution tolerances of diatoms and blue-green algae, respectively.

Zooplankton. Zooplankton are free-floating aquatic protozoa and small animals. Many species are sensitive indicators of pollution. Particularly in lakes and reservoirs, zooplankton can provide information on the presence of specific toxics. Zooplankton are often collected by towing a plankton net through a measured or estimated volume of water. To calculate population density it is necessary to determine the volume of the sampling area, using a flow meter set in the mouth of the net or calculations based on the area of the net opening and the distance towed. Laboratory analyses can provide information similar to that for phytoplankton.

Benthic Macroinvertebrates. Benthic macroinvertebrates are organisms such as plecoptera (stoneflies), ephemeroptera (mayflies), and trichoptera (caddisflies) that live in and on sediments. Like plankton, benthic macroinvertebrates include useful indicator species that can provide valuable information about the degree of organic enrichment, local dissolved oxygen conditions, and the presence and nature of toxics in the sediments of lakes and reservoirs.

Monitoring teams generally use dredges, artificial substrates, and kicknets to sample benthic macroinvertebrates, depending on the bottom substrate and water depth. Samples are either preserved in their entirety in polyethylene bags or other suitable containers or are washed through a fine sieve and then preserved in a suitable container (Klemm, 1990). The sample can be analyzed for taxa present, the total density of each taxon, relative abundance by numbers or biomass of these taxa, changes in major and indicator species populations, and the total biomass of benthic macroinvertebrates present.[7]

[7] Three manuals (U.S. EPA, 1983b, 1984a, 1984b) discuss the interpretation of biological monitoring data for larger bottom-living invertebrates. *The Rapid Bioassessment Protocols* (Plafkin et al., 1989) manual discusses the use of fish and macroinvertebrates as a screening method in assessing environmental integrity. *Macroinvertebrate Field and Laboratory Methods for Evaluating the Biological Integrity of Surface Waters* (Klemm, 1990) discusses analysis of qualitative and quantitative data, community metrics and pollution indicators, pollution tolerance of selected macroinvertebrates, and Hilsenhoff's family-level pollution tolerance values for aquatic arthropods.

6.4.4 Analysis of Biological Data

Community structure can be described in terms of species diversity, richness, and evenness. Diversity is affected by colonization rates, the presence of suitable habitats, extinction rates, competition, predation, physical disturbance, pollution, and other factors (Crowder, 1990).

A qualitative data assessment can help determine which factors have caused measured variation in species diversity. In such an assessment, the collected species and their relative population sizes are compared with their known sensitivities to contaminants present. The tendency of species to be abundant, present, or absent relative to their tolerances or sensitivities to sediments, temperature regimes, or various chemical pollutants can indicate the most likely cause of variation in species diversity at the sampled sites.

Two cautions should be noted regarding qualitative analysis. First, different strains of the same species can sometimes have differing sensitivities to a stressor, particularly where species have undergone extensive hatchery breeding programs. Second, because listed characteristics of organisms can vary from region to region, it is important when using lists of indicator species to note whether the data were collected in the same region as the CSO study. Investigators should generally limit the use of diversity indices as general indicators of environmental effects to comparisons within the study where sampling and sample analysis methods are consistent. Before conducting a biological assessment, investigators should contact local authorities to determine whether biological reference data can be obtained to use in the CSO study. Data should be from biological reference sites that have similar physical characteristics (e.g., comparable habitat).

Rapid Bioassessment Protocols

Rapid biological assessments, using techniques such as rapid bioassessment protocols (RBPs), are a valuable and cost-effective approach to evaluating the status of aquatic systems (Plafkin et al., 1989). RBPs integrate information on biological communities with information on physical and chemical characteristics of aquatic habitats.

RBPs have been used successfully to:

- Evaluate whether a stream supports designated aquatic life uses
- Characterize the existence and severity of use impairments
- Identify sources and causes of any use impairments
- Evaluate the effectiveness of control actions
- Support use attainability analyses
- Characterize regional biotic components within ecosystems.

Typically, RBPs provide integrated evaluations that compare habitat and biological measures for studied systems to empirically-defined reference conditions (Plafkin et al., 1989). Reference conditions are defined based on data from systematic monitoring of either a site-specific control station or several comparable sites in the same region. A site-specific control is generally considered to be representative of the "best attainable" conditions for a particular waterbody. When using data from several regional sites, the sites are selected to represent the natural range of variation in "least disturbed" water chemistry, physical habitat, and biological conditions. A percent similarity is computed for each biological, chemical, or physical parameter measured at the study sites relative to the conditions found at the reference site(s). These percentages may be computed based on the total number of taxa found, dissolved oxygen saturation, or the embeddedness of bottom material.

Generally, where the computed percent similarity is greater than 75-80 percent of the corresponding reference condition (depending on the parameter compared), the results can indicate that conditions at the study sites are sufficiently similar to those occurring at the reference site(s). For such cases it is reasonable to conclude that the study sites' conditions are "non-impaired." In contrast, where the computed percent similarity of conditions at the study sites is less than 50 percent of the reference conditions (depending on the parameter compared), it is reasonable to conclude that conditions at those study sites are "severely impaired," relative to the reference site(s). For those sites with a percent similarity falling between these ranges, the results can indicate that conditions at the study sites are "moderately impaired" (Plafkin et al., 1989). An application of the use of RBPs in two case studies is presented in *Combined Sewer Overflows and the Multimetric Evaluation of Their Biological Effects: Case Studies in Ohio and New York* (U.S. EPA, 1996).