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STUDY OF FEDERAL WATER QUALITY MONITORING EFFICIENCY

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STUDY OF FEDERAL WATER QUALITY MONITORING EFFICIENCY

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FOREWORD

This "Study of Federal Water Quality Monitoring Efficiency" reports on one of two parallel projects contracted by the Council on Environmental Quality with Enviro Control, Inc., in compliance with Section 11 of the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500). The second report is entitled "Study of Federal Water Quality Planning Efficiency." Section 11 directs in part that:

> "The President shall conduct a full and complete investigation and study of ways and means of utilizing in the most effective manner all of the various resources, facilities, and personnel of the Federal Government in order most efficiently to carry out the objective of the Federal Water Pollution Control Act..."

This study was performed by Enviro Control, Inc., under contract to the Council on Environmental Quality, and was subsequently reviewed by those Federal agencies substantially affected by its findings. Nearly all of these agencies' factual corrections and many of the qualitative comments that could be justified on their merit and within the scope of this effort were incorporated in this final version.

The original research was completed in August 1974, though some updating took place during the subsequent agency review. Consequently, information with a time value, such as program budgets and status should be considered applicable only as of that date.

This report was prepared by Dr. Alex Hershaft, with the assistance of many members of the Enviro Control staff. Special acknowledgement is due to Ms. Doris Bauer and to Messrs. Jerome Horowitz and Pierre Sprey for their important contributions to the original compilations, and to Ms. Cathy Steele for typing the many drafts.

We are deeply grateful to Mr. Steffen Plehn and Dr. James Reisa of the Council on Environmental Quality for their valuable guidance and sympathetic understanding for some of the handicaps and delays we faced in the performance of this study. In addition, very little of this information could have been compiled without the helpful cooperation of the many Federal and state officials listed in the Appendix. Finally, we derived much useful information from pertinent reports by the General Accounting Office.

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I. OVERVIEW AND SUMMARY

Water quality monitoring is a vital tool in the process of cleaning up our nation's waters. This study seeks to improve the effectiveness and efficiency of water quality monitoring through a critical review and analysis of pertinent Federal policies and practices. Here, we provide an overview of the scope, performance, and findings of our work.

A. PURPOSE AND SCOPE OF THE STUDY

The deteriorating quality of our waters has been long regarded as a most serious environmental problem facing the nation, as rivers, lakes, estuaries, coastal waters, and at times, underground aquifers became polluted beyond their assimilative capacity. Consequently, water pollution control has absorbed the largest share of the national commitment to the enhancement of environmental quality, and improvements in the efficiency of water quality management promise a relatively high return.

Accordingly, in Section 11 of the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500) the U. S. Congress has directed the President to "conduct a full and complete investigation and study of ways and means of utilizing in the most effective manner all of the various resources, facilities, and personnel of the Federal government in order most efficiently to carry out the objective of the Act". This <u>Study of Federal Water Quality Monitoring Efficiency</u> seeks to fulfill in part the requirements of Section 11. A parallel effort has been undertaken to investigate the efficiency and effectiveness of Federal water quality planning activities.

The purpose of this study, then, is to investigate the ways and means of utilizing, in the most effective manner, the various resources of the Federal government, in order most efficiently to carry out the monitoring objectives of PL 92-500. More specifically, it is to review and examine critically Federally supported water quality monitoring activities, to identify problem areas, and to recommend specific ways and means of improving their effectiveness and efficiency.

Accordingly, the thrust of our investigation has been directed to those activities and other items of information that bear a direct relevance to the efficiency of current Federal programs in water quality monitoring, in general, and implementation of PL 92-500, in particular. Some areas of interest that have received only scant or no attention include:

- Methodologies and analytical techniques of water quality monitoring
- Major findings of monitoring programs, such as water quality trends
- State and local monitoring programs that are not Federally funded
- Water monitoring activities undertaken for objectives other than those of PL 92-500.

Finally, the validity and firmness of our conclusions and recommendations must be weighed in the light of the limited resource (one-half of a person year) available for the completion of this study. Consequently the recommended actions reflect only our best, educated judgment based on limited information, and any resultant attempt to reorient a major program should be preceded by a specific, in-depth tradeoff analysis.

The sections that follow provide an overview of the content and findings of this report.

B. OBJECTIVES AND REQUIREMENTS

The effectiveness of water quality monitoring should be judged in terms of how well the data obtained serves the monitoring objectives. Chapter II discusses these objectives and the corresponding monitoring requirements under the following headings:

- Nature and objectives of monitoring
- Data collection requirements
- Processing and dissemination requirements.

1. Nature and Objectives of Monitoring

Monitoring of water quality consists of sample collection, transportation, and analysis, as well as transmission, storage, processing, retrieval, and dissemination of data for the purpose of characterizing the quality of a body of water. This definition excludes stream flow and stage measurements undertaken for the purpose of forecasting availability of water supplies and probabilities of flooding, although flow rate is certainly an important consideration in determining water quality. Water quality monitoring is further characterized in terms of:

- Objectives of monitoring
- Type of information sought
- Timing and spacing of measurements.

The major objectives of water quality monitoring are formulated here as characterization and regulation of discharges, water quality planning, and scientific investigation. The various types of information needs may be sought through chemical and physical monitoring, biological monitoring, and remote sensing. Timing and spacing of measurements divides monitoring activities into long-term monitoring programs and intensive surveys.

Characterization and regulation of discharges is discussed in terms of industrial and municipal point sources, as well as various types of non-point sources. The latter includes rural runoff, urban runoff, ground water upflow, and sludge blankets. Regulation of discharges serves to implement the effluent limitations imposed under the National Pollutant Discharge Elimination System and/or as a result of waste load allocation for water quality-limited segments.

Monitoring for water quality planning may serve a number of water quality planning and management objectives, such as determination of compatibility with intended uses, definition of problem areas, assessment of the long-term trends. Scientific investigations that require monitoring of water quality may be classified as geochemical biochemical and biological, or hydrological and hydraulic.

2. Data Collection Requirements

Data collection requirements are examined in terms of water quality parameters, sampling frequency and location, and analytical methods. After listing a number of water quality parameters collected by various agencies, a dozen of the more important ones are discussed in terms of their impact on water quality and the peculiarities of their measurements.

In a subsequent section, the location of the monitoring station and frequency of measurement are related to the spatial and temporal variability of the parameters measured and their importance to the program objectives. This is done both for long-term monitoring programs and for comprehensive surveys.

The last section under Data Collection Requirements addresses the handling and analysis of the sample including annotation, transportation to the analytical laboratory, performance of analysis with adequate quality control, and data reduction and storage. The discussion encompasses the advantages and drawbacks of central vs. field laboratories, and the need for a reliable analytical method guarded by strict quality control measures.

3. <u>Processing and Dissemination Requirements</u>

The data generated by an effective water quality monitoring program should be of a quality and form that would facilitate and legitimize their application to the solutions of the problem that prompted their collection, as well as of other current and future water quality problems. Thus, one should look beyond the data collection step, to storage, processing, retrieval, dissemination, as well as application of water quality data by the user.

The logical steps of the procedure following collection, transportation, and analysis of the water samples should include cataloging of data and performance of validity checks, processing of the data into suitable format, storage in a readily accessible and processable form, and maintenance of an ongoing review of the system's capability to meet changing user requirements.

C. DATA COLLECTION ACTIVITIES

The past, current, and anticipated data collection activities are reported in Chapter III under the following headings:

- Chemical and physical monitoring
- Biological monitoring
- Remote sensing.

1. Chemical and Physical Monitoring

The extent and type of chemical and physical monitoring of water quality conducted by Federal, state, and local agencies in the U. S. are presented on the basis of information furnished by the Digest of the 1972 Catalog of Information on Water Data, compiled by the Office of Water Data Coordination of the U. S. Geological Survey. Figures 1 and 2 show the total number of active water quality stations in each state, as distributed by agency and type of water body, respectively. In sum, 12 Federal and 135 non-Federal agencies reported operation of 6,414 and 6,154 surface water stations, respectively, while 6 Federal agencies and 37 non-Federal agencies reported the operation of 2,854 and 2,615 ground water stations, respectively, for a grand total of 18,037 water quality monitoring stations as of January 1972. Table 1 breaks down this number in accordance with the Federal agency responsible and the type of water body, while Tables 2 and 3 report the number of stations and the relative frequency of measurement of the various surface and ground water quality parameters, respectively.

The two major national monitoring networks are taken up next. The National Stream Quality Accounting Network (NASQAN) is operated by the U.S. Geological Survey to monitor water quality of waterways and to provide uniform, national data for determining water quality trends. The Network consists of 525 monitoring sites located in "Hydrographic Accounting Units" spaced sequentially along the nation's major waterways. Approximately 345 monitoring stations are in operation at the present time, and the Network is expected to be fully operational by July 1976.

The National Water Quality Surveillance System (NWQSS) is implemented by the Environmental Protection Agency in compliance with Section 104 (a)(5) of PL 92-500. Its objective is to obtain a long-term base for determination of trends, establishment of relationships between land use and water quality, and evaluation of the effectiveness of pollution control efforts. At present, 150 stations, including 60 pairs, report 25 parameters on a biweekly and 5 parameters on a monthly basis.

Federal monitoring of coastal water quality is conducted by the U. S. Environmental Protection Agency, the National Oceanic and Atmospheric Administration, and the U. S. Coast Guard in the following areas:

- Development of a national coastal monitoring plan
- Monitoring of offshore dumping sites
- Marine ecosystems investigations
- Measurements of salinity and temperature.

Table 4 lists the number of monitoring stations and measurements taken in the coastal zone of 28 states and indicates that a number of states have increased their coastal monitoring efforts considerably in recent years.

The last portion of the section on chemical and physical monitoring deals with the Analytical Quality Control Program conducted by EPA's Quality Assurance Division in the Office of Research and Development and by the 10 regional offices. The principal activities include validation of new analytical methods, preparation of guidelines and manuals for analytical procedures and quality control programs, inspection of EPA and state water quality monitoring programs, and provision of reference samples. In the near future, EPA regulations promulgated under Section 106 (e)(1) will require all states to institute quality control programs that meet with the approval of EPA regional offices.

2. <u>Biological Monitoring</u>

The usefulness and need for biological monitoring of water quality has only recently received its long-deserved recognition. The nature and contributions of biological monitoring are discussed in Section B of

Chapter III, along with the types of surveys undertaken and the current Federal and state biological monitoring activities.

The more common types of biological investigations include identification of specific indicator organisms, community diversity studies, bioaccumulation surveys, and lake eutrophication surveys. Biological monitoring seeks to complement, rather than replace, chemical and physical monitoring by introducing such advantages as fidelity, sensitivity, instantaneity, and cumulativity. Each of these characteristics is discussed in turn.

The two principal Federal agencies concerned with biological monitoring are the U. S. Environmental Protection Agency and the Bureau of Sport Fisheries and Wildlife (BSFW). EPA conducts both field and laboratory studies to establish water quality criteria for the recognized beneficial uses and to develop biological monitoring techniques. Biological field studies include reconnaissance surveys, synoptic surveys, and comparative evaluations. The laboratory investigations involve development of methods and manuals for collecting, processing, and evaluating biological data.

The major biological water quality monitoring activities of the BSFW consist of studies of the Great Lakes, reservoirs, and large rivers, as well as the pesticide monitoring program. The latter program involves the collection of several specimens of three designated species of fish at 100 stations throughout the U. S. and their analysis for nearly 20 pesticides and heavy metals.

At present, only a handful of states appear to have viable and systematic biological monitoring programs under way. However, Section 106(e)(1) of PL 92-500 requires that all states institute such programs by July 1974. To assist the states in meeting this requirement, the EPA has compiled a Model State Water Monitoring Program incorporating guidelines on biological monitoring.

3. Remote Sensing

The applicability of remote sensing as a complementary tool in water quality monitoring is examined in the last section of Chapter III in terms of its capabilities and potential benefits. The remote sensing vehicles considered include low and high altitude aircraft, observation satellites, and data collection platforms.

The water quality parameters detectable by remote sensing instruments include sediment, algae, oil, acids, and temperature. The major advantages of remote sensing may be characterized as synopticity, rapid coverage, and serendipity. The principal shortcomings are poor penetration beneath the water surface, dependency on reflected light, inability to penetrate cloud cover, and inability to yield reliable quantitative estimates. Each characteristic is discussed in some detail.

Subsequent portions of the section on remote sensing address data collection and processing techniques, as well as aircraft monitoring, space satellite monitoring, and data collection platform programs. Aircraft programs include both low altitude and high altitude overflights, as well as the remote sensing activities of EPA's National Environmental Research Center in Las Vegas. Discussion of space satellite programs covers Earth Resources Technology Satellite (ERTS), Skylab, Earth Observation Satellite (EOS), and Geostationary Operation Environmental Satellite (GOES).

D. PROCESSING AND DISSEMINATION

Current methods for processing and dissemination of water quality data vary widely, from a drawer full of notebooks and files to complex computerized storage and inventory systems. Chapter IV describes these methods under the following headings:

- Traditional methods
- Automated storage and retrieval systems (STORET and WATSTOR)
- Inventory systems (NAWDEX and ENDEX).

1. Traditional Methods

The traditional methods of storing water quality data in files and laboratory notebooks works reasonably well, provided that the data are properly cataloged and organized and that their existence is known to prospective users. Unfortunately, most water quality data files do not meet these criteria and must be sought among the holdings of a number of different agencies.

2. Automated Storage and Retrieval Systems

EPA's storage and retrieval systems (STORET) has the capability of receiving, storing, processing, and retrieving vast amounts of water quality data, with access by remote terminals. At present, it contains water quality data from some 200,000 active and inactive stations operated by Federal and State agencies at over 300 sites, and additional stations and data quality controls are being introduced. The STORET system is comprised of the Water Quality File, which includes primarily data on bodies of water, and the General Point Source File covering data on point source effluents. The future status of the latter is uncertain.

The U.S. Geological Survey's National Water Data Storage and Retrieval System (WATSTORE) collects and processes large amounts of both surface and ground water quality data and geologic data pertinent to ground water aquifiers. Data are supplied by approximately 40 of the Water Resources Division's district offices, more than 9,000 automated data collection stations and the USGS's three central water quality laboratories. Raw or processed data can be retrieved through computer terminals at most of the Water Resources Division's district offices.

3. <u>Inventory Systems</u>

The U.S. Geological Survey (USGS) and the National Oceanic and Atmospheric Administration (NOAA) have attempted to fill the need for inventories of water quality data collected by the many Federal, state, and local agencies through the development of cataloging and inventory systems, such as the Catalog of Information on Water Data, the National Water Data Exchange (NAWDEX), and the Environmental Data Exchange (ENDEX).

The Catalog of Information on Water Data compiles information on the extent and nature of water quality monitoring, as well as measurement of stream flow and stage that is of use in water resources planning. Information on water quality data includes station identification and location, type of water bodies sampled, period of record, form of data storage, parameters and their measurement frequency, and reporting agency.

The USGS National Water Data Exchange (NAWDEX) is slated to serve as an indexing and filing system for storage and retrieval of water and related data in such areas as geology, meteorology, and water quality. It will provide participating groups with standardized guidelines for data handling, storage, and retrieval. Inception of services is scheduled for late 1975, with full implemen-

The Environmental Data Exchange (ENDEX) is a part of NOAA's Environmental Data Services and consists of a compilation of inventories and directories. Of primary interest to water quality data users is the Environmental Data Base Directory, an inventory of environmental data available throughout the world. The range of topics includes meteorology, geology, geophysics, space, solar energy, as well as inland and oceanographic water data. The ENDEX-EDBD system is scheduled to begin operations in the summer of 1974.

E. LEGISLATION AND PROGRAMS

A number of Federal, state, and local agencies are engaged in water quality monitoring, frequently without coordination, or even knowledge of each other's activities. Chapter V seeks to describe the programs of Federal and state agencies under the headings of:

- Legislation and funding
- Federal programs
- State programs.

1. Legislation and Funding

This section begins with a review of the water quality monitoring provisions of the Water Pollution Act of 1972 (PL 92-500) and the Marine Protection, Research, and Sanctuaries Act of 1972 (PL 92-532). Next, the ensuing EPA monitoring policy, regulations, and guidelines are described.

The estimated monitoring budgets for Federal and state agencies are presented in Tables 5 and 6, respectively. The Federal budget for fiscal year 1975 is approximately $17 million, whereas the combined budget of all states, including Federal subsidies, is in excess of $26 million.

2. Federal Programs

The principal Federal agencies involved in water quality monitoring are the U. S. Environmental Protection Agency, the U. S. Geological Survey, and the U. S. Army Corps of Engineers. However, as is noted in Table 7, a number of other Federal agencies are substantially involved in this effort. These include the U. S. Atomic Energy Commission, the Bureau of Reclamation, the Bureau of Sport Fisheries and Wildlife, the U. S. Coast Guard, the National Aeronautics and Space Administration, the

National Oceanic and Atmospheric Administration, and the Soil Conservation Service. The remainder of this section describes the mission and major water quality monitoring programs of each agency.

3. State Programs

Water quality monitoring on the state level is performed primarily in support of pollution control and public health programs. These programs have grown rapidly since 1966 and are expected to surpass the Federal effort in the near future. The last section of Chapter V presents the state programs in terms of the typical agency and their relationship, the number of stations and annual budgets, and the raising of monitoring revenues through surveillance fees. The latter are charges levied against dischargers by state or local agencies to defray the cost of monitoring the discharges and the resultant ambient water quality.

F. ANALYSIS

The analysis of the effectiveness and efficiency of Federally supported water quality monitoring activities described in the preceding chapter is presented in Chapter VI in terms of the following major problem areas, after a discussion of the purpose and scope of the analysis:

- Quality of monitoring data
- New monitoring methods
- Coordination of monitoring
- Utilization of monitoring data.

1. Quality of Monitoring Data

This first section examines the prevalent quality of monitoring data in terms of the relevance of sampling station location and scheduling, as well as sample handling and analysis, to the specific needs and objectives of the monitoring program. An examination of the number of measurements for various parameters contained in the STORET data file reveals that there is little relation between the relevance of a parameter to water quality management and frequency of measurement. Selection of sampling location and timing frequently suffers from a similar lack of relevance to program objectives. Another major affliction of water quality monitoring programs lies in the lack of validity and reproducibility of analytical results, which leads to several adverse consequences.

2. New Monitoring Methods

The promise and importance of the newer monitoring methods are examined here, including biological monitoring, sediment analysis, and remote sensing.

The analysis points out that the first and most important measurement directed at detection of toxic substances and assessment of the viability of a water body should be the concentration of toxicants in representative aquatic animals and plants, followed by sediment analysis to characterize the nature, location, and extent of the problem. Only then, measurements in the water column should serve to pinpoint the sources of discharges and transport mode of the toxic substances. Both biological monitoring and sediment analysis are receiving increasing attention as a result of implementation of the monitoring provisions of PL 92-500.

In the last portion of this section, the major advantages and problems of remote sensing systems to water quality monitoring are listed and discussed and several avenues to improve past performance are outlined.

3. Coordination of Monitoring

Uncoordinated water quality monitoring programs of the many different Federal, state, and local agencies create considerable gaps and overlaps in the availability of useful data. Moreover, the findings and reconciliation of these data present a formidable task to the potential user.

The analysis in this section begins with the recounting of our own experiences in attempting to use data generated by various agencies. Next, it examines some state and Federal efforts to alleviate these problems, including those of the USGS Office of Water Data Coordination. The advantages and problems of NAWDEX, ENDEX, and STORET are discussed in some detail. Finally, the analysis turns to the examination of the suitability of several types of regional agencies for coordinating water quality monitoring and concludes that states are best equipped for this task.

4. Utilization of Monitoring Data

The analysis in this section points out that water quality data is frequently collected, but not used for any worthwhile purposes and cites as evidence our own experience with monitoring files of ten states. The efforts of several other states to analyze and publish their data on a systematic basis are mentioned as well. The analysis concludes by pointing out that PL 92-500 provides a clear mandate for analysis of water quality data by states.

G. RECOMMENDATIONS

The recommendations for improving the effectiveness and efficiency of Federally supported monitoring activities are presented in Chapter VII on the basis of the analysis performed in the preceding chapter. The organization of the material corresponds to that of the analysis chapter, under the headings of:

- Purpose and scope of the recommendations
- Quality of monitoring methods
- New monitoring methods
- Coordination of monitoring
- Utilization of monitoring data.

1. Purpose and Scope of the Recommendations

The purpose of these recommendations is to suggest ways and means of improving the effectiveness and efficiency of those areas of Federal monitoring activities that were analyzed in the preceding section. Consequently, all of the qualifications on the selection and treatment of problem areas apply here as well. In other words, the recommendations focus on Federal resources involved in water quality management, on areas that are particularly significant or troublesome, and on solutions that are implementable without a major disruption in the present institutional and program structure.

Two additional points need to be noted. First, the recommendations address program functions, rather than specific program elements and their detailed funding allocations. More importantly, the recommended actions reflect only our best educated judgment, based on limited information, and any resulting attempt to reorient a major program should be preceded by a specific, in-depth tradeoff analysis.

2. <u>Quality of Monitoring Data</u>

Improvements in the quality of monitoring data are sought here in terms of improved record keeping by state agencies, evaluation of monitoring programs by Federal agencies and provisions of analytical quality controls. The pertinent recommendations are as follows:

- The U.S. Environmental Protection Agency and the U.S.Geological Survey should require that all records of Federally funded water quality monitoring programs be properly organized and annotated
- EPA regional offices should conduct an annual evaluation of the effectiveness of Federally supported water quality monitoring programs through on-site inspection of properly annotated state monitoring records
- Federal agencies involved in water quality monitoring should conduct a periodic, coordinated evaluation of the effectiveness of their monitoring activities
- EPA should require each state to incorporate an adequate analytical quality control procedure in its water quality monitoring program.

3. New Monitoring Methods

New water quality monitoring methods, such as biological and sediment analysis and remote sensing, are expected to provide a worthy complement to the traditional chemical and physical monitoring approach. Accordingly the following pertinent recommendations are made:

- EPA should require each state to incorporate biological monitoring and sediment analysis as part of its routine water quality monitoring and intensive surveys and to report annually on its progress
- EPA and the National Aeronautics and Space Administration should continue their joint development and demonstration effort in remote sensing techniques for water quality monitoring, with the cooperation of the U.S. Geological Survey and the U.S. Department of Agriculture

4. Coordination of Monitoring

Regional coordination of monitoring activities is expected to assist in filling gaps and reducing overlaps in data coverage and in steering potential users to appropriate sources of data. Accordingly, the following recommendations are made:

- EPA should seek to have each state catalog all water quality monitoring activities within its borders by publishing annual reports giving the location, description, and operating agency of each station; this effort should be coordinated with the USGS NAWDEX and Office of Water Resources Coordination Programs.

- EPA should seek to have each state inventory all water quality data collected within its borders by publishing periodic compilation of the type of information required for station descriptive summary, as well as information on the location, format, and availability of the data; this effort should be coordinated with the USGS NAWDEX and Office of Water Resources Coordination Programs
- The National Oceanic and Atmospheric Administration should strive to avoid duplicating the functions of the NAWDEX program
- The U.S. Geological Survey should direct the major thrust of its NAWDEX program toward coordinating, guiding, and supporting state water quality data inventory programs, as well as toward maintaining inventory of water quality data of national significance
- EPA should seek to have each state review biennially and report on the desirability of consolidating all or a part of the water quality data collected within its borders in one or more central locations
- EPA should gradually redirect the major thrust of its STORET program toward complementing, supporting, and guiding state water quality data storage and processing programs, and toward improving its capabilities for data of national significance
- EPA should seek to have each state review biennially and report on the desirability of consolidating in

some form selected water quality monitoring activities within its borders

- EPA regions should seek to have various states consolidate in some form selected water quality monitoring activities in the water bodies which they share with other states
- EPA should review biennially its water quality monitoring activities to determine the desirability of consolidating some of these operations within one office.

5. Utilization of Monitoring Data

Utilization of water quality monitoring data will be encouraged substantially through implementation of our earlier recommendations. Additional assurance can be sought through the following recommendation:

- EPA should seek to have each state monitoring program emphasize the analysis and application aspect to the full extent commensurate with program objectives and the quality and quantity of data collected.

PRESENTATION

II. OBJECTIVES AND REQUIREMENTS

The effectiveness of water quality monitoring must be measured in terms of how well the data obtained serve the monitoring objectives. These objectives and the corresponding monitoring requirements are discussed here under the following headings:

- Nature and objectives of monitoring
- Data collection requirements
- Processing and dissemination requirements

A. NATURE AND OBJECTIVES OF MONITORING

Monitoring of water quality can be a vital and effective tool of water quality planning and management, provided that it is performed and applied judiciously and in concert with its legitimate objectives. These general concepts are explored here, while the specific data collection, processing, and dissemination requirements are taken up in the sections that follow.

1. Nature of Monitoring

Monitoring of water quality consists of sample collection, transportation, and analysis, as well as transmission, storage, processing, retrieval and dissemination of data for the purpose of characterizing the quality of a body of water. This definition excludes streamflow and stage measurements undertaken for the purpose of forecasting availability of water supplies and probabilities of flooding, although flow rate is an important consideration in determining water quality. Water quality monitoring may be characterized on three levels, as follows:

- Objectives of monitoring
- Type of information sought
- Timing and spacing of measurements.

The major objectives of water quality monitoring may be formulated as follows:

- Characterization and regulation of discharges
- Water quality planning
- Scientific investigations.

A precise definition of the objective of monitoring is essential to the successful collection and application of water quality data. For this reason, each of these objectives is covered separately in the sections that follow.

The type of information sought represents the most common level of classification and one that we will use here in describing data collection methods in the next chapter. It divides monitoring activities into:

- Chemical and physical monitoring
- Biological monitoring
- Remote sensing

Chemical and physical monitoring consists of measuring the more traditional water quality parameters, such as biochemical oxygen demand, dissolved oxygen, dissolved solids, suspended solids, nitrates, phosphates, color, odor, pH, and conductivity. A crucial, long neglected, aspect is analysis of the bottom sediment that frequently contains the less soluble toxic substances. Biological monitoring, which is only now receiving due recognition, involves the determination of the effects of water pollution on aquatic organisms. Finally, remote sensing, still largely in the experimental stage, appears as a valuable tool for identifying critical areas requiring additional investigation and for detecting gross changes in water quality.

The last classification typically divides monitoring activities into routine monitoring programs and intensive surveys. The former are conducted routinely, over the full extent of all bodies of water at broad intervals of space and time, by measurement of uniform parameters at fixed stations, typically for the purpose of assessing long-term trends in water quality or the effects of a management action. Intensive surveys, on the other hand, are undertaken in accordance with a special design, over a specific portion of a water body, using measurements closely spaced in area and time, and to meet a specific and temporary objective, such as the investigation of a fish kill or the planning of a construction project affecting water quality.

2. Characterization and Regulation of Discharges

Discharges responsible for pollution of water bodies are generally classified as issuing from either "point" or "non-point" sources. In the past, the classical point sources consisting of municipal and industrial wastewater discharge fallout pipes, have formed the sole area of concern for water pollution abatement efforts. More recently, however, the focus of attention has been shifting toward non-point sources, which appear to contribute much of the pollutant loading in many water bodies, including those adjacent to urban areas. Non-point sources may be classified as:

- Rural runoff
- Urban runoff
- Ground water flow
- Offshore dumping
- Sludge blankets

Rural runoff from rain and snow melt carries with it substances dissolved or scoured from the land over which it runs. These substances range from naturally occuring salts, soil particles, animal waste, and decomposing plant matter, to man-influenced pesticides, herbicides, fertilizers, livestock manure, acid mine drainage, metal leachates, and phosphate slime. The man-influenced substances are generated by crop and livestock production, logging and land clearing operations, as well as extraction and processing of minerals. As a result of the sporadic nature of rainfall and snow melt, and the lack of adequate pollution controls, rural runoff is frequently the principal cause of the remarkable variability in water quality.

Urban runoff is of similar character, but originates from the roofs of buildings and paved surfaces of the more built-up and densely populated urban areas. It contains dirt, organic matter, bacteria, viruses, metal and rubber particles, oil, and grease, produced by street litter, pet excrements, vehicular traffic, construction, and atmospheric fallout.

Precipitation or irrigation water percolating down to subsurface aquifers, leach out substances along the way causing pollution of ground water. These substances include naturally occurring salts in the soil, pesticides, fertilizers, discharges from cesspools, septic tanks, and leaky sewers, and leachates from solid waste dumps and sanitary landfills. This ground water frequently flows into surface waters and provides nearly the entire surface flow during dry spells.

Sludge blankets are polluted bottom sediments generated by deposition of insoluble or slightly soluble substances that are discharged into the water from point sources or formed in the water by reactions among soluble pollutants. Toxic substances contained in these deposits are released gradually into the water column through direct dissolution, through biochemical transformation into a soluble form (as illustrated by the conversion of insoluble mercury metal to the soluble and deadly methyl mercury salt by benthic microorganisms), or through ingestion by benthic organisms and consequent transmission in the food chain.

Characterization of both point and non-point source discharges is needed to inventory the loads and flows of a given area and to provide for waste load allocations, two essential steps of the water quality planning process. Such characterization requires first the detection of the source, then the determination of the amount and composition of the discharge as a function of time, over the period of interest.

Regulation of discharges serves to implement the effluent limits imposed under the National Pollutant Discharge Elimination System and/or as a result of waste load allocations for water quality limited segments. Effluent standards for point sources have been under development for several years, and non-point source standards are currently under consideration by EPA officials.

3. Water Quality Planning

The determination of water quality may serve a number of water quality planning and management objectives outlined below:

- Determination of compatibility with intended uses
- Definition of problem areas
- Assessment of the effects of a management action
- Assessment of long-term trends.

Determination of the compatibility of water quality with such intended uses as municipal water supply, propagation of fish and wildlife, contact sport, noncontact recreational activities, irrigation, industrial processing, or power plant cooling, is performed by checking specific water quality parameters against the standards and criteria first promulgated by the U. S. Public Health Service and subsequently expanded by the Federal Water Pollution Control Administration (now EPA). A gross characterization, including biochemical oxygen demand, dissolved oxygen, dissolved and suspended solids, coliform count, color, and odor is relatively easy to obtain. The more subtle effects of pollutants on aquatic organisms require extensive biological monitoring.

The remaining objectives of monitoring for water quality planning all serve the general purpose of achieving cleaner waters by focusing management action on the more critical problem areas and then assessing the effectiveness of these actions. Typically, a preliminary gross determination is obtained through routine long-term monitoring, and more precise localized results are achieved by specially designed intensive surveys. It is expected that remote sensing will make a valuable contribution to the former phase, while biological monitoring has already proven its worth to the latter.

4. Scientific Investigations

Scientific investigations that require monitoring of water quality may be classified as follows:

- Geochemical
- Biochemical and biological
- Hydrological and hydraulic

Geochemical investigations constitute one of the earliest applications of water quality monitoring by personnel of the U. S. Geological Survey. Some of these investigations have attempted to relate the mineral constituents of streams to the geochemistry of their basins. Primary emphasis has focused on the common salts of sodium, potassium, and calcium, but naturally occurring toxic substances, such as barium, lead, and mercury are being investigated as well.

Biochemical and biological investigations constitute perhaps the largest and most complex area of scientific monitoring. Fundamental questions now being addressed include the fate of trace toxicants in the food chain and their metabolic transformations, effects of trace toxicants and such common water parameters as salinity, transparency and temperature on individual aquatic species or communities, and the nature and role of limiting nutrients in eutrophic waters.

Investigations of hydrological and hydraulic phenomena have contributed substantially to water quality planning and management. Modeling of pollutant transport and water circulation and flow patterns has shed considerable light on the crucial relationship between the composition and amount of waste discharges and the quality of the receiving waters, as well as the assimilative capacity of streams. Investigations of ground water flow through various geological formations and the fate of pollutants in that process are important to the understanding of the contributions of ground water to both the quantity and quality of surface waters.

B. DATA COLLECTION REQUIREMENTS

Data collection requirements must be spelled out carefully to fulfill the specific objectives of a given monitoring program. These requirements are discussed below in terms of water quality parameters, sampling frequency and location, and analytical methods.

1. Water Quality Parameters

The more commonly measured water quality parameters are:[1]

- Dissolved oxygen (DO)
- Biochemical or chemical oxygen demand (BOD or COD)
- Dissolved solids (DS)
- Suspended solids (SS)
- Nutrients (nitrogen and phosphorus compounds)
- Toxic substances
- Coliform bacteria
- Color and/or turbidity
- Odor
- Temperature
- pH
- Conductivity
- Radioactivity

Dissolved oxygen represents the ability of the water to support aquatic life, whereas biochemical and chemical oxygen demands indicate the amount of oxygen-consuming matter present, and thus serve to help predict future DO levels. Dissolved solids are the soluble salts of sodium, potassium, calcium, magnesium, and other elements that remain upon evaporation of the water, while suspended solids are small particles that may settle out upon standing, or remain in colloidal suspension. Nutrient content indicates the likelihood of eutrophication, or the attainment of a nutrient level capable of promoting an explosive growth of algae that consume the DO and choke off other aquatic life.

Toxic substances encompass the salts of heavy and other toxic metals, such as beryllium, bismuth, cadmium, copper, lead, mercury, and zinc, as well as phenols, chromate, and cyanide ions, and pesticides. Coliform bacteria, while not harmful themselves, serve as an indicator of possible presence of pathogenic microorganisms. Color, turbidity, and odor serve primarily aesthetic considerations. The frequent measurement of pH and conductivity is difficult to justify for water quality planning, because the acidity of most waterways fluctuates between very narrow limits, while variations in conductivity can be due to a vast array of dissolves salts ranging from harmless to extremely toxic.

Since no sensible water quality monitoring program can, or should, measure all known water quality parameters, it becomes very important to select carefully those characteristics that represent faithfully the effects sought. Although each monitoring program should be designed specifically to serve its stated objectives, some general guidelines for parameter selection are given below.

There is little or no point in measuring dissolved oxygen monthly, or even weekly, at a single site, only during daylight, or at an unknown distance from a moving sag point. On the other hand, frequent DO measurements are essential at such critical occasions and locations as at peak discharges of organic wastes, high water temperatures, or under ice cover. Intensive, short-term, multiple-station DO surveys are likely to yield far more useful information than many years of periodic measurements at fixed sites. The single five-day analysis of biochemical oxygen demand is misleading and should be replaced by a three-point measurement of, e.g., 1, 5, and 10 day BODs, to account for the variable locations of the oxygen sag point.

Frequent measurements of dissolved solids are not necessary for water quality planning. Similarly, there is no point in measuring nutrients, unless an algal problem is anticipated. When such a problem does occur, total nitrogen or phosphorous should be measured, rather than a few fashionable components, such as ammonia, nitrates, orthophosphates, unless there is a need to identify sources of the components.

Since many toxic substances are only slightly soluble in water, measurement of their concentration in the water column will not reflect their total content and potential harm. For this reason, the most important measurement of toxic substances should take place in representative aquatic organisms and in bottom sediments. Measurement of fecal coliform bacteria is a better indicator of human pathogens than total coliform counts, since the latter include organisms from sources other than sewage.

All other parameters, again, should be measured only to the extent that the resulting data will be used to further the stated monitoring objectives. Concurrent flow measurements are essential to the subsequent calculation of gross mass balances for the various pollutants. This is a crucial step in water quality planning, which is discussed in more detail in our report on water quality planning efficiency.

2. Location and Frequency of Measurement

Location of the monitoring station, i.e., the site where the water quality parameters are measured, or where water samples are collected for subsequent analysis, should reflect the spatial variability of the parameters being measured. Similarly, frequency of measurement should be commensurate with the temporal variability of the given parameter and its importance to the program objectives. Both decisions should be consistent with the objectives of the monitoring program.

For example, in conducting a comprehensive survey of a water body, monitoring stations should be located so as to reflect any variation in water quality, e.g., due to stratification. If, on the other hand, one seeks to assess the contribution to water quality by a major urban or agricultural area, similar monitoring stations should be located on the upstream and downstream sides of the area under observation.

Scheduling of monitoring in a comprehensive survey of the water body should again provide for measurements at times that reflect any variability due to diurnal, monthly, or seasonal changes and under various representative meteorological conditions, such as temperature, precipitation, and air turbulence. For example, dissolved oxygen varies seasonally with temperature, ice cover, and windy weather, while eutrophic lakes exhibit considerable variations between daytime and nighttime measurements. Pollutants contributed by runoff, such as sediment, nutrients, and pesticides, should be sampled immediately after a rain storm, as well as during a dry spell, even though the former may involve a personal inconvenience.

A determination of upstream-downstream differences in loads ideally requires the separation of sampling times by the approximate time of travel of the sampled water, since many pollutants of interest can not be assumed to approach steady-state concentration. However, this practice may be prohibitively costly.

3. Analytical Methods

Once the sample collection program has been designed to comply with the requirements of the monitoring objectives, there follows a complex and delicate sequence of events that may be outlined as follows:

- Collect, preserve, and annotate samples (with respect to location, time, anomalies)
- Transport properly to the analytical laboratory
- Conduct analyses according to standard methods, with adequate quality control
- Reduce data
- Transmit to storage

The exact method of collecting, transporting, and analyzing the water samples can have a critical effect on the validity of the resulting data. For example, a number of constituent reactions, as well as the metabolism of most microorganisms, are highly sensitive to temperature changes, or even to vibrations of the sample container, so that the sample arriving at the laboratory may be no longer fully representative of the water quality collected at the sampling station.

For these reasons, the issue of centralization of laboratory facilities needs to be resolved to suit the best interests of the monitoring objectives. Centralized facilities tend to have better trained personnel, more reliable equipment, and less opportunity for inconsistencies of methods and procedures. On the other hand, field laboratories avoid the problems of transportation and long data "turn-around" time.

Although standard analytical methods have been developed and promulgated, they should be supplemented by a systematic quality control process. Such a process should entail at least annual inter-laboratory testing and certification, in cooperation with the EPA Method Studies and Quality Assurance and Laboratory Evaluation programs, as well as documented continuing performance checks within each laboratory. It should include determination of the precision and accuracy of each analytical method over its useful range, and analyses of replicate, split, spiked, and blind samples. An extensive presentation of laboratory quality control techniques, from equipment selection through data handling, has been published by EPA to aid in such endeavors.

Implementation and development of a sound quality control program would lead to increased exchange of data through enhanced confidence in their validity.

C. PROCESSING AND DISSEMINATION

The data generated by an effective water quality monitoring program should be of a quality and form that would facilitate and legitimize their application to the solution of the problem that prompted their collection, as well as of other current and future water quality problems. Thus, one should look beyond the data collection step, to storage, processing, retrieval, dissemination, and application of water quality data by the user.

1. Storage and Processing

The logical steps of the storage and processing portion of a monitoring program may be listed as follows:

- Receive and catalog data
- Conduct validity checks
- Process data into suitable format for storage
- Store data in readily accessible and processable form

Cataloging of data is important to ensure its availability for subsequent use and to other users. It should include station location, sampling time and frequency, parameter coverage, units, and method of analysis. Validity checks serve to eliminate at least the more glaring errors in the data. Data storage does not necessarily require the availability of a computer. A neat, well organized, and thoroughly cataloged set of notebooks or files is an acceptable substitute.

2. Retrieval and Dissemination

The logical steps of the retrieval and dissemination portion of a monitoring program should be as follows:

- Advertise holdings among prospective users
- Provide convenient access
- Accommodate requests for data promptly
- Maintain an ongoing review of the systems's capability to meet changing user requirements

Here again, provision of convenient access must not necessarily conjure up vision of shiny computer terminals within the arm's reach of the user. An effective catalog of the data files, coupled with the availability of nearby working space and a copying machine should do fine in the interim.

III. DATA COLLECTION ACTIVITIES

Current water quality data collection practices vary widely in sophistication from analysis of a grab sample in a local ill-equipped laboratory to vast networks that utilize electronic sensors to measure *in situ* a number of parameters and are interconnected by elaborate data transmission systems. The past, current, and anticipated data collection activities are reported here under the following headings:

- Chemical and physical monitoring
- Biological monitoring
- Remote sensing

The institutions responsible for these activities and their monitoring programs will be covered in Chapter V.

A. CHEMICAL AND PHYSICAL MONITORING

Collection of chemical and physical data on water quality has been the traditional approach to water quality monitoring. Recently, however, this activity has been expanded to include large networks of monitoring stations, monitoring of coastal water quality, and a growing quality control program.

1. Extent and Type of Monitoring

The extent and type of chemical and physical monitoring being conducted by Federal, state, and other agencies in the U. S. has been compiled biennially by the Office of Water Data Coordination of the U. S. Geological Survey in response to the Office of Management and Budget Circular A-67. The Circular calls upon the Department of the Interior to coordinate certain water data acquisition activities conducted by

Federal Agencies. The major items of information provided by this compilation are as follows:[2]

- Who is collecting data
- What data is being collected
- Where is the data being collected
- What are the periods of record and frequency of data collection

Figures 1 and 2 show the total number of active water quality stations in each state, as distributed by agency and type of water body. In all, 12 Federal and 135 non-Federal agencies reported operation of 6,414 and 6,154 surface water stations, respectively, while 6 Federal agencies and 37 non-Federal agencies reported the operation of 2,854 and 2,615 ground water stations, respectively, for a grand total of 18,037 active water quality monitoring stations as of January 1972. Table 1 breaks down this number in accordance with the Federal agency responsible and the type of water body. It may be noted that the U.S. Geological Survey has by far the largest number of stations with 6,262, while streams represent the most monitored type of water body with 9,846 stations.[2]

Table 2 provides a picture of the relative frequency of measurements of the various surface water quality parameters, as well as the number of stations. Temperature was the most frequently measured parameter with 10,804 stations reporting. Table 3 gives the same information for ground water quality stations.[2]

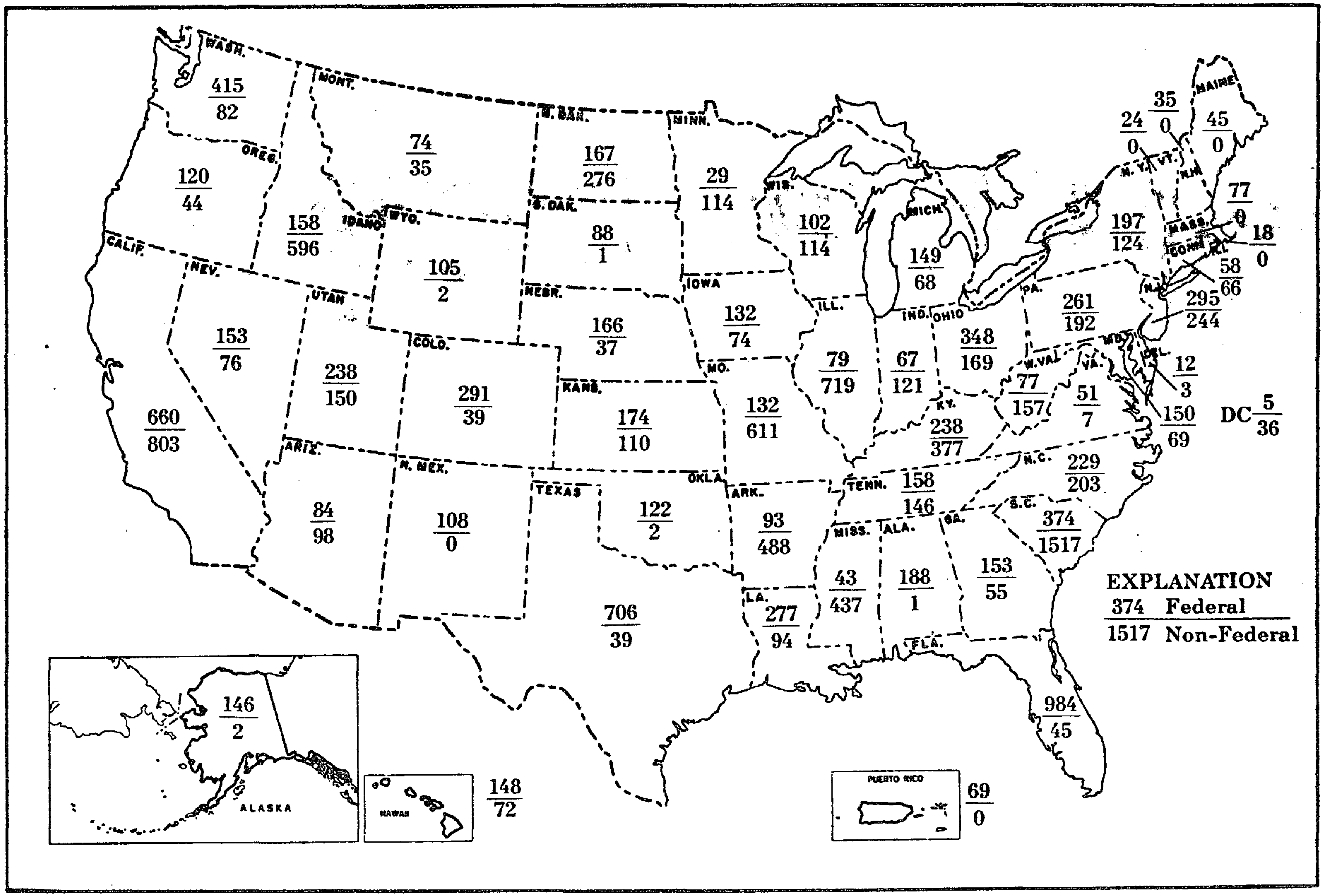

FIGURE 1. Active Federal and Non-Federal Water Quality Stations [2]

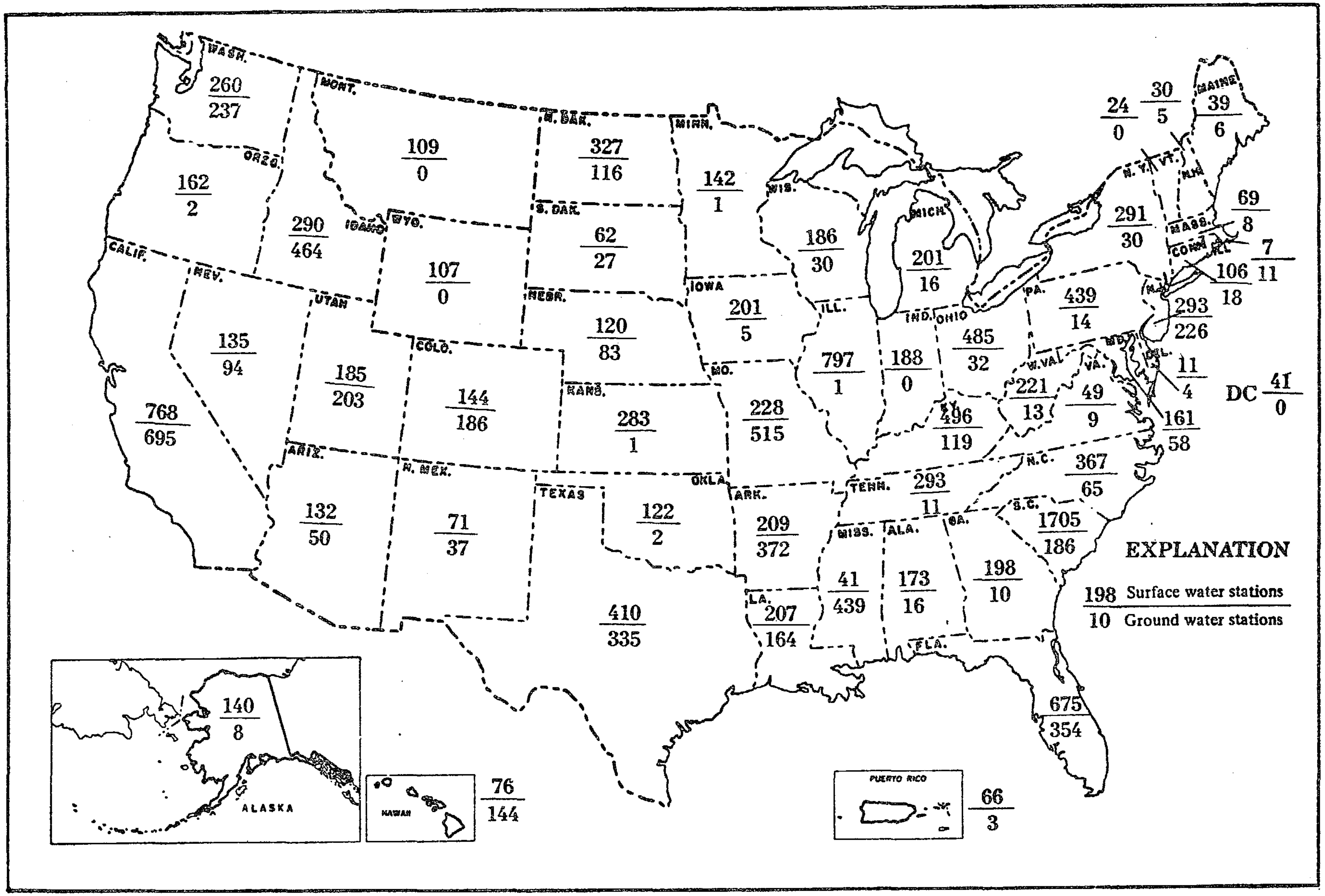

FIGURE 2. Active Surface and Ground Water Quality Stations [2]

TABLE 1. Active Water Quality Stations Reported By Agency and Water Body [2]

Agency	Streams	Canals	Lakes	Reservoirs	Estuaries	Springs	Wells	Drains	Other	Total
Atomic Energy Commission	101	11	8	5		1	451	0	22	599
Bureau of Reclamation	105	41	0	31	55		18	23	12	285
Bureau of Sport Fisheries and Wildlife	25	1	4	33						63
Corps of Engineers	466	35	38	148	45				2	734
Environmental Protection Agency	268	8	102	28	119	23	34	1	1	584
Forest Service	100		2	1						103
Geological Survey	3,771	166	197	39	75	84	1,866	41	23	6.262
Int'l Boundary and Water Commission	42	1							4	47
Marine Corps				2			105		2	109
National Marine Fisheries Service	11			7	2					20
Naval Facilities Eng. Command	11		7	11			272		1	302
Tennessee Valley Authority	58			101				1		160
Federal agencies subtotal	4,958	263	358	406	296	108	2,746	66	67	9,268
Non-Federal agencies subtotal	4,888	85	487	421	213	103	2,512	16	44	8,769
Total	9,846	348	845	827	509	211	5,258	82	111	18,037

TABLE 2. Frequency of Measurement and Number of Reporting Stations on Surface Water Quality Parameters 2

Parameter	Continuous	Daily	Weekly	Monthly	Quarterly	Annual	Seasonal	Other periodic	Irregular	Unknown	Total
	Number of stations										
Temperature	845	858	354	4953	1277	594	162	1568	19	174	10804
Specific conductance	311	387	92	2560	956	715	93	1366	24	206	6710
Color	3	98	120	2433	924	644	17	963	12	212	5426
pH (field)	112	104	44	600	2908	576	180	876	9	111	5520
pH (laboratory)	22	473	256	1822	1374	762	131	1481	26	348	6695
Dissolved solids	10	159	152	2425	1291	947	57	1293	22	294	6650
Chloride	21	185	170	1946	1598	818	38	1614	10	201	6601
Nutrients--Nitrogen	4	31	121	3853	1129	587	80	1184	22	203	7214
--Phosphorus	7	13	104	3561	1095	872	57	1352	20	287	7368
Common ions	10	425	147	1935	1655	841	69	1543	27	341	6993
Hardness	6	352	141	1609	1154	799	88	1180	26	512	5867
Radiochemical	5	6	47	174	561	208	6	175	18	316	1516
Dissolved oxygen	128	52	242	3549	1160	695	95	961	20	138	7040
Minor elements		6	23	287	767	1823	25	526	8	74	3539
Pesticides	1		11	70	251	1722	22	228	5	59	2369
Detergents		5	59	781	557	42	5	296	11	318	2074
Coliform	5	263	317	3565	1171	89	74	647	18	75	6224
BOD	4	10	188	2583	848	108	34	398	6	236	4415
Carbon--Total		7	3	207	137	57	4	65	3	21	504
Other micro-organisms	1	9	32	282	156	46	42	213	5	336	1122
Sediment--Suspended	11	277	75	267	82	21	10	416	6	186	1351
Particle size--											
Suspended	3	15	4	108	81	39	12	520	7	122	911
Bed Material		4	1	59	16	15	1	250	1	26	373

TABLE 3. Frequency of Measurement and Number of Reporting Stations on Ground Water Quality Parameters[2]

Parameter	Continuous	Daily	Weekly	Monthly	Quarterly	Annual	Seasonal	Other periodic	Irregular	Unknown	Total
	Number of stations										
Temperature	14	45	15	149	87	1111	41	1972	2	57	3493
Specific conductance	9	12	6	106	90	1238	42	1544	1	41	3089
Color		1	14	96	37	739	2	1092	2	117	2100
pH (field)		32	10	52	12	296	7	1060	2	87	1558
pH (laboratory)	3	24	13	81	71	1691	44	2124		156	4207
Dissolved solids	1	2	6	66	60	1560	38	1604	2	99	3438
Chloride	3	18	23	178	173	678	37	2104	2	13	3229
Nutrients--Nitrogen			2	33	47	305	5	1420	1	26	1839
--Phosphorus		1	2	22	33	189	1	1252		32	1532
Common ions	14	6	6	99	216	1764	40	2090	4	159	4398
Hardness	1	17	11	102	116	1584	40	1599	2	73	3545
Radiochemical		1	9	177	140	99	1	201	3	22	653
Dissolved oxygen			5	22	9	94		93	1	41	265
Minor elements			1	8	8	66	1	821	3	5	913
Pesticides			1	2	3	44	1	41		4	96
Detergents		1	4	19	6	131		503	2	33	699
Coliform		5	329	1238	16	75	1	573	2	31	2270
BOD			8	27	7	13		4		10	69
Carbon--Total				5	1			1		4	11
Other micro-organisms		1	9	43	4			6		11	74
Sediment--Suspended	1	5	12	8	4			234		7	271
Particle size-- Suspended		2		13	5	2		12		3	37
Bed material		3		1				12		1	17

2. Monitoring Networks

Past water quality data collection practices have suffered from a number of inadequacies that were felt particularly acutely in attempts to assess long-term quality trends, or contributions to pollutant loading from a given area. These may have involved station location, sampling frequency and timing, type of parameter measured, and uniformity of analytical methods. In an effort to remedy these inadequacies, the U. S. Geological Survey (USGS) and the U. S. Environmental Protection Agency (EPA) recently began implementation of two large networks of water quality monitoring stations.

The National Stream Quality Accounting Network (NASQAN) was designed by the USGS to monitor water quality of waterways downstream and to provide uniform, nationwide data for the purpose of planning and determining water quality trends. The network consists of single monitoring stations at 525 sites in 324 "hydrographic accounting units" located sequentially along the nation's major waterways. The principal parameters measured are temperature, conductivity, pH, flow, nitrogen, and phosphorous, as well as coliform bacteria, phytoplankton, and periphyton. Most are measured and recorded on a monthly basis, though samples for determination of pesticides and radioactivity are collected at selected stations four times a year. The data are stored in the USGS water quality file and in EPA's STORET system, and will be cataloged by the NAWDEX system.

At present, 345 monitoring stations are in operation. An additional 230 stations are expected to become part of the network by July 1975, and implementation of all 525 sites is slated for July 1976. Some 15 parameters, involving physical characteristics, nitrogen and phosphorus species, common ions, suspended solids, trace elements, and bacteria are to be measured monthly, and nearly 40 other parameters are slated for less frequent measurements.

The cost of NASQAN in FY 1974 has been approximately $450,000 and the anticipated cost for FY 1975 is $2,300,000. The eventual annual cost of the complete system is expected to be about $4,500,000.

The National Water Quality Surveillance System (NWQSS) is being implemented by EPA in compliance with Section 104 (a)(5) of PL 92-500. Its stated objective is to obtain a long-term base for determination of trends, establishment of relationships between land use and water quality, and evaluation of the effectiveness of pollution control efforts. Inclusion of population, employment, and industrial development data is anticipated, to permit the evaluation of social and economic impacts of pollution abatement.

The system is expected to consist of 60-100 sets of paired stations scattered throughout the United States, as well as state primary monitoring network stations, EPA intensive surveys, and monitoring activities by other groups and agencies. The paired stations are to be located upstream and downstream of segments adjoining land uses of special interest, such as municipal/industrial, rural/

agriculture, or estuarine/coastal areas, to determine changes in water quality due to contributions of both point and non-point sources. Intensive surveys will be conducted in selected areas to determine cause and effect relationships between point and non-point sources of pollution and water quality.

Implementation of the NWQSS began in January 1974, with a replacement of EPA's 584 haphazard stations monitoring 4-5 parameters monthly to the present carefully designed network of 150 stations (including 60 pairs) that report 25 parameters on a biweekly and 5 parameters on a monthly basis. Specific parameter and frequency selections will be tailored to the requirements of the site. Analysis of pesticides and metals are being added, while biological and sediment analyses are still in the planning stage. The data will be sampled and analyzed primarily by the USGS and stored in the Water Quality File (WQF) of EPA's STORET System.

A plan for the expansion and operation of the NWQSS will be prepared to cover the following areas:

- Inclusion of ground water, estuaries, ocean water
- A review procedure for evaluating the system's operation vis-a-vis its objectives
- Delineation of EPA headquarters, EPA regional, and state relationship in the operation of the system

The NWQSS budget for fiscal years 1974 and 1975 is only about $560,000, with some 80 percent of this going to USGS for station operation and data analyses, and the remainder to the states and EPA regional offices.

3. Coastal Monitoring

Monitoring of water quality off the shores of the continental United States and the Great Lakes falls under the jurisdiction of the 30 coastal states and three Federal agencies. These activities are discussed below.

Table 4 lists the number of monitoring stations and measurements taken in the coastal zone of 28 of the 30 coastal states and the District of Columbia (data for Alaska and Hawaii were not available). It will be noted that the number of stations has generally risen considerably between 1960 and 1970, with the most pronounced growth occurring in the state of Illinois, while several states actually lost stations.[3]

A number of states have increased monitoring efforts considerably in recent years, as is shown in Table 4. The most intensive monitoring and planning programs have been developed by the states in the Great Lakes region. The development of these programs stems from reliance on Great Lakes waters for municipal drinking water supplies and the commerical fishing industry. A recent USEPA survey of existing monitoring programs for thermal, municipal, and industrial discharges in coastal areas estimates that a minimum of 11,000 stations and 4.25 million measurements are needed just to monitor waste discharges.[3]

The most common parameters measured are:

- Salinity
- pH
- Temperature
- Dissolved oxygen
- Color

TABLE 4. Coastal Monitoring Activities Reported By State[3]

Coastal States	Number of Stations 1960	Number of Stations 1970	% Change	Number of* Measurements (1970)
Alabama	1	14	1300	828
California	239	316	32	527,006
Connecticut	59	65	10	42,095
Delaware	4	6	50	44,623
D. C.	22	33	50	71,495
Florida	490	1019	108	312,367
Georgia	4	25	525	107,452
Illinois	7	140	1900	43,379
Indiana	3	26	767	2,759
Louisiana	58	83	43	205,481
Maine	6	2	-67	17,520
Maryland	61	69	13	35,825
Massachusetts	6	34	467	36,100
Michigan	67	188	181	152,558
Minnesota	6	10	67	11,564
Mississippi	17	1	-94	11
New Hampshire	0	0	0	0
New Jersey	285	137	-52	91,649
New York	116	143	23	96,740
North Carolina	86	22	-74	86,202
Ohio	20	77	285	416,895
Oregon	73	98	34	181,373
Pennsylvania	12	37	208	137,417
Rhode Island	6	7	17	17,798
South Carolina	1	7	600	868
Texas	42	35	-17	9,398
Virginia	11	3	-73	1,248
Washington	70	99	41	395,771
Wisconsin	7	63	800	38,188
	1779	2759		3,084,610

*Continuous or telemetered data, as well as intermittent sampling, were treated as one sample per hour.

- Floating solids
- Coliforms.

Analyses for other parameters, such as heavy metals and nutrients, are also performed occasionally.

Federal monitoring of coastal water quality is conducted by the U. S. Environmental Protection Agency (EPA), the National Oceanic and Atmospheric Administration (NOAA), and the U. S. Coast Guard (USCG) in the following areas:

- Development of national coastal monitoring plan (EPA)
- Monitoring of offshore dumping sites (EPA)
- Marine ecosystems investigations (NOAA)
- Measurements of salinity and temperature (USCG)

The EPA has begun implementation of a national plan for coastal water quality monitoring that will involve a coordinated effort for acquiring, storing, retrieving, exchanging, and using data at both local and national levels. The agency has also promulgated guidelines for monitoring of offshore waste disposal sites under the Marine Protection, Research, and Sanctuaries Act of 1972 (PL 92-532). These guidelines establish requirements for baseline surveys to be conducted by the Federal government on a routine basis and require that these be supplemented by monitoring efforts, through which dumpers seek to determine the impacts of their own wastes.

The NOAA marine ecosystem investigations are looking into the changes in marine ecology due to human activities, the impacts of these changes, and the development of a reference base for planning and managing future use of marine resources to minimize any adverse impact. The measurements of salinity and temperature by the USCG is performed on a monthly basis at locations 100-150 miles offshore for the purpose of predicting current patterns and development of fisheries.

4. Quality Control

The U. S. Environmental Protection Agency is conducting an extensive and growing program of quality control through its Quality Assurance Division within the office of Research and Development, its Monitoring and Data Support Division within the Office of Water and Hazardous Materials, and its ten regional offices. The principal activities of the Quality Assurance Division may be listed as follows:[4]

- Validation of new analytical methods
- Preparation of guidelines and manuals for analytical procedures and quality control programs
- Inspection of EPA and state water analysis programs
- Provision of reference samples.

The first activity is formalized in the Analytical Methods Validation Program. This consists of requesting 20-40 laboratories around the country to perform an analysis of a sample using a new method, typically developed by the Equipment and Techniques Division, and of determining the precision and accuracy of results to assess the validity of the method. The second activity has produced Guidelines Establishing Test Procedures for Analysis of Pollutants and Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents, as well as a number of workshops around the country.

Inspection of EPA and state water quality monitoring programs by regional personnel entails inter-laboratory performance tests, on-site evaluation, and checking of data, and will cover all aspects of a monitoring program, from sample collection to data storage and processing. Finally, the Reference Material Program provides any laboratory with an opportunity to check the validity of its procedures by requesting standard samples prepared by the National Bureau of Standards and the EPA Methods Development and Analytical Quality Control Research Laboratory in Cincinnati, along with the correct results.

At the present time, only half of the EPA regional offices have a staff member assigned to quality control on a full time basis, but both staffing and programs are expected to grow considerably during FY 1975. Many states have quality control programs, but their effectiveness is not well know. In the near future, EPA regulations promulgated under Section 106 of PL 92-500 will require all states to institute quality control programs that meet with the approval of EPA regions.[4]

The U.S. Geological Survey uses standard water samples periodically to test the analytical accuracy of each field laboratory, while more comprehensive quality assurance procedures are employed at the larger laboratories. A preliminary report of the Federal Interagency Work Group on Designation of Standards for Water Data Acquisition was completed in December 1972, and the Office of Water Data Coordination is compiling a list of recommended acquisition methods.

B. BIOLOGICAL MONITORING

The usefulness and necessity of biological monitoring of water quality has only recently received wide recognition, and this approach is being increasingly implemented. The nature and contributions of biological monitoring are discussed below, along with the types of surveys undertaken, and the current Federal and state monitoring activities.

1. Nature and Benefits

Biological monitoring can be defined as the determination of water quality on the basis of measurements performed on the aquatic biota. The underlying concept of biological monitoring is that the quality of the water will be reflected to a large degree in the condition of organisms that are surrounded by this environment. The more common types of biological investigations are as follows:

- Identification of specific indicator organisms
- Community diversity studies
- Bioaccumulation surveys
- Eutrophication surveys

The first method relies on determining the presence or absence of an organism that is particularly sensitive, or particularly tolerant to a given contaminant. Community diversity studies involve the development of biota indexes that measure the relative impact of certain contaminants. The common indexes are population density, species diversity, and dominance. The types of organisms used most frequently in the first two methods include phyto- and zooplankton, macroinvertebrates (e.g., worms, clams), and various species of fish.

Bioaccumulation surveys attempt to detect and measure the presence of toxic substances, such as pesticides, heavy metals, or radionuclides, in individual specimens. These substances frequently accumulate in the organisms and their concentration becomes magnified through the food chain. Finally, eutrophication surveys seek to classify the trophic condition of fresh water lakes and reservoirs, i.e., the amount of nutrients they contain, primarily by determining the extent and type of algal growth.

Biological monitoring seeks to complement, rather than replace, chemical and physical monitoring by introducing a number of advantages that may be formulated as follows:

- Fidelity
- Sensitivity
- Instantaneity
- Cumulativity

The first and most important feature refers to the fact that the condition of aquatic biota reflects the suitability of water quality for most intended uses more faithfully than most single chemical or physical characteristics. Secondly, the sensitivity of some organisms to certain toxic substances is greater than that of common analytical methods. Furthermore, living organisms often react instantaneously to a fleeting effect that may be missed by chemical and physical analyses that are scattered both in space and time. Finally, living organisms may accumulate small doses of toxic substances that could be missed by sporadic sampling and common analytical methods, but become magnified through the food chain.

2. BSFW Activities

The Bureau of Sport Fisheries and Wildlife (BSFW) and the U. S. Environmental Protection Agency (EPA) are the two principal Federal agencies concerned with biological monitoring. The major water quality monitoring activities of the BSFW may be classified as follows[5]:

- Great Lakes studies (Div. of Fishery Research)
- Reservoir studies (Div. of Fishery Research)
- Large river studies (Div. of River Basins)
- Pesticide monitoring (Div. of Fishery Services)

Research on the Great Lakes, begun in 1927, has produced numerous publications on the changes which have occurred in the fish populations and the lakes' environment since the late 1800's. Studies of Lakes Superior and Michigan serve to determine the success of the sea lamprey control programs, as well as the lake trout population rehabilitation and coho salmon introduction programs. In addition, bloaters, lake trout, and coho salmon in Lake Michigan are routinely sampled for DDT, dieldrin, and PCB residues. Mercury concentrations in fish are measured in Lake St. Clair.

The Lake Erie program is designed to determine the effect of accelerated eutrophication from industrial and domestic pollution on the fish and invertebrate populations. Sampling techniques and information obtained are similar to those reported for Lakes Superior and Michigan, but commercial catch rates are also monitored. Lake Ontario was the site of intensive sampling in 1972 by Canadian, State of New York, and Great Lakes Laboratory biologists, under the auspices of the "International

Field Year for the Great Lakes". After analysis of the data, the most efficient biological monitoring program was to be designed and implemented.

The National Reservoir Research Program has no field monitoring function, but obtains and analyzes data from other agencies concerning fish standing crops, angler use and harvest, temperature, dissolved oxygen, and conductivity. Biological monitoring of reservoirs has been conducted since 1962 on four Missouri River impoundments, and since 1972, on the Jocassee Reservoir. The objective of these investigations is to determine the effects of thermal effluent from nuclear and fossil fuel power plants.

Projects on the Delaware, Connecticut, and Hudson Rivers are coordinated by committees comprised of representatives from the National Oceanic and Atmospheric Administration (NOAA) and state agencies. Field work has primarily been done by the state agencies or private consulting firms. None of these programs were developed as monitoring programs, but they provide some indication of the reproduction, abundance, and composition of the fish stocks, as a baseline for determining any changes.

Monitoring of fish pesticide residues was initiated in 1967 at 50 collecting stations in different drainage basins and expanded to 100 stations in 1970. Three to five specimens of each of three designated species are collected annually at each station, and their length and weight are recorded. All specimens are analyzed for lipids, aldrin, arsenic, BHC, cadmium, chlordane, DDE, DDT, dieldrin, endrin, heptachlor, heptachlor epoxide, lead, mercury, PCB, TDE, and toxaphene. The program is conducted by the Washington headquarters, as well as six regional offices, and three research laboratories. The fish are collected by the regional offices and shipped for analysis to laboratories of the Division of Fish and Wildlife Research in Columbia (Missouri), or Denver, or to the Warf Institute in Madison (Wisconsin). The data are then forwarded to Washington for interpretation, integration, and dissemination, including publication in Pesticide Monitoring Journal, published by the Federal Working Group on Pest Management.

In addition, visual counts of several endangered species are performed routinely at various locations throughout the United States, to determine their population abundance.

3. EPA Activities

The role of aquatic biology in the water pollution control program of the U. S. Environmental Protection Agency (EPA) consists of both field and laboratory studies to establish water quality criteria for the recognized beneficial uses and to develop biological monitoring techniques. Field studies are employed to measure the toxicity of specific pollutants to individual species or communities of aquatic organisms, to detect violations of water quality standards, to evaluate the trophic status of waters, and to determine long-term trends in water quality.[6]

EPA conducts three basic types of biological field studies:

- Reconnaissance surveys
- Synoptic surveys
- Comparative evaluations.

Although there is a considerable amount of overlap, each of these activities has certain specific requirements.

Reconnaissance surveys are generally conducted to obtain information for designing more comprehensive studies. They may range from a brief perusal of the study area by boat, plane, or car, to an actual field study, in which samples are collected for the purpose of characterizing the physical boundaries of the various habitat types and obtaining cursory information on the flora and fauna.

A special case in point is the National Eutrophication Survey begun by EPA in mid-1972 to identify those lakes and other impounded bodies of water, which are threatened by excessive fertilization and which might respond to nutrient control measures. The survey will eventually involve sampling of 800 lakes across the nation, but preliminary results are available from 242 lakes in ten states that had been subject to accelerated eutrophication.

Synoptic surveys are undertaken to determine the kinds and relative abundance of organisms present in the area under investigation. This type of survey may be expanded to include quantitative estimates of standing crop or production of biomass, but is generally more qualitative. A deliberate attempt is made to collect systematically specimens from all types of habitats. Synoptic surveys provide useful data for establishment of baselines and evaluation of seasonal and long-term changes.

Comparative evaluations may involve comparisons of the flora and fauna in different areas of the same body of water, at different times in a given location in a body of water, and in different bodies of water. Comparative evaluations frequently involve both quantitative and qualitative methods.

In addition to these field studies, EPA is conducting an active program of laboratory studies for the purpose of developing biological monitoring methods. These studies serve to measure the effects of known, or potentially deleterious substances on aquatic organisms, to estimate "safe" concentrations, and to determine environmental requirements, such as temperature, pH, dissolved oxygen, of the more important and sensitive species of aquatic organisms. Examples of current projects are:

- Development of a biological methods manual
- Development of methods for sample collection
- Development of sample processing methods
- Development of organism identification methods
- Development of methods for measuring biomass and rates of biological processes
- Development of bioassay, biomonitoring, and bioaccumulation methods

- Development of methods for processing and evaluating biological data
- Conducting of interlaboratory evaluations of biological methods.

4. State Activities

Biological monitoring has been largely neglected by state water pollution control agencies, and to date, only five states (California, Florida, New York, Pennsylvania, and Wisconsin) have viable programs under way. However, Section 106(e)(1) of PL 92-500 requires that all states institute biological monitoring programs by 1 July 1974, if funds are available. To assist the states in meeting this requirement, the EPA has compiled a Model State Water Monitoring Program incorporating regulations and guidelines, including a section on biological monitoring.[7]

The objective of the model program is to gather water quality data in order to:

- Determine suitability of aquatic environments for supporting abundant, useful, and diverse communities of aquatic organisms
- Provide information adequate to detect, evaluate, and characterize changes in the biological productivity, diversity, and stability of aquatic systems
- Detect presence and/or buildup of toxic and potentially hazardous substances in aquatic biota
- Provide information adequate to periodically update the eutrophic condition classification of freshwater lakes.

To meet the above objectives, a program is recommended consisting of the following elements:

- Intensive surveys
- Long-term trend monitoring
- Monitoring of toxic substances
- Classification of eutrophic conditions

A biological monitoring sampling station should be located within a reach of river of an area of lake, reservoir, or estuary adequate to represent a variety of typical habitats. The actual number of stations (both trend and intensive) required will, of course, depend on the size of the state, amount of water, and problems encountered.

C. REMOTE SENSING

Remote sensing of water quality is a rapidly developing monitoring tool that is expected to represent a valuable complement to current in situ sampling and analysis operations. The applicability of remote sensing as a complementary tool in water quality monitoring is examined here in terms of capabilities and potential benefits. The remote sensing vehicles considered include low and high altitude aircraft, observation satellites, and data collection platforms.

1. Nature and Benefits

Remote sensing instruments operate by detection of reflected or emitted electromagnetic radiation. As a result, their direct detection capability is limited to those parameters that modify the reflective or emissive characteristics of the surrounding aqueous medium. These parameters include:

- Suspended load
- Chlorophyll
- Oil
- Acids
- Temperature

Additional results can be obtained by inference supported by "ground truth". For example, a warm, acid-containing plume near an industrial plant can be interpreted with a high degree of certainty as industrial discharge, even though many of its important components are not discernible. Flow rate of a river can be determined from ground measurement of its flow velocity, combined with the remote measurement of its width, once the relationship between width and the river's cross section at that location has been established.

The major advantages of remote sensing vis-a-vis <u>in-situ</u> sampling and monitoring are:[8]

- Synopticity - the capability to present a simultaneous pictorial representation of the entire area
- Rapid coverage - the capability to cover vast areas in a short time
- Serendipity - the capability to observe at a later date phenomena that were not sought, or at least not at the time the data was being collected.

The first quality is very helpful in areawide or basinwide planning, when information on adjacent land use is crucial to sound water quality management decisions, and large, often remote, areas must be monitored. The last characteristic is particularly useful in general surveillance work, or in situations calling for comparison of current values of a newly measured parameter against historical records.

On the other hand, the principal shortcomings of remote sensing are:

- Poor discrimination (from space satellites)
- Low resolution (from space satellites)
- Poor penetration beneath the water surface
- General dependence on reflected light
- General inability to penetrate cloud cover
- Inability to yield reliable quantitative estimates

The first characteristic limits the number of contaminants that can be detected, as well as their minimum detectable concentrations. The resolution, which may vary anywhere from less than one meter, for low-altitude aircraft, to 80 meters, for the ERTS-1 satellite, affects the number of pollution sources that can be detected. Low penetration beneath the water surface can yield misleading results. For example, some species of algae do not form the characteristic surface scum, while others tend to grow in depth, rather than along the surface.

Dependence on reflected light for all but infrared and microwave sensing, combined with the inability to penetrate a heavy cloud cover, generally reduces monitoring opportunities to daylight hours and clear weather conditions. Finally, the inability to yield reliable estimates of pollutant concentrations limits the information provided to qualitative assessments.

2. Data Collection and Processing

Remote sensing to determine water quality of water bodies uses the properties of emissions, absorption, reflectance, and scattering of electromagnetic radiation by the water and adjacent terrain. Emitted energy in the infrared region is useful for thermal mapping. Measurements of absorbed, reflected, and scattered energy, use either the sun or some airborne generator as the source of incident radiation. The principal types of sensor available are: [9]

- Cameras (photographic and television)
- Scanning radiometers
- Spectrometers

Photographic cameras, the most important type of remote sensor, operate in the visible part of the spectrum and the nearby infrared and ultraviolet. Photographic systems, can be made to rigorous standards and can be employed to measure accurately the locations, shapes, and sizes of objects. Stereoscopic photography, in which the same scene is recorded simultaneously from two slightly different angles permits three dimensional representations. Television cameras also operate in the visible range and transmit both black and white and color information. They do not require film or any other material medium for the transfer of the information, so that the user can review the information in real time, even at large distances.

Scanning radiometers, or scanners, operate in the ultraviolet, visible, infrared, and microwave energy regions. Unlike cameras, which record all parts of a scene simultaneously, scanners sense one spot at a time, covering the surface by sweeping their view from side to side by means of a rotating or oscillating mirror, as the aircraft, or spacecraft, moves forward. Pictures produced by these means are called images to distinguish them from direct photographs. The information can also be recorded on magnetic tape. Spectrometers are based upon the principle that the electromagnetic energy absorbed, emitted, or reflected by any substance is distributed over the various wavelengths in a characteristic pattern, or spectrum, which can be used to characterize the substance. Thus, unlike cameras or scanners, spectrometers are capable of identifying specific components in the water.

Information collected, or eventually recorded, by any photographic method is stored as density and color variations on film. Black-and-white film can resolve density differences much smaller than those detectable by eye, and color films are even more sensitive to tone differences. Film densities can be measured electronically, with a photodensitometer, which scans the record and displays the amplified density variations on a strip chart or digital printout. A more qualitative, but very sensitive, photographic interpretive technique, known as "density slicing," assigns arbitrary colors to those portions of the image lying within various narrow density ranges. In cases, where the information is stored in digital form on magnetic tapes, a large array of so-called computer image enhancement techniques are available to achieve special interpretive effects.

3. Aircraft Programs

The U. S. Environmental Protection Agency is implementing an aerial remote sensing capability to help meet the research, surveillance, and enforcement requirements of EPA regional offices, the Office of Enforcement and General Counsel, and the Division of Oil and Hazardous Materials. At present, this capability consists of a fleet of a dozen aircraft and helicopters, instrumented with a variety of sensors, and supported by extensive shop and data processing ground facilities, at the National Environmental Research Center in Las Vegas, Nevada.[9]

The Center has been charged with developing applicable monitoring techniques and programs and providing demonstration studies to assess their effectiveness. To meet this responsibility, the Monitoring Operations Laboratory has been developing an integrated system for the collection, processing, interpretation, and reporting of remote sensing data. An integral part of the system is a computerized data acquisition system, which allows for partial automatic data processing of aerial thermal mapping and multispectral measurements. Simultaneous photographic coverage is time-related to radiometric measurement for detailed analysis, and a video system, which records analog data on magnetic tape, provides the near real-time interpretation necessary to respond to emergency situations.

This remote sensing capability is designed to meet specific EPA objectives in the following areas:

- Outfall detection and inventory
- Reaction to spills of oil and other hazardous materials
- Development of agricultural runoff models
- Detection of likely sources of ground water pollution
- Thermal mapping surveys
- Monitoring of pollution from non-point sources

The outfall detection, location, and analysis program is developing a catalog of wastewater outfall characteristics associated with aerial monitoring for the more significant categories of outfalls. The oil spill damage assessment and documentation program involves the improved management of aerial surveillance responses to major incidents of oil or other hazardous material spills. The remote sensing portion of the agricultural chemical runoff model program seeks to provide certain quantitative terrain parameters which can be inserted into mathematical models of river basins. Detection of likely sources of ground water pollution involves sanitary landfills and other land disturbances.

Thermal mapping by infrared scanners is being used to conduct temperature surveys in connection with power plant siting and in detection of industrial and municipal wastewater discharges, as well as algal growth in lakes and reservoirs. Finally, definition of the most effective approaches to monitoring of the various types of non-point source pollution will be accomplished through intensive literature review and contact with EPA personnel engaged in investigating such sources.

In addition to the EPA remote sensing programs, other Federal and state government agencies, as well as private firms, have engaged private contractors to conduct water quality monitoring by aircraft. For example, the U. S. Army Corps of Engineers has tried this approach in enforcement of the discharge permit program, while utility companies have used remote sensing techniques for mapping thermal effluent plumes from their power generating plants.

All of the above discussion applied to monitoring activities from low-altitude aircraft, i.e., aircraft that operate below about 40,000 feet. Recently, however, the Department of Defense has released a number of high-altitude military surveillance aircraft to the National Aeronautics and Space Administration, on an experimental basis, for earth resource observation work. These aircraft, such as the RB-57 and the ill-fated U-2, operate at altitudes in excess of 60,000 feet and are capable of producing photographs with a resolution as high as 3-10 meters. There are even better sensors available but their use and capabilities are still subject to the cloak of military security.

4. Space Satellite Programs

Remote sensing systems carried by man-made satellites make it possible to study vast expanses of water and surrounding land continuously and rapidly and greatly simplify the acquisition and processing of information on remote areas. The principal satellite program associated with water quality monitoring is the Earth Resource Observation Survey (EROS) program operated by the U. S Geological Survey (USGS) and the National Aeronautics and Space Administration (NASA).

As part of the EROS program, in July 1972, NASA launched the first Earth Resources Technology Satellite (ERTS-1) into a near-circular, near-polar orbit at an altitude of 920 km (570 miles). A second satellite (ERTS B) is slated for launching in 1975. The satellite orbits the earth every 103 minutes, and covers the same orbital path every eighteen days. It carries a multispectral scanner (MSS) imaging system that produces images about 185 km (100 nautical miles or 115 statute miles) on a side, with an area of approximately 34,000 sq. km (13,000 sq. miles). Another imaging system, the return beam vidicon (RBV) has been deactivated, when a malfunction occurred soon after launch.

The MSS is a line-scanning device which records reflected radiation simultaneously in four spectral bands, which bring out different features. For example, vegetation and water turbidity are best imaged in the shorter wavelengths, while the water/land interface shows up best in the infrared bands. The resolution of the ERTS imagery is about 70-80 meters, but varies somewhat with the shape of the object and the contrast between the object and its surroundings.

The video MSS signal is converted to digital data and telemetered from the satellite to a receiving station on earth. The data is converted at the Goddard Space Flight Center Data Processing Center into digital tapes, black and white images of individual bands made from the digital data, or false-color composites of several bands. These data products are then disseminated to users at nominal cost by the EROS Data Center in Sioux Falls, South Dakota.

The ability of the ERTS system to detect and map large scale turbidity in rivers and estuaries has been demonstrated by several investigators, and semi-quantitative estimates have been attempted in the 25-150 mg/l concentration range. The growth and movement of algae and other aquatic organisms have been investigated, and semi-quantitative estimates have been attempted at concentrations up to 30 mg/l. High concentrations of industrial acid wastes have been detected, apparently due to the presence of colored ferric sulfide, but attempts to detect acid mine waste and oil slicks have not been successful. The EPA Office of Enforcement and General Counsel has used ERTS imagery in prosecuting the International Paper Company for discharging paper process wastes into Lake Champlain and the Reserve Mining Company for dumping taconite tailings into Lake Superior.

In addition to the ERTS system, several other satellite earth resource observation systems have been launched, or are in various stages of planning, and design. These include:

- Skylab
- EOS
- GOES

The Skylab orbiting laboratory was launched on 14 May 1973 and inserted into a 234 nautical mile circular orbit at 50° inclination. At various periods, this spacecraft was occupied by a 3-man crew, which conducted extensive scientific observations and experiments. Observations of earth resources were performed with the aid of the Earth Resources Experiments Package (EREP), which included a multispectral photographic facility with an earth terrain camera, an infrared spectrometer, and a multispectral scanner. The earth resource tasks of interest to this study included delineation of effluent plumes in rivers and estuaries, characterization of water pollution, and development of water quality monitoring techniques.

The Earth Observation Satellite (EOS), on the other hand, is an advanced version of ERTS, currently in the conceptual design stage and slated for initial launch in the late 1970's. It's special feature will be a pointable lens that will provide resolutions as high as 10 meters for specific small areas. The Geostationary Operation Environmental Satellite (GOES) was developed by the National Aeronautics and Space Administration (NASA), and the first mission was launched in May 1974, to relay environmental data from automatic unattended Data Collection Platforms (DCP). The U. S. plans to launch one additional GOES and the European space research organization, the U.S.S.R. and Japan each plan to launch one, for an eventual total of five satellites.

5. <u>Data Collection Platforms</u>

The Data Collection Platforms (DCP) are automated unattended environmental monitoring stations that relay water quality and meteorological information to their respective data processing centers via an earth satellite, such as ERTS or GOES. In addition to the DCP's, the system encompasses a receiver-recorder-transmitter package on board the satellite, receiving stations located at the Goldstone and Goddard space centers, and the data processing facility, where the information is processed and distributed to users.

Data from each of as many as eight sensors are collected by the DCP and transmitted several times per day to the satellite overhead for retransmission to one of the receiving stations. A 125 DCP network is now in operation, in conjunction with ERTS-1, with installations in 22 states and five foreign countries, extending from Alaska to Honduras and from Iceland to Hawaii.

Nearly 30 users are involved in the program, representing six Federal agencies, one state, one foreign country, four universities, and one industrial firm. Monitoring information is obtained in the areas of meteorology, hydrology, agriculture, vulcanology, and water quality. Water quality installations are supplying data to regulatory agencies one or more times a day.

The experience to date suggests that additional developmental effort is required to improve the sensor elements to the point where they are capable of long periods of reliable unattended operation. Nevertheless, the ERTS DCP experiment has demonstrated the feasibility and reliability of the space relay portion of the system for automatic collection of data from <u>in-situ</u> environmental sensors and extended a promise of successful future operation of such systems. The development of the DCP program is presumably continuing in conjunction with the ERTS-B and the GOES spacecraft systems.

IV. PROCESSING AND DISSEMINATION

Once the water quality data has been collected, its method of storage, processing, retrieval, and dissemination to the users can well determine the success or failure of the entire monitoring program. Current methods vary widely in sophistication from a drawerful of notebooks and files to complex computerized storage and inventory systems. These systems are described here under the following headings:

- Traditional methods
- Storage and Retrieval Systems(STORET and WATSTORE)
- Inventory systems (NAWDEX and ENDEX)

A. TRADITIONAL METHODS

The traditional methods of storing water quality data in files and laboratory notebooks works reasonably well, provided that the data is properly cataloged and organized and that its existence is made known to prospective users. Unfortunately, most water quality data files do not meet these criteria and must be sought among the holdings of a number of different agencies.

While combing the agency files for water quality data applicable to one's problems, it is usually a good idea to consult with cognizant agency officials, who can frequently make up for cataloging and organizational deficiency from their personal knowledge of the status of the data. These officials are frequently very busy and somewhat resentful of Federal interference in what they regard as their own affairs, so that a large dose of diplomatic finesse is very helpful in extracting the information required.

A frequent problem with local water quality data files is the inherent institutional fragmentation. For example, the Department of Health keeps only bacteriological data while the Departments of Natural Resources or Environmental Protection may be interested in a number of other water quality parameters. Alternatively, the regional agency may keep some records, while the central state office may maintain other records. The growing monitoring role of the Federal government has further compounded this fragmentation problem by increasing data collection and storage requirements imposed on local agencies and by introducing local offices of several Federal agencies into the monitoring picture.

Some of these problem are being tackled by the Federal storage, retrieval, and inventory systems, which are discussed in the sections that follow.

B. STORAGE AND RETRIEVAL SYSTEMS (STORET AND WATSTORE)

Development of a computerized water quality data storage and retrieval system to be known as STORET began under the Division of Water Supply and Pollution Control, U.S. Public Health Service, Department of Health, Education and Welfare in the early 1960's and is continuing to this day under the aegis of the U. S. Environmental Protection Agency. The STORET system has the capability of receiving, storing, processing, and retrieving vast amounts of water quality data, with access be remote terminals. At present it handles water quality data from 200,000 historical and active stations operated by some 50 Federal and state agencies in over 300 locations. More stations are being added, and controls are being introduced over data quality and annotations.

The STORET system currently contains two file sections: the Water Quality File (WQF) and the General Point Source File (GPSF). The WQF includes primarily data on bodies of water, such as rivers and lakes, with some point source data. The GPSF contains only data on point source effluents and was being set up to facilitate administration of discharge permit systems, but its future is uncertain. The WQF has no provision to monitor the data for possible errors, while the GPSF has some built-in quality control.

The STORET system does not provide an inventory of the stored data to the states and to EPA regions. Data are indexed and can be retrieved on the basis of a number of monitoring determinants. The parameters measured are identified by three word definitions and five digit numbers. The numbers refer to a definition file, from which precise parameter descriptions and the analytical methods used can be identified. Several output programs, including formatting and statistical analyses are being developed for the WQF.

Two adjunct systems are curently in the planning stage. BIO/STORET (Biological Storage and Retrieval System) will be part of System 2000, a data-handling software package distinct from the main STORET system. BIO/STORET will be designed to handle biological data and the related chemical and physical water quality data and will also contain a program for validity testing of the data. A quality assurance screening process will be designed to perform a gross screening of input data to eliminate unreasonable values. Implementation of this program for some parameters, such as temperature, is anticipated to take place within the next two years, though completion date for all parameters has not been projected.

The budget of the STORET system for fiscal years 1974 and 1975 is $4,000,000. This figure includes temporary loans of computer terminals to state users, as well as all state processing pertinent to the requirements of PL 92-500.

The USGS National Water Data Storage and Retrieval System (WATSTORE) is a large-scale computerized system for storage and dissemination of water and water-related data collected through the Survey's activities. WATSTORE is composed of five files. The "daily values file" contains all water data parameters measured on a daily or continuous basis, or those numerically reduced to daily values. Annual maximum or peak streamflow and gauge height values are stored in the "peak flow file". The "water quality file" stores results of the analysis of surface and ground water samples. The "ground water site inventory file" contains data on the physical, topographic, hydrologic, and geologic characteristics of ground water sites, which are cross-referenced to corresponding data stored in the water quality and daily values files. Finally, the "station header file" indexes all sites for which data are stored in the daily values, peak flow, and water quality files.

C. INVENTORY SYSTEMS

Water quality monitoring is performed by a wide variety of Federal, state, and local agencies and private organizations for a broad range of uses. The data is then stored by these agencies, frequently unprocessed and not readily accessible to other contemporary or future users. The U. S. Geological Survey and the National Oceanic and Atmospheric Administration have attempted to alleviate this problem through the development of such water quality data cataloging systems, as the Catalog of Information on Water Data, the National Water Data Exchange (NAWDEX), and the Environmental Data Exchange (ENDEX).

1. Catalog of Information on Water Data

The extent and nature of water quality monitoring, as well as information on surface water stream flow and stage, being collected by Federal, state, and other agencies in the U. S. has been compiled biennially since 1968 by the Office of Water Data Coordination of the U. S. Geological Survey. This compilation is conducted in response to the Office of Management and Budget Circular A-67, which calls upon the Department of the Interior to coordinate certain water data acquisition activities conducted by Federal agencies and to maintain a central catalog of information on such data.[2]

Two committees have been constituted to promote this coordination function and to represent the views of the non-Federal community. The Interagency Advisory Committee on Water Data is composed of representatives of 36 Federal agencies, bureaus, and departments. On the other hand, the Advisory Committee on Water Data for Public Use is made up of 25 representatives from water-oriented national, state, and regional organizations, professional and technical societies, and the academic community.

Information in the 1972 edition of the catalog is presented in 21 separate volumes, one for each of the water resources regions designated by the Water Resources Council. The catalog contains information on surface water quality data reported by 12 Federal agencies for 6,414 stations and by 135 non-Federal agencies for 6,154 stations, for a total of 12,568 surface water quality stations, as well as information on ground water quality data reported by 6 Federal agencies for 2,854 stations and 37 non-Federal agencies for 2,615 stations, for a grand total of 5,469 ground water quality stations. The compilation reflects the situation in effect as of 1 January 1972, but it is comprehensive only to the extent that the monitoring agencies have been willing to report their activities. The following specific information is provided for water quality data:

- Station identification and location
- Type of water body sampled
- Period of record
- Form of data storage
- Parameters and their frequency of measurement
- Reporting agency.

Prior to the 1972 edition, information in the catalog was published in four sections. Three of these, Index to Surface Water, Index to Water Quality and Index to Ground Water, contained information on data acquired on a recurrent basis at specific locations for a period of 3 years or more. The fourth section, Index to Areal Investigations and Miscellaneous Activities, was concerned with specific projects or shorter-term data collection activities involving field or laboratory measurements that were not included in the other sections of the catalog.[2]

2. National Water Data Exchange

The National Water Data Exchange (NAWDEX) was designed by a Federal interagency advisory group as a voluntary activity of data acquisition organizations, and all such Federal, state, local, and private organizations have been solicited to participate.[10] The NAWDEX management function will be to provide search assistance to users and to produce standardized storage and retrieval guides for the participating groups. It will cover water-related data in such areas as geology, meteorology, and water quality.

The inventory will provide detailed information on the origin, quality, and availability of the data. Inventories of the STORET files are expected to comprise approximately 75 percent of the NAWDEX system. NAWDEX will have a central office, where an inventory (the Master Water Data Index) of the data available to its member organizations will be maintained, along with the Water Data Source Directory. Access to the central index files will be provided through a national network of local assistance centers located with participating member organizations. The latter will maintain their own data files and provide the data directly to requestors.[11]

A contract for designing the index system format was awarded in May 1974, and should be completed by June 1975. Inception of services is scheduled for April 1975. NAWDEX was funded at $250,000 in fiscal years 1974 and 1975, and a slightly higher funding level is expected for fiscal year 1976. By fiscal year 1977, the cost is expected to be $1,500,000, with full implementation anticipated in fiscal year 1978 at an annual cost of $2,500,000.

3. Environmental Data Exchange

The Environmental Data Exchange (ENDEX) is a part of NOAA's Environmental Data Service (EDS) and consists of a compilation of inventories and directories. These inventories and the information they contain are as follows:

- Large inventories of international projects
- Detailed inventories of environmental data, with information on who has what, on which topics, where it is stored, how much data there are
- Accession and processing inventory, which keeps abreast of the location of data within NOAA
- Users' inventory, which lists users of various kinds of data, to determine what the demand is
- Environmental Data Base Directory (EDBD), an inventory of environmental data, which are available in the world, with emphasis on the U. S.

The EDBD defines what data are where, how they were collected, how many data there are, how they are stored, how to get them, and any restrictions on their availability or use. The range of topics includes meteorology, geology, geophysics, space, solar energy, as well as inland and oceanographic water data. To reduce duplication with NAWDEX, EDBD is not seeking out waste discharge data and places the emphasis on rivers, streams, and coastal waters. Both historical and current data are included.

Access to ENDEX can be by subject, parameter, specific test method, etc., from very precise definitions to broad ones. Inquirers will be referred to other inventories and files (such as NAWDEX), if appropriate. Cataloging is planned for all environmental data, including information contained in STORET.

Loading of the computer program and system testing began in April 1974, and the ENDEX-EDBD system is scheduled to be made available to users beginning in June 1974. At the outset, the inventory will contain primarily information on the eastern states and coastal waters.

The cost of ENDEX for fiscal year 1974 is estimated at $250,000 (most of the original funding of $2,000,000 was impounded), while requested financing for fiscal year 1975 is $2,000,000. Originally, the cost of developing the ENDEX system was estimated at $8,000,000 over a 6-year period.

D. REPORTING

The basic reporting elements of the Federally funded water quality monitoring program are:

- A one-time report by EPA in February 1974 describing the present state of water quality and a projection of water quality in 1977, 1983, and post-1983.
- An annual report by EPA on the state of water quality in the surface and ground waters and the oceans
- An annual report by the USGS on the quality of U.S. surface waters
- Annual reports by USGS district offices on water resources in each state
- Annual reports by the states beginning in 1975.

The state reports are slated to describe the present state of water quality, project water quality to 1983, analyze the extent to which "no discharge" technology is being employed or will be needed, provide an economic and environmental cost/benefit assessment of statewide pollution control activities, and give a description of non-point source pollution along with a recommended control strategy.

V. LEGISLATION AND PROGRAMS

A number of Federal agencies are engaged in water quality monitoring, frequently in joint efforts with state agencies, and it is very important to define their respective functions and programs, in order to assess the efficiency of their individual and collective activities. This material is presented here under the following headings:

- Legislation and funding
- Federal programs
- State programs

A. LEGISLATION AND FUNDING

Much of the authority and requirements for conducting water quality monitoring programs is derived from two recent Federal laws, but the commitment of resources to these programs is not well defined. These factors are discussed briefly below.

1. Legislative Overview

The Federal and most state requirements for water quality monitoring are embodied in the:

- Federal Water Pollution Control Act of 1972 (PL 92-500)[12]
- Marine Protection, Research, and Sanctuaries Act of 1972 (PL 92-532)[13].

A vast plethora of earlier Federal laws has been superseded by these acts or are only marginally relevant to water quality monitoring. In addition, a number of states have enacted their own water quality monitoring requirements.

Public Law 92-500 represents a fundamental shift in the nation's approach to improving the quality of its waters, for it declares illegal all pollutant dischargers, except under a permit that specifies the required degree of effluent reduction. The legislation also places new emphasis on a nationally coordinated water quality monitoring effort and on regional water planning and management. Specifically, Section 104(a)(5) of the Act requires that the Administrator of the EPA shall

> "In cooperation with the states, and their political sub-divisions, and other Federal agencies establish, equip, and maintain a water quality surveillance system for the purpose of monitoring the quality of the navigable waters and ground waters and the contiguous zone and the oceans and the Administrator shall, to the extent practicable, conduct such surveillance by utilizing the resources of the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration, the Geological Survey, and the Coast Guard, and shall report on such quality in the report required under Section 516(a)."

Section 106(e) of the Act further provides that:

> "Beginning in fiscal year 1974, the Administrator shall not make any grant to any state, which has not provided or is not carrying out as a part of its program the establishment and operation of appropriate devices, methods, systems, and procedures necessary to monitor, and to compile and analyze data on (including classification according to eutrophic conditions), the quality of navigable waters and to the extent practicable, ground waters including biological monitoring; and provision for annually updating such data and including it in the report required under Section 305 of this Act."

The Marine Protection, Research, and Sanctuaries Act of 1972 was intended to protect the nation's coastal areas and contains the following major monitoring provisions:

- Section 102 authorizes EPA to issue permits for the transportation and dumping of all other material, except dredged and fill material, and to establish criteria for reviewing and evaluating such permits and designating sites and times for dumping
- Section 103 authorizes the U.S. Army Corps of Engineers to issue permits, or regulations for Federal projects, for the transportation of dredged material for ocean dumping, according to criteria established by EPA
- Section 107 authorizes the Coast Guard to conduct surveillance of dumping activities and enforcement of regulations
- Sections 201, and 202, authorize NOAA to initiate a comprehensive and continuing program of monitoring and research regarding the effects of ocean dumping.

2. Regulations and Guidelines

EPA policy, regulations, and guidelines on water quality monitoring are contained chiefly in three documents:

- Water Quality Strategy Paper (15 March 1974)
- Appendix A - Water Quality and Pollutant Source Monitoring (Federal Register, 28 August 1974)
- Appendices A and B of Final Regulations and Criteria Governing the Transportation for Dumping and the Dumping of Material into Ocean Waters (February 1974)

The section on Monitoring and Evaluation of the Water Quality Strategy Paper lists the objectives of monitoring and evaluation, describes current and planned operation of the National Water Quality Surveilance System, and states the three basic monitoring reporting programs listed in the preceding section. Next, the Paper lists the objectives of the state monitoring programs under Section 106, stressing the importance of quality assurance programs, and presents a policy for evaluating the state program. The following ranking of effort is proposed for fiscal year 1975:

- Achievement of an effective level of field and laboratory support which includes a valid quality assurance component
- Establishment of an efficient data handling, storage, and reporting capability which includes an effective data quality control component
- Monitoring required for the development of permit conditions and for the issuance of permits
- Monitoring and facilities inspections required for the assessment of discharge compliance with permits
- Beginning the five year cycle of basin, or segment, management unit status surveys
- Establishing the primary network stations
- Design and establishment of the ground water monitoring network.

Appendix A to EPA grant regulations under Section 106 of PL 92-500 establishes and qualifies details of the grant award limitations for monitoring and sets forth the requirements the states must meet to satisfy the monitoring provisions of the act.

The Appendix describes the following requirements:

- Development of a monitoring strategy
- Coordination with other entities
- Support to the state continuing planning process
- Intensive monitoring surveys
- A primary monitoring network
- Compliance monitoring
- Evaluation of water quality with respect to standards
- Toxic pollutant monitoring
- Ground water monitoring
- Classification of publicly owned fresh water lakes by eutrophic conditions
- Laboratory support and quality assurance
- Data reporting, handling, and storage
- Collection, analysis, and evaluation of the basic information needed for the annual inventory reports required by Section 305(b) of the act
- Annual planning and reporting of program accomplishments in monitoring.

More specifically, states are required to comply with the following provisions:

- Development, maintenance and implementation of a statewide monitoring strategy which details the present monitoring activities and describes the monitoring plan necessary to progress systematically toward implementation of monitoring regulations

- Submission of an annual schedule of intensive monitoring surveys specifying station location, parameter coverage, and sampling frequencies
- Description of the primary monitoring network, specifying station locations, parameter coverage, and sampling frequencies
- Establishment and maintenance, to the extent practicable, of a statewide ground water monitoring program
- Preparation of an inventory of publicly owned significant fresh water lakes by 15 April 1975
- Emphasis on quality assurance and adherence to procedures set forth in the Appendix.
- Utilization of an information system capable of preparing, screening, validating, and submitting the water quality data to EPA.

Requirements for the performance of baseline surveys and monitoring surveys in connection with the ocean dumping of wastes are set forth in Appendices A and B, respectively of the Final Regulations and Criteria Governing the Transportation for Dumping, and the Dumping of Material into Ocean Waters. These regulations cover the following major provisions:[15]

- Planning and implementing surveys necessary for disposal site evaluation or designation studies
- Regulating times, rates, and methods of dumping and quantities and types of materials dumped
- Arranging for effective surveillance of dumping operations
- Developing and maintaining effective ambient monitoring problems for the site
- Conducting disposal site evaluation and designation studies
- Recommending modifications in site use and/or designation.

3. <u>Commitment of Resources</u>

The magnitude, if not necessarily the effectiveness or efficiency of a water quality monitoring program may be assessed in terms of the commitment of resources, i.e., funds, personnel, and equipment. Unfortunately, most Federal or state agencies, including EPA, consider water quality monitoring as an integral part of their respective programs that the monitoring is designed to support, and consequently, do not break this out as a separate budget item.

Where monitoring budgets are broken out, they frequently include monitoring of effluents to ensure compliance, which is not of direct interest to this study. State agencies frequently overestimate water quality monitoring costs they report under Section 106(f) by including salaries of personnel engaged in other ancillary activities, or under-estimate them by omitting monitoring services provided by other agencies.

Indeed, compilation of comprehensive, precise information on the amount, content, and cost of water quality monitoring programs would require on-the-scene full-scale audits of working files, laboratory reports, and personnel activities of hundreds of Federal, state, and local agencies. In Tables 6 and 7, we have attempted to do the next best things, commensurate with our temporal and budgetary limitations, to obtain approximate overviews of the distribution and costs of water quality monitoring efforts of Federal and state agencies, respectively. These overviews are based on published agency budgets and interviews with cognizant officials.

The state ambient monitoring budgets were obtained from the states' annual reports under Section 106 and from EPA's mid-year evaluation by assuming that some 80 percent of the monitoring program element budget is attributable to ambient monitoring, with the remainder assigned to compliance monitoring. For states that did not report a distribution of program elements, ambient monitoring was assumed to represent 20 percent of the total state program budget.[17]

TABLE 5. Water Quality Monitoring Programs of Federal Agencies

Agency	Program	Budget ($1000) FY 1974	FY 1975	Remarks
EPA	State grants	$ 6,600	$ 2,000	Rough estimate of the water quality monitoring share of overall state grants
	NWQSS	560	560	
	STORET	4,000	4,000	
	EPA Total	$11,160	$ 6,560	
USGS	Chemical monitor.	$ 3,300	$ 5,100	Rough estimate, including NSQAN, which accounts for FY 75 raise
	Sediment monitor.	670	670	Rough estimate
	NAWDEX	100	100	Represents 40 % of total NAWDEX budget associated with water quality monitoring
	USGS Total	$ 4,070	$ 5,870	
CoE	Reservoir Management	$ 2,350	$ 2,400	
	Urban Studies	190	500	
	Other	1,760	1,800	
	CoE Total	$ 4,300	$ 4,700	
BSFW	Pesticide monitoring in fish	$ 320	$ 320	
	Total water quality monitoring budget of principal Federal agencies	$19,850	$17,450	

TABLE 6. Projected State Water Quality Monitoring Budgets[a]

State	FY 1974 Total ($1000)	FY 1974 Federal Share (%)	FY 1975 Total ($1000)	FY 1975 Federal Share (%)
Alabama	316	81	314	86
Alaska	82	39	52[b]	50
Arizona	113	75	242	52
Arkansas	442	57	437	60
California	2,596	24	1,868	21
Colorado	198	33	174	33
Connecticut	160	47	358	37
Delaware	116	50	374	53
District of Columbia	94	60	101	62
Florida	501	17	930[b]	22
Georgia	233	58	423	61
Guam	30	72	68[b]	73
Hawaii	160	31	130[b]	44
Idaho	114	46	123	47
Illinois	1,637	26	1,704	20
Indiana	602	53	720	53
Iowa	185[b]	62	167[b]	79
Kansas	104	48	123	41
Kentucky	291[b]	40	126	39
Louisiana	480	64	478	59
Maine	206	33	235	11
Maryland	535	15	643	22
Massachusetts	224	46	153	49
Michigan	1,103	33	1,287	38
Minnesota	398	36	398	36
Mississippi	94	73	144	51
Missouri	202	69	230	65
Montana	122	54	94	59
Nebraska	82	58	101	56
Nevada	45	40	64	45
New Hampshire	163	21	172	15
New Jersey	460	42	373	32
New Mexico	66	46	91	50
New York	1,325	33	1,208	24
North Carolina	754	51	730	52
North Dakota	43	77	33	62
Ohio	1,179[b]	26	376	29
Oklahoma	241	50	140	64
Oregon	77	41	250	41
Pennsylvania	187	39	1,538	29
Puerto Rico	88	66	158	60
Rhode Island	129	75	138	60
South Carolina	510	45	389[b]	41
South Dakota	34	70	62	75
Tennessee	557	43	490	43
Texas	1,160	23	1,008	23
Utah	42	55	60	45
Vermont	158	30	197	23
Virginia	675	20	802	20
Virgin Islands	66	78	66	66
Washington	415[b]	42	451	49
West Virginia	238	47	88	49
Wisconsin	914	31	742	32
Wyoming	32	76	33	37
	20,978		21,856	

(a) Applies to ambient monitoring only, which is assumed to represent 80 percent of the monitoring grant program element, with the other 20 percent assigned to compliance monitoring.

(b) These entries were not reported by the states and were obtained by assuming that ambient monitoring represents 20 percent of the total state program budget.

B. FEDERAL PROGRAMS

The largest Federal water quality monitoring programs are conducted by the U. S. Geological Survey (USGS), the U.S. Environmental Protection Agency (EPA), and the U.S. Army Corps of Engineers (CoE). However, as is noted in Table 7, a number of other Federal agencies are substantially involved in this effort as well. These include the U. S. Atomic Energy Commission (AEC), the Bureau of Reclamation (BuRec), the Bureau of Sport Fisheries and Wildlife (BSFW), the U. S. Coast Guard (USCG), the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), and the Soil Conservation Service (SCS). The mission and major water quality monitoring programs of these agencies are described briefly below.

1. U. S. Geological Survey

The U. S. Department of the Interior Geological Survey (USGS) collects, interprets, and disseminates information on the nation's mineral and water resources and physical features. Specifically, the Water Resources Division is responsible for the investigation and appraisal of the source, quantity, quality, distribution, movement, and availability of both surface and ground waters. This work includes investigations of floods and droughts, interpretive studies of existing or potential water problems, research in the field of hydrology and related sciences, scientific and technical assistance to other Federal agencies, and coordination of Federal activities in the acquisition and dissemination of water data.[16]

TABLE 7. Water Quality Monitoring Functions of Federal Agencies

	AEC	BuRec	BSFW	USCG	CoE	EPA	NASA	NOAA	SCS	USGS
Collection										
• State grants						X		X		
• Inland	X	X		X	X	X	X		X	X
• Coastal	X			X	X	X		X		
• Biological	X		X			X		X		
• Remote						X	X			X
Storage/Inventory										
• Storage						X				
• Catalog										X
• Inventory								X		X

The USGS has a cooperative water quality monitoring program in conjunction with most states, which operates about 3,400 stations, where states cover about half of the costs of operations. The data from these stations were published annually until 1968 as the Surface Water Quality Series, but more recently, results have been stored in a USGS computer system and published by USGS district offices, except for special projects.

In addition, the USGS has operated about 700 stations funded by other Federal agencies and about 290 USGS-funded stations, including 40 baseline stations to monitor water quality in areas undisturbed by man's activities. Traditionally, most of these stations have been monitoring on a monthly basis and have emphasized dissolved mineral water quality constituents, sediment, DO, and nutrients. The USGS also maintains a number of stations that measure only sediment and/or temperature. Finally, the Survey collects samples, which are analyzed by EPA, under a cooperative pesticide monitoring program.

The Office of Water Data Coordination publishes a biennial catalog of water data, which was described in Section IV C. New USGS water quality activities are the National Stream Quality Accounting Network (NASQAN), the EROS satellite data program, and the National Water Data Exchange (NAWDEX) system. These activities were likewise described in some detail in the preceding chapters.

The USGS obtains water quality monitoring funds through direct appropriations, as well as through contributions from other Federal agencies and states. The approximate amounts from these sources for fiscal year 1974 are $3.5, 1.8, and 2.3 million, respectively, for a grand total of $7.6 million. An additional $1.7 million for sediment monitoring is derived in accordance with a somewhat similar split. The water quality monitoring expenditures include the cost of operating the National Stream Quality Accounting Network, which was $460,000 in fiscal year 1974, but is expected to rise to $2.3 million in fiscal year 1975. The $250,000 annual cost of operating the National Water Data Exchange is not included in the above figures.[8]

2. <u>Environmental Protection Agency</u>

The U. S. Environmental Protection Agency (EPA) is responsible for establishing and enforcing environmental protection standards consistent with national goals. In the water quality area, the Agency is charged with implementing the provisions of Public Law 92-500 and related legislation and with fostering a supply of water that is adequate in quality for all beneficial purposes, including public water supply, propagation of fish, aquatic life, and wildlife, as well as recreational agricultural, industrial and other uses.[16]

The principal water quality monitoring programs of the U. S. Environmental Protection Agency are:

- State grants
- National Water Quality Surveillance System (NWQSS)
- Storage and Retrieval System (STORET)
- Other monitoring programs
- Research activities.

The state grant allocations for all water quality monitoring and planning activities, including administration of the discharge permit, municipal facilities, and compliance monitoring programs, for fiscal years 1974 and 1975, are $19.4 and 40.0 million, respectively. The portion granted to ambient water quality monitoring has been estimated at about ten percent of the 1974 and five percent of the 1975 amount. In addition, in fiscal year 1974, EPA provided states one-time grants of $9.2 million for performance of intensive surveys and development of models, leading to classification of segments as effluent or water quality-limited. Approximately one-half of these funds are estimated to have been devoted to ambient water quality monitoring.[9]

EPA' National Water Quality Surveillance System (NWQSS), a national network of 150 paired and single monitoring stations, and the STORET system for storing and retrieval of water quality data, contributed primarily by states, USGS, as well as EPA, have been described in some detail in the preceding chapters. Their respective annual budgets are $560,000 and $4 million.

While the above programs are under the jurisdiction of the Monitoring and Data Support Division, several other offices are engaged in lesser monitoring activities.[20] Thus, the Office of Pesticides Programs conducts:

- The National Monitoring Program for Water
- The Estuarine Fish and Shellfish Monitoring Program
- The Ocean Monitoring Program.

The first of these comprises 128 stations throughout the United States which are expected to grow to 153 during fiscal year 1975. Water and sediment samples are collected quarterly and semi-annually, respectively, by the U.S. Geological Survey and the Environmental Health Services Command of the U. S. Army and are analyzed for chlorinated hydrocarbons and organophosphates by EPA's National Pesticide Monitoring Laboratory at Bay St. Louis, Mississippi. The data are stored in the USGS computer, then transfered to EPA's STORET. The Estuarine Fish and Shellfish Monitoring Program operates a network of stations located in 113 primary estuaries listed in the National Estuarine Survey. Fish samples are collected semi-annually by universities and state marine agencies under contract to EPA and analyzed for lead, cadmium, arsenic, mercury, and chlorinated hydrocarbons at EPA's Mississippi test facility. Finally, the Ocean Monitoring Program involves analysis by the EPA Mississippi laboratory of fish samples collected from time to time by the National Oceanic and Atmospheric Administration.

The Office of Radiation Programs operates an Environmental Radiation Ambient Monitoring System (ERAMS) which consists of a drinking water and a surface water component. The first of these involves 76 quarterly samples of drinking water from major population centers and selected nuclear facility environs. The surface water component consists of 55 surface water sampling stations located downstream from nuclear facilities or at background stations. Samples are collected quarterly by EPA regional offices and analyzed at their regional laboratories.

The Water Supply Division in the Office of Water Program Operations works with the Food and Drug Administration to monitor some 700 water supplies serving a population of 83 million and the water supply on interstate carriers (e.g., aircraft, trains). Sample collection is sporadic, and analyses are performed in various laboratories and reported through the states. In addition, the Water Supply Division occasionally becomes involved in special studies that include water monitoring.

Research on monitoring techniques is being conducted by the Methods Development and Analytical Quality Control Research Laboratory in Cincinnati and by the Quality Assurance Division of the Office of Research and Development. This activity was described in Section III A 4.

3. Corps of Engineers

The U. S. Army Corps of Engineers (CE) has been authorized by Congress to investigate, develop, conserve, and improve the nation's water, land, and related environmental resources. This program encompasses a broad range of resource development activities for navigation, flood control, major drainage, shore and beach restoration and protection, hurricane flood protection, related hydroelectric power development, water supply, water quality control, fish and wildlife conservation and enhancement, outdoor recreation, and environmental quality. The Corps also participates in regional or river basin water resources planning studies.[16]

The Corps conducts water quality monitoring only to the extent required by its original water resource management functions and not otherwise provided for by other agencies. Typically, the Corps stations are designed to establish a short-term record relevant to a Corps activity, or to provide data that are not of interest to other water quality data collection agencies. Consequently, the Corps does not have effective dissemination procedures and access to these data is usually difficult. The principal Corps activities involving water quality monitoring are as follows:

- Reservoir management program
- Urban studies program
- Dredge materials research program
- Other programs.

The objective of water quality monitoring within the Reservoir Management Programs, is to minimize any adverse effects and maximize the beneficial effects of water releases from reservoirs operated by the Corps. The monitoring consists of vertical profiles of such parameters as suspended solids, dissolved oxygen, salinity, pH, conductivity, temperature, and in some cases, coliform counts. These vertical profiles provide valuable inputs to the decision on which stratum to release from, in order to provide desirable downstream water quality. At present, the Corps conducts water quality monitoring at 245 reservoirs, with 88 more reservoirs being added during the next 5 years. This activity is being carried out under the authority of PL 87-88, and about 5 percent of the reservoirs are being monitored for the Corps by other agencies.

The Urban Studies Programs are designed to examine wastewater management alternatives in 21 areas across the United States. Despite its attempt to rely on existing water quality data, the Corps has found it necessary to undertake additional monitoring at the site of some areas. Half of these are being monitored for the Corps by other agencies. The Dredged Materials Research Program was initiated under authority of Public Law 91-611 to investigate the effects of dredging and disposal of dredge spoils. Consequently, water quality measurements are now made by the Corps in connection with most of its major dredging operations.

Other U.S. Army Corps of Engineers programs involving water quality monitoring include wastewater management at military establishments, waste treatment at recreational areas, as well as salinity, mine drainage, and sediment control projects. The first two activities involve periodic measurement of the quality of streams receiving effluents from wastewater treatment facilities at military establishments and recreational areas under the Corps jurisdiction. The remaining activities refer to a limited number of pollution control projects for which the Corps is responsible.

The cost of water quality monitoring activities in connection with the Reservoir Management Program was $1.6 million in fiscal year 1974 and is expected to rise to $3.4 million in fiscal year 1975. The additional monitoring undertaken for the Urban Studies Program is budgeted at

$112,000 for fiscal year 1974 and $518,000 for fiscal year 1975. The cost of water quality monitoring activities in connection with the Dredged Materials Research Program and several lesser projects listed is expected to rise from $1.5 million in fiscal year 1974 to $1.9 million in fiscal year 1975.[21]

4. Bureau of Sport Fisheries and Wildlife

The Bureau of Sport Fisheries and Wildlife (BSFW), within the U. S. Department of the Interior exercises the Federal responsibilities for wild birds, mammals, and inland sport fishes. Under the Fish and Wildlife Coordination Act, the BSFW has responsibility to investigate the reports on water resource development projects prior to their construction or license by the Federal Government, to determine the probable effects of such projects on fish and wildlife resources and associated habitats, and to recommend measures for preventing or reducing damages to these resources.[16]

The principal contribution of BSFW to water quality monitoring is the inspection of fish for pesticides and metals. This monitoring program was described in some detail in Section III B. The annual cost of this program was $318,000 in fiscal years 1974 and 1975, with 52 percent going for the regional collection effort, about 20 percent for the laboratory analysis and some exploratory work, and the remainder for headquarters operations, including administration and data dissemination.[2]

Similar monitoring of birds is performed, but the species involved are all either migratory or non-aquatic, thus yielding no measure of local water quality. In addition, BSFW is completing a research monitoring effort at four Missouri River reservoirs, covering zooplankton, benthic, and "young of the year" fish sampling, but the data are not organized in a manner useful for water quality planning purposes.

5. National Oceanic and Atmospheric Administration

The National Oceanic and Atmospheric Administration (NOAA) in the Department of Commerce gathers, processes and issues information on weather and climatic conditions, coastal tides and currents, and ecological relationships between game fish and other marine and estuarine organisms. Its principal areas of activity related to water quality monitoring are as follows:

- Coastal zone management
- Manned underwater activities
- Marine ecosystems analyses

Under the Coastal Zone Management Act of 1972, NOAA is authorized to encourage and assist Federal, state, and local governments and regional agencies in the development and operation of coastal zone management programs, which may include monitoring of coastal water quality.

The manned underwater activities program provides manned underwater support to include ecological and environmental surveys in regions where shellfish and other food stocks have been depleted, and investigation of the movement of sediment and other pollutants on the continental shelf. Marine ecosystems investigations in selected areas consist of studies of the ecology of the marine environment, changes due to human activity, impacts of those changes, and the development of ecological descriptions. This is designed to provide a reference base for planning and managing future uses of marine resources in order to minimize adverse impact on the environment.

6. Other Federal Agencies

Other Federal agencies active in the water quality monitoring area are the U. S. Atomic Energy Commission, Bureau of Reclamation, U. S. Coast Guard, National Aeronautics and Space Administration, Soil Conservation Service, and Tennessee Valley Authority.

The U. S. Atomic Energy Commission oversees monitoring of water quality by contractors in conjunction with siting surveys for nuclear power plants. On occasions, the Commission has studied the effects of temperature on aquatic biota. Its annual environmental monitoring budget of $9.5 million is not broken down further, but water quality monitoring represents only an insignificant fraction of the total.

The Bureau of Reclamation in the U. S. Department of Interior, is concerned with development of water and related land resources in the 17 western states. The primary functions covered by the Bureau include irrigation, municipal and industrial water supply, flood and erosion control, preservation and propagation of fish and wildlife, outdoor recreation, drainage, pollution abatement, and water quality control The Bureau operates local water quality monitoring stations in conjunction with these specific responsibilities.

The U. S. Coast Guard, in the U. S. Department of Transportation, monitors physical parameters, such as temperature and salinity, on a monthly basis, for the waters 100 to 150 miles off shore. The purpose of this monitoring is to determine the temperature distribution points parallel to the shore line, to predict current development, and to determine fish organization and fish species. The USCG believes that it has major potential for contributing to coastal water quality monitoring, because of the many vessels, aircraft and facilities the agency operates in the coastal zone.

The contribution of the National Aeronautics and Space Administration to water quality monitoring consists primarily of experimental remote sensing programs, such as Skylab, ERTS, and high-altitude aircraft. These were described in some detail in Section III C.

The Soil Conservation Service in the U. S. Department of Agriculture conducts local water quality monitoring to assess the environmental impact of specific projects and collects data on sedimentation of streams, in cooperation with the USGS.

C. STATE PROGRAMS

Water quality monitoring on the state level is performed primarily in support of pollution control and public health programs, by a number of agencies that frequently do not coordinate their activities or exchange data. The monitoring programs of state and local agencies have grown rapidly since 1966 and are expected to surpass the Federal effort in the near future. The state programs are presented here in terms of the typical agencies and their relations, the number of stations and funding, and raising of monitoring revenues through surveillance fees.

1. Agencies

Water quality monitoring on the state level is frequently divided among several state agencies. A common arrangement calls for either the water pollution control or the public health agency to collect the samples, while the laboratory analysis is performed by the public health agency. Moreover, metropolitan pollution control agencies, as well as various other governmental, industrial, or academic institutions conduct their own sampling and analysis, frequently without coordination or exchange of data with the state agencies. This results in considerable overlaps and gaps in the availability of monitoring data, difficulties in finding and reconciling conflicting data, and lack of uniformity and consistency required for performance of regional assessment and planning.

A fitting illustration of this situation is afforded by our study of the thirty miles of the Maumee River and Bay in the vicinity of Toledo. This body of water is monitored with varying frequency by no fewer than a dozen disparate agencies, including the U. S. EPA, the U. S. Geological Survey, the U. S. Army Corps of Engineers, the Lake Survey (formerly part of the Corps, now part of NOAA), Canada Center for Inland Waters, Ohio EPA, Toledo Pollution Control Agency, Toledo Division of Water Reclamation, Toledo Municipal Waterworks, Lucas County Sewage Treatment Plant, Toledo/Lucas County Port Authority, local universities, as well as several Toledo-based environmental groups. In addition, effluents are monitored by each of the major dischargers, including Interlake Steel, several oil refineries, power plants, and sewage plants. There has been little, or no attempt to coordinate the sampling effort, to standardize sampling protocols and analytical procedures, or to exchange data. In fact, most of the agencies listed appear to be only dimly aware of the others' monitoring activities.

With the increasing centralization of state pollution control functions in a department of natural resources, or environmental protection, some of these agencies are also acquiring their own laboratories. USEPA Region V has led an effort to retrieve large amounts of water intake monitoring data along the shores of Lake Erie. Wisconsin uses conservation wardens to collect water samples, while Indiana maintains an excellent network of 100 monthly stations, operated by only two staff members, due to voluntary contribution of water quality data by industry. However, our telephone survey of eight likely states

(Michigan, New Mexico, New York, North Dakota, Oklahoma, Oregon, Virginia, and Wisconsin) produced no obvious examples of cost-saving "piggybacking" of sample collection and analysis efforts by different agencies.

2. Programs

The magnitude, if not necessarily the quality, of state water quality monitoring programs can be characterized by the number of monitoring stations and/or the annual budget. Both are taken up below.

The number of state monitoring stations can be obtained from the annual state reports to EPA under Section 106(f) of PL 92-500 or from information compiled by the Office of Water Data Coordination of the U. S. Geological Survey. The former source is more likely to reflect the actual number of state stations, whereas the latter reports on most non-Federal stations within a given state. The number of stations operated by both Federal and non-Federal agencies within each state as of January 1974 is reported in Figure 1. The figure and Table 2 indicates that state and local agencies operated just under 50 percent of all stations, with the states of Illinois and South Carolina clearly in the lead in this respect. Since 1966, the number of non-Federal stations has risen much more rapidly than that of Federal stations and this trend is expected to be accelerated by the implementation of Section 106(e) of PL 92-500.

The annual budgets for state monitoring programs are likewise reported to EPA under Section 106(f), but given the heterogeneity and lack of coordination of the various state and local monitoring programs, one should regard these reports as reflecting the monitoring budget of the reporting body, usually the state pollution control agency. If this agency does not pay the public health agency for laboratory services, then monitoring costs may be seriously understated. On the other hand, there may well be personnel reported in monitoring activities who are spending most of their time on enforcement case preparation, thus leading to overstatement of monitoring costs.

With these precautions in mind, the state monitoring budgets for fiscal years 1974 and 1975 are reported in Table 6 and discussed in Section V A 3. It may be noted that the budgets for all states in these years are slightly in excess of $20 million, with EPA grants providing approximately 35 percent of the total amount. Some ten percent of the states' budget is, in turn, transfered to the U. S. Geological Survey for operation of some state monitoring stations.

3. <u>Surveillance Fees</u>

Surveillance fees are charges levied against dischargers by state or local agencies to defray the cost of monitoring the discharges and the resultant ambient water quality. A survey of 20 states conducted in the fall of 1973 by a joint team from the Office of Management and Budget and the Environmental Protection Agency disclosed that, in spite of their many advantages, only three jurisdictions (the states of Michigan and Wisconsin and Maricopa County, Arizona) were in fact collecting surveillance fees on a systematic basis. Two more states were collecting the fees sporadically, while four others had the statutory authority, but did not exercise it, primarily because the low legislative ceiling imposed on the fee rendered the effort unproductive.

The advantages of surveillance fees have been cited as follows:

- Raising of funds to defray monitoring costs
- Internalizing of some costs of pollution in the price of the polluting commodity
- Rendering the discharger more aware of the costs of pollution and his responsibility for its abatement.

On the other hand, critics of these levies point to the difficulty of making the charges equitable and to the additional paperwork they require.

Collection of a surveillance fee by the State of Michigan Department of Natural Resources was authorized by the state legislature in 1970. The fee is assessed annually on the basis of the nature, concentration, flow rate, and location of the discharge. During the three years that followed, the state collected over $728,000, nearly $1 million, and $1.2 million, respectively, with an average fee of $567 per plant and a theoretical maximum of $9,000. This source of income now rivals the state's annual contribution from EPA. The situation in Wisconsin is rather similar, though the annual revenue is only about $250,000, primarily because of the state's smaller industrial base.

ANALYSIS AND RECOMMENDATIONS

VI. ANALYSIS

The analysis of the effectiveness and efficiency of Federally supported water quality monitoring activities described in the preceding chapters is presented here in terms of the major problem areas, following a discussion of the purpose and scope of the analysis:

- Quality of monitoring data
- New monitoring methods
- Coordination of monitoring
- Utilization of monitoring data.

The next chapter proposes a number of recommendations designed to alleviate these problem areas.

A. PURPOSE AND SCOPE OF THE ANALYSIS

The purpose of this analysis is to examine critically Federal monitoring activities in order to identify and characterize ineffective or inefficient utilization of Federal resources under provisions of the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500). The results of this analysis lead to a set of recommendations designed to improve the effectiveness and efficiency of utilizing these resources. Because of budgetary and temporal constraints, this analysis focuses on the activities of those agencies that are directly involved in water quality monitoring, on the more significant and troublesome problem areas, and moreover, on those areas that could be improved without a major uprooting of the existing institutional and program structure.

It will be useful at this point to define our interpretation of the key concepts of "effectiveness" and "efficiency". The Random House Unabridged Dictionary defines "effective" as "adequate to accomplish a purpose", or "producing the expected or intended result", and "efficient" as "performing or functioning in the best possible and least wasteful manner". In other words, effectiveness reflects the direction of the effort with respect to the position of the goal sought, while efficiency measures progress along that direction as a function of the commitment of resources. This is somewhat akin to the notion of direction and speed in navigation.

The major problems afflicting water quality monitoring activities can be characterized as misdirection, futility, overlaps, conflicts, delays, and unaddressed issues. The first two problems relate to the concept of effectiveness, since misdirection addresses the alignment of the chosen course represented by a given activity with the goal sought, while futility deals with the extent to which the expected result will advance this goal. On the other hand, overlaps of jurisdiction, conflicts between functions of different organizations, and delays in implementation of useful programs, are major displays of the concept of inefficiency. Unaddressed issues involve observations of missed opportunities that could affect either concept.

B. QUALITY OF MONITORING DATA

This section examines the prevalent quality of monitoring data in terms of the relevance of sampling station location and scheduling, as well as sample handling and analysis, to the specific needs and objectives of the monitoring program.

1. Relevance to Program Objectives

A complete characterization of a water body would entail the collection and detailed analysis of a countless number of water samples, as well as detailed identification of all biota present. Thus, any practical water quality monitoring program must reflect its temporal and budgetary constraints, but most importantly, it must reflect its major objectives. The major objectives of water quality monitoring are the characterization of the cause, nature, and extent of water quality problems, enforcement of discharge regulations, and assessment of the effectiveness of pollution abatement programs. The selection of the monitoring station, including location, sampling frequency and timing, the parameters to be measured, as well as the method of analysis, must reflect faithfully the specific needs of the monitoring program. This was spelled out in some detail in Section II A.

An indication of the relevance of parameter selection on a national level to the objectives of water quality planning may be obtained through an analysis of the parameter coverage in the STORET data file, which was described in Section IV B. Such an analysis was performed recently by the Environmental Protection Agency, and the results are rather significant.

Among the most frequently measured parameters are conductivity, pH, dissolved oxygen (DO), and 5-day biochemical oxygen demand (BOD_5). Conductivity is an indicator of the concentration of dissolved salts, which is of interest in hydrogeologic studies of the type conducted by the U. S. Geological Survey and in assessing the suitability of water supplies for crop irrigation and other uses. However, concentration of dissolved salts is almost never controlled in water quality planning.

The pH can affect the chemical form, and therefore, the effect of certain pollutants. However, the pH of most water bodies rarely fluctuates beyond a small range, except in the immediate vicinity of an acid source. Measurements of DO and BOD are, of course, very crucial to water quality planning, but measurement of the five-day demand does not reflect the fact that the dissolved oxygen sag frequently occurs after 1-2 days of travel downstream.

The group of parameters with the next highest frequency of measurement includes some nutrients, such as ammonia, nitrate, and phosphate, but total nitrogen and phosphorus measurements, which are essential to establish relationships with algal growth, are missing.

This group also contains such parameters as turbidity and total coliform, that don't correlate well with suspended solids and raw sewage, which they purport to represent. The least measured group of parameters includes important toxic metals, such as cadmium, lead, and zinc, while other equally important toxic metals are hardly measured at all.

Selection of sampling location and timing has suffered from similar lack of relevance. For example, quality of a water body subject to turbulent flow, seiches, or tidal movements, has been deduced from a single sample collected from a convenient bridge, while the presence of insoluble toxic substances has been assessed from their concentration in the water. Manual sample collection is sometimes skipped in inclement weather, when nearly all discharges from non-point sources take place. Similarly, dissolved oxygen (DO) measurements in eutrophic areas are usually taken during daylight hours, although the more serious depletion of oxygen occurs at night, when the algae metabolize their food. The use of automatic monitors has corrected these problems to a large extent. These considerations are discussed in additional detail in Section II B.

2. Analytical Quality Control

In addition to the sampling problems discussed above, a major affliction of water quality monitoring programs is lack of validity and reproducibility of analytical results. This can result from a number of causes, including improper application of the analytical method, insufficient sensitivity of the method selected to the given concentration, or interference from another chemical species present. For example, widespread reports on the improvement of the quality of the Willamette River in the late 1960's have been found somewhat misleading, because they were based largely on Winkler measurements of DO in the presence of sulfite liquor, which causes erroneous readings. Our examination of the BOD load during that period showed no reduction, despite the comprehensive cleanup measures.

Faulty analytical methods may lead to several major adverse consequences. In the first place, the effort of collecting and analyzing the sample has been wasted; secondly other agencies are less likely to trust the data and more likely to duplicate the monitoring effort. Most importantly, the faulty results may lead a water quality manager into making an inappropriate decision.

C. NEW MONITORING METHODS

In addition to the more traditional chemical and physical measurements of the water column, or of grab samples taken from it, there are newer monitoring methods that fill special needs, such as biological monitoring, sediment analysis, and remote sensing. The promise and importance of these methods are discussed in this section.

1. Biological and Sediment Analysis

Toxic substances, such as pesticides from agricultural runoff and heavy metals from industrial discharges, frequently form insoluble compounds in the receiving waters and precipitate to the bottom. There, they are introduced and accumulated in the food chain through benthic organisms, converted to a soluble form and released back to the water column, or picked up and deposited farther downstream by gushes of rapid or turbulent flow.

Thus, detection of toxic substances and assessment of the viability of a water body is an important first step in the measurement of the concentration of toxicants in representative aquatic animals and plants. The next step may be to perform sediment analyses to characterize the nature, location, and extent of the problem. Finally, measurements of the water column can serve to pinpoint the sources of discharges and transport modes of the toxic substances.

The usefulness and necessity of biological monitoring of water quality has only recently received wide recognition, under the stimulus of the Federal Water Pollution Control Act of 1972 (PL 92-500), which calls for the restoration and maintenance of biological integrity of the nation's waters, protection and propagation of fish and wildlife, and prohibition of toxic discharges. The more common types of biological investigations are identification of specific indicator organisms, community diversity studies, bioaccumulation surveys, and lake eutrophication surveys.

Biological monitoring seeks to complement, rather than replace, chemical and physical monitoring, and it introduces a number of useful features. The first and most important of these refers to the fact that the condition of aquatic biota tends to reflect the suitability of water quality for most intended uses more faithfully than chemical or physical characteristics. Secondly, the sensitivity of some organisms to certain toxic substances is greater than that of common analytical methods. Third, they are likely to react instantaneously to a fleeting, but critical effect that may be missed by scattered chemical and physical analyses. Finally, living organisms tend to accumulate and magnify through the food chain small doses of toxic substances that could be missed by sporadic sampling and common analytical methods.

The principal Federal biological monitoring activities are conducted by the Bureau of Sport Fisheries and Wildlife (BSFW) and U. S. Environmental Protection Agency (EPA). The major thrust of the BSFW program consists of fish population counts and pesticide and heavy metal analysis of fish tissues in the Great Lakes, reservoirs, and rivers. EPA activities involve primarily field and laboratory studies designed to establish water quality criteria for various beneficial uses, and to develop biological monitoring techniques. In addition, EPA has developed a Model State Water Monitoring Program to assist states in the implementation of the biological monitoring requirement of Section 106(e) of PL 92-500.

Our recent (April, 1974) survey of all EPA senior regional biologists revealed that only a handful of states (e.g., California, Florida, Indiana, New York, Pennsylvania, and Wisconsin) are conducting any kind of consistent biological monitoring program, and some of these are rather superficial. The biological monitoring requirement of Section 106(e) provides a convenient and effective means for increasing state participation.

Sediment analysis has been largely ignored in past water quality monitoring efforts, because the procedure is complex and costly and because the appropriate analytical techniques require much additional research and development. More recently, the importance of sediment analysis has received some recognition as a result of the discovery of pesticides in stream bottoms, growing interest in biological monitoring, the EPA requirement for analysis of dredge spoils that are dumped at off-shore sites, the U. S. Army Corps of Engineers Dredged Materials Research Program, and the need to deal with sludge blankets in waterway cleanup efforts.

2. Remote Sensing

Remote sensing of water quality is still largely an experimental, but rapidly developing monitoring tool that is expected to represent a valuable complement to current *in-situ* sampling and analysis operations. The detection capability of aircraft and satellite remote sensing instruments is limited to those parameters that modify the reflective or emissive characteristics of the surrounding aqueous medium. These include suspended load, chlorophyll, oil, acids, and temperature. Additional results can be obtained by inference supported by "ground truth."

Several avenues are open to improve past performance of remote sensing systems. Extensive tests of remote sensing imagery against ground truth should be conducted to evaluate the relative reliability and effectiveness of various interpretation techniques. The gain on the multispectral scanner could be raised to increase the number of data levels, and therefore, the discrimination capability of the sensors over the poorly reflecting water surface. Spatial discrimination in satellite imagery could be improved by increasing spatial resolution of the sensors. Additional work is needed in removal of noise and atmospheric efforts in data processing procedures. The turn-around time at the data processing center could be reduced to bring out the real time advantages of remote sensing.

The major advantages of remote sensing vis-a-vis in-situ sampling and monitoring are synopticity (capability to present a simultaneous pictorial representation of the entire area), rapid coverage (capability to cover vast areas in a short time), serendipity (capable to observe at a later date phenomena that were not sought at the time that the data was being collected). On the other hand, the current system exhibits a number of shortcomings, such as fixed and relatively low pass frequency, poor discrimination, low resolution, poor penetration beneath the water surface, dependence on reflected light, inability to penetrate cloud cover, and inability to yield reliable quantitative estimates.

The major role of remote sensing systems in water quality monitoring is expected to lie in real-time detection of major changes in water quality, in directing in-situ investigations to the most critical areas, in reporting on phenomena requiring numerous synoptic data points, such as discharge plume contours, and in assessment of long-term trends in water quality. These specific applications appear likely with present technology:

- Detection of sediment discharges from non-point sources to assist in establishing and enforcing waste load allocations in large bodies of water
- Delineation of dispersion patterns from offshore dumps to assist in issuance and enforcement of dumping permits and in the investigation of offshore circulation patterns
- Characterization of long term trends in sedimentation and eutrophication of large bodies of water, to assist in establishing pollution abatement priorities.

A more detailed discussion of remote sensing of water quality appears in Section III C.

D. COORDINATION OF MONITORING

There exist considerable gaps and overlaps between the largely uncoordinated water quality programs of the many different Federal, state, and local monitoring agencies. The USGS NAWDEX and Office of Water Data Coordination programs are attempting to cope with a part of this problem. However, coordination of monitoring activities and cataloging and/or storage of the data should be conducted on a level that is close enough to the generator and user of the data yet broad enough to promote some consistency and centralization.

1. Need for Coordination

Extensive water quality monitoring programs are being conducted by institutions at all jurisdictional and functional levels of both the public and private sectors. These institutions include Federal, state, county, and municipal agencies dealing with environmental protection, public health, water treatment, wastewater treatment, and navigation, as well as industrial firms and research institutions. Frequently, a number of such programs are carried out within a small area by different agencies, with little or no knowledge of each others activities, let alone any attempt at coordination of effort.

Thus, the potential user of water quality data must face the nightmarish task of first determining which agencies have collected data on the water body of interest, then checking on the availability and quality of the data, and finally, trudging from one agency to another, to assemble the data and attempt to resolve conflicts. This process requires the services of relatively senior personnel, well versed in the arts of water quality monitoring and interpersonal diplomacy, since most of the leads are obtained by word of mouth, while the data is provided by the grace of the collecting agency. Under these conditions, the potential user may well run out of funds or patience, before his task is complete, and the resulting plan or decision may be based on insufficient or inadequate information.

To be sure, water quality monitoring serves in a number of support roles, which need to be closely coordinated with the supported activity. Moreover, institutions are frequently unwilling to trust each other's data or to be constrained by the priorities of others. Nevertheless, it is also widely recognized that excessive fragmentation of the monitoring programs leads to needless duplication of effort, dissipation of limited monitoring resources, and limited usefulness of the large body of data produced, due to lack of consistency in sampling and analysis.

On the Federal level, the overview in Section V B pointed out that a number of Federal agencies collect and analyze water quality data. Sometimes these activities may be undertaken by several departments within the same agency, as is the case with EPA. On the state and local level, the problem rapidly becomes more complex. This was illustrated in Section V C 1 for the Maumee River and Bay near Toledo, where monitoring has been performed by a dozen disparate agencies with little coordination and only dim awareness of one another's activities. Although this situation may not be fully representative of all metropolitan areas, none of the ten states, where we have conducted in-depth investigations of water quality monitoring programs, were aware of all monitoring activities taking place within their borders.

2. Current Coordination Efforts

Some states have launched limited, but commendable efforts to alleviate these problems. Indiana publishes an annual compilation of the data collected by its network of 100 water quality monitoring stations. Wisconsin issues periodic summaries reporting on both effluent and water quality measurements for each basin.

Attempts to correct the situation by providing a national water quality data inventory, storage, and processing capability have been made by the U. S. Geological Survey (USGS), through its NAWDEX (National Water Data Exchange) system and Office of Water Data Coordination program, by the National Oceanic and Atmospheric Administration (NOAA), through its ENDEX (Environmental Data Exchange) system, and by EPA, through its STORET (Storage and Retrieval) system. All three programs were described in some detail in Chapter IV.

The inventory function of ENDEX encompasses all environmental data, ranging from meteorology to geology, whereas NAWDEX covers primarily water quality and related data. Although neither system is fully operational at this time, both are expected to suffer in different degrees from similar drawbacks:

- Overlap of function with each other's and states' efforts

- Incompleteness of information
- Insufficient attention to water quality planning data
- Difficulty of access by local officials.

In terms of the specific need of water quality management, the two national inventory systems have the advantages of providing information on water quality data on a national level and within the context of other relevant data on meteorology, hydrology, and geology. Yet, they currently lack the comprehensiveness, degree of detail, and accessibility that could be provided by a series of more localized inventories.

The USGS Office of Water Data Coordination provides an important coordination function through its publications and through the two committees formed in response to OMB Circular No. A-67. However, the coordination effort is limited primarily to Federal agencies and is based on voluntary participation among the member agencies.

The EPA water quality data storage and retrieval system is operational and still growing. It provides a vast data storage function, versatile processing capability and access by remote terminals. Its major drawbacks are somewhat similar to those of the national inventory systems:

- Incompleteness of data
- Lack of uniformity of measurement and reporting
- Lack of data inventory and station identification

- Lack of data annotation and quality control
- Overlap of function with state efforts
- Diffidence by state and local officials.

Some of these problems could be alleviated in part by improving the communication with and enlisting the cooperation of state agencies, but much of the difficulty is endemic to excessive centralization. In our own attempts to use STORET data for assessment of national trends in water quality, we found these drawbacks deeply frustrating. If it aspires to become anything more than sometime state data repository, STORET must deal resolutely and rapidly with these problems.

3. Optimal Level of Coordination

The preceding analysis points to the need for coordination of water quality data by some regional body. Such a body must be close enough to the generators and potential users of the data to permit adequate annotation and ready availability, but must not be so small and localized as to require the user to visit a number of different agencies in search of the data he requires. This body must also have sufficient institutional resources to obtain and maintain the data and some legislative authority to legitimize this function. The likely candidates are:

- EPA regions
- Basin commissions
- States
- Counties.

EPA regions are considerably removed, in both the geographic and the institutional sense, from the local and state agencies that generate most of the data and from the segment or regional planners, who are the likely users of the data. The advantages of greater uniformity and provision for interstate waters, may well be offset by communication problems between Federal and state institutions.

Selection of the basin commissions would offer the benefit of hydrologic integrity, but this would be more than offset by the lack of commissions for a number of major basins and the poor institutional resources of the existing ones.

State governments are reasonably close to both the generators and the likely users of the data, and usually have the authority that is required to obtain the needed information from local agencies, as well as the institutional resources to maintain it. Moreover, states are required by Sections 106(e) and 305(b) of PL 92-500 to compile, analyze, and report data on the quality of their waters. To comply with these provisions, each state must assemble, catalog, and analyze a large amount of data on the waters within its borders.

Finally, county governments are close to both the generators of data and their likely users. However, they represent excessive fragmentation, and they frequently lack the resources to obtain and maintain adequately water quality data. This evaluation process is summarized in the chart below.

Selection Criteria	County	State	Basin Commission	EPA Region
Access to generators	X	X		
Access to users	X	X		
Legislative authority		X		
Institutional resources		X		X
Hydrologic integrity			X	

E. <u>UTILIZATION OF MONITORING DATA</u>

Any measure of effectiveness or efficiency of monitoring activities must require that the collected data be used for some worthwhile purpose. Surprisingly, this is frequently not the case.

1. <u>Current Use of Data</u>

In our review of water quality monitoring files of ten states (California, Illinois, Indiana, Maryland, Michigan, Minnesota, Ohio, Oregon, Pennsylvania, and Wisconson), we have found large amounts of data that have not been analyzed. Some of these appeared to be relics of earlier programs, the objectives of which have long since been forgotten, while others have been collected without a specific objective in mind. This situation is illustrated by the chart on the next page, which attempts to assess the ability of each Great Lakes state to answer some rather fundamental questions about the quality of its waters. In fact until EPA began implementing the provisions of Section 305(b), we were aware of only a few states (e.g., Indiana, Michigan, and Wisconsin) that systematically analyzed their water quality data to identify the status, trends, and sources of water quality problems on a state-wide basis.

A number of states, however, do use water quality monitoring data, on a sporadic basis, to support or even derive clean-up orders and load allocations in a few problem areas. These cases are heavily dominated by DO problems resulting in BOD load limits. For example, Regional Water Quality Control Boards in California occasionally use low DO observations and water quality standards as the basis for load limit orders, though explicit calculations are not available. Michigan has a small number of well-documented abatement actions based on excellent intensive DO/BOD surveys and sophisticated models. Maryland has, since 1965, performed approximate "Point of Discharge Evaluations" setting load limits on the basis of crude water quality data and calculations. Issuance of abatement orders based on ambient monitoring for toxic substances is very rare. Most such orders are based on effluent monitoring, which is usually restricted to substances on the state's approved list, regardless of the nature of local discharges.

2. <u>Reporting Requirements</u>

The Federal Water Pollution Control Act Amendments

ASSESSMENT OF WATER QUALITY DATA ANALYSIS IN THE GREAT LAKES STATES

Question	Pennsylvania	Ohio	Indiana	Illinois	Michigan	Wisconsin	Minnesota
Does State know its water quality and violations of water quality standards?	NO - intentional emphasis on effluents	NO - although USGS data are available	YES - fixed stations; NO - other violations	RARELY	RARELY - sporadic surveys of high quality	YES - approximate with low frequency sampling	NO - 4 short term stations available in basin.
Does State know point sources and their strength?	NO - despite lots of sampling	NO	YES - only for some large dischargers	NO	SOMETIMES - when surveyed	YES - for BOD and SS	NO
Does State know area sources?	NO	NO	NO - has file on feedlots	NO	NO	NO	NO
Does State do sensible load allocation and orders?	NO	NO	?	NO	YES - sporadic, less primitive but no better than Wisc; BOD and SS mainly	YES - thorough coverage but primitive	NO
Does State inspect, enforce and achieve compliance?	NO - lots of inspections, some enforcement, little compliance	NO	YES - at a very slow pace	NO - recent flurry of enforcement	NO - almost no enforcement, inspections and cases are good though few	YES - though load verification is weak	NO
Does State know whether water improved after compliance?	NO	NO	MAYBE - data is available	NO	ALMOST NEVER - only when a survey happens to look for improvement	YES	NO
Has water quality improved in State?	NO	NO	?	NO	NO	YES - in some places	NO

of 1972 (PL 92-500) provide a clear mandate for analysis of water quality data by the states. Specifically, Sections 106(e) and 305(b) of PL 92-500 require that the states report to EPA, for transmittal to Congress, a description of the quality of their waters, including the degree of achievement of water quality standards and major water quality trends. Moreover, Section 106(e) requires "the establishment and operation of appropriate devices, methods, systems, and procedures necessary to monitor, and to compile and analyze data on ... the quality of navigable waters and... ground waters including biological monitoring".

VII. RECOMMENDATIONS

The recommendations for improving the effectiveness and efficiency of Federal monitoring activities are presented here on the basis of the analysis performed in the preceding chapter. The organization of the material corresponds to that of the analysis chapter:

- Purpose and scope of the recommendations
- Quality of monitoring data
- New monitoring methods
- Coordination of monitoring
- Utilization of monitoring data

A. PURPOSE AND SCOPE OF THE RECOMMENDATIONS

The purpose of these recommendations is to suggest ways and means of improving the effectiveness and efficiency of those areas of Federal monitoring activities that were analyzed in the preceding chapter. Consequently, all of the qualifications on the selection and treatment of problem areas apply here as well. In other words, the recommendations focus on Federal resources involved in water quality management, on areas that are particularly significant or troublesome, and on solutions that are implementable without a major disruption in the present institutional and program structure.

Two additional points need to be noted. First, the recommendations address program functions, rather than specific program elements and their detailed funding allocations. General implementation guidelines are suggested with each recommendation, but the detailed implementation steps are left to the administrative wisdom of the cognizant agencies. More importantly, the recommended actions reflect only our best educated judgment, based on limited information, and any resulting attempt to reorient a major program should be preceded by a specific, in-depth tradeoff analysis.

Areas for further investigation are suggested in cases where our analysis points to a substantial problem area, but our investigation lacks the depth to make a valid recommendation commensurate with the gravity of the problem. A case in point would be the major inefficiency of a large and important Federal program that would call for an in-depth study by an agency like the General Accounting Office or the Office of Management and Budget.

B. QUALITY OF MONITORING DATA

Improvements in the quality of monitoring data are sought here in terms of improved record keeping by state agencies, evaluation of monitoring programs by Federal agencies, and provision of analytical quality controls.

1. Improved Record Keeping

A requirement for keeping and annotating water quality records in a manner that points up the reason for the collection and potential use of the data bears three beneficial consequences. It makes the monitoring agency more aware of the connection between data collection and use, facilitates considerably use of the data by an outside party, and makes possible inspection of their utility by an independent auditor.

<u>The U. S. Environmental Protection Agency (EPA) and the U. S. Geological Survey (USGS) should require that all records of Federally funded water quality monitoring programs be better organized and more properly annotated.</u>

More specifically the data should be organized by sampling stations, and each station file should be headed by a descriptive summary containing at least the following information:

- Station location
  - regional basin
  - specific water body
  - precise coordinates and depth
- Sampling characteristics
  - timing and its relation to other events, e.g., rainfall
  - collection procedure
  - transport and storage procedure
- Reporting characteristics
  - parameters measured
  - method of analysis
  - reporting format and units
- Analysis and interpretation
  - types of data analyses performed
  - conclusions drawn
  - impact on program objectives
- Program objectives
  - pollution problem being addressed
  - type of data available
  - objectives of additional monitoring

- Relevance to program objectives
  - location of all related stations
  - sampling characteristics
  - reporting characteristics

2. Evaluation of Monitoring Programs

The usefulness of monitoring programs should be evaluated on a continuing basis, in terms of the relevance of monitoring stations and data analysis to the monitoring objectives, the actual use made of the data, and the availability of equivalent data from other sources. The organization and annotation of monitoring records in the previous recommendation will facilitate this task considerably.

The agency performing the evaluation should have the required technical qualification, should be free of vested interests, and should have the authority to enforce its findings. In the case of Federally supported state monitoring programs this function could be performed by EPA, while in the case of monitoring activities by Federal agencies, these agencies would have to engage cooperatively in the evaluation process.

EPA regional offices should conduct an annual evaluation of the cost effectiveness of Federally supported water quality monitoring programs through on-site inspection of properly annotated state monitoring records.

Federal agencies involved in water quality monitoring should conduct periodic coordinated evaluation of the effectiveness of their monitoring activities.

The evaluations should be based on the following criteria:

- Relative importance of the problem being addressed within the context of the
  - regional basin plan
  - areawide plan
  - local segment classification
- Relevance of the monitoring program to the solution of the problem in terms of
  - availability of other data
  - data likely to be obtained from the program
  - decisions or actions likely to result from the data
  - utility of the data for other important objectives
- Relevance of the stations and parameters to the monitoring programs
  - station location
  - sampling procedure
  - analytical procedure
  - analysis and interpretation
- Ability to obtain substantially equivalent data through
  - cooperative arrangements with other agencies or industry
  - piggy-backing of sample collection and/or analysis
- Need to introduce new program elements through
  - additional state or EPA funding
  - replacement of a less useful program element
  - funding by surveillance fees

3. Analytical Quality Control

Improvement in the reliability, accuracy, and precision of analytical results can be obtained by systematic application of comprehensive analytical quality control measures. Such measures are being developed by EPA's Methods Development and Analytical Quality Control Research Laboratory in Cincinnati and implemented by the Quality Assurance Division. The USGS has been using quality control measures to improve the accuracy and comparability of its analytical results. However, very few states have any kind of analytical quality control programs and/or protocols for certifying analytical laboratories, primarily because of the cost, which can run between 15-20 percent of the analytical budget.

EPA should require each state to incorporate an adequate analytical quality control procedure in its water quality monitoring program.

Such procedure should entail at least annual interlaboratory testing and certification and documented continuing performance checks within each laboratory. It should include determinations of the precision and accuracy of each method over its useful range, and analyses of split, spiked, and blind samples. This recommendation is already being implemented in large measure by EPA.

C. NEW MONITORING METHODS

New water quality monitoring methods, such as biological and sediment analysis and remote sensing, are expected to provide a worthy complement to the traditional physical/ chemical approach.

1. Biological and Sediment Analysis

Biological monitoring and bottom sediment analysis should serve as routine screening tools, before initiating intensive chemical and physical surveys, as well as a part of intensive surveys, to complement chemical and physical measurements in the water column.

EPA should require each state to incorporate biological monitoring and bottom sediment analysis as part of its routine water quality monitoring and intensive surveys under the monitoring requirement of Section 106(e), and to report annually on their progress under the Section 106(f) reporting requirement. The biological monitoring program should emphasize bioassay for toxic substances, including tissue analysis. Implementation of this requirement by EPA, began with the issuance of monitoring regulations in August 1974.

2. Remote Sensing

Remote sensing techniques have shown sufficient promise for water quality monitoring to warrant additional development work.

EPA and the National Aeronautics and Space Administration should continue their joint development and demonstration effort in remote sensing techniques for water quality monitoring, with the cooperation of the U.S. Geological Survey and the U.S. Department of Agriculture. Special emphasis should be placed on the improvements suggested in the analysis section.

D. COORDINATION OF MONITORING

Coordination of monitoring activities is proposed here on the four succeeding levels of cataloguing of monitoring activities, inventory of available data, storage of monitoring data, and occasional consolidation of monitoring activities.

1. Cataloging of Monitoring Activities

Publication by a central body of all water quality monitoring activities within a state or region is expected to assist in filling gaps and reducing overlaps in coverage, in promoting coordination of sampling and analysis methods, and in steering potential users to appropriate sources of data.

EPA should seek to have each state catalog all water quality monitoring activities within its borders by publishing annual reports giving the location, description, and operating agency of each station; this effort should be coordinated with the USGS NAWDEX and Office of Water Data Coordination programs.

The description should include precise transverse, longitudinal, and vertical location, sampling schedule, parameters measured, and analytical method used. The report should cover agencies at different levels of jurisdiction (i.e., state, region, county, city) and function (e.g., health department, department of environmental protection, department of natural resources). An optional section in the report could describe any adjustments in the monitoring programs undertaken during the past year.

2. Inventory of Monitoring Data

The next logical step in the progression of regional coordination of water quality monitoring programs is to assign to a regional body the task of inventorying the collected data. A national system is available to provide needed coordination and guidance.

EPA should seek to have each state inventory all water quality data collected within its borders, by publishing a periodic compilation of the type of information required for station descriptive summary in Recommendation B1, as well as information on the location, format, and availability of the data; this effort should be coordinated with the USGS NAWDEX and Office of Water Data Coordination Programs.

Such an inventory could be patterned on the water quality section of the "Catalog of Information on Water Data" published biennially by the U.S. Geological Survey, Office of Water Data Coordination. Comprehensive and accurate coverage should be emphasized over attempts to automate the inventory. This requirement should be contingent in part on the parallel implementation of the next recommendation.

The National Oceanic and Atmospheric Administration should strive to avoid duplicating the function of the

USGS NAWDEX program; USGS should gradually direct the major thrust of its NAWDEX program toward coordinating, guiding, and supporting state water quality data inventory programs, as well as toward maintaining inventory of water quality data of national significance.

Support for state programs could include actual performance of the inventory function on behalf of the state. Water quality data of national significance, include data from the National Stream Quality Accounting Network (NASQAN) and the National Water Quality Surveillance System (NWQSS), described in Section III A, as well as data from water bodies considered representative of the nation's waters.

3. Storage of Water Quality Data

The consolidation of storage and dissemination of water quality monitoring data by a central body may be desirable in areas of excessive monitoring fragmentation and/or where there are large distances between monitoring agencies.

EPA should seek to have each state review biennially and report on the desirability of consolidating all or a part of the water quality data collected within its borders in one or more central locations.

The central records could contain simple copies of properly organized and annotated records of the data generating agency. Comprehensive coverage and detailed annotation should be emphasized over uniform format or automation. The report should include the findings, the reasons therefor, and a discussion of potential funding sources (e.g., user fees).

EPA should gradually redirect the major thrust of its STORET program toward complementing, supporting, and guiding state water quality data storage and processing programs, and toward improving its storage, processing, and retrieval capability for data of national significance.

The state support function and data of national significance are defined as above. Improvement of the storage, processing, and retrieval capability should address the problems pointed out in the analysis.

4. Consolidation of Monitoring Activities

Consolidation of monitoring activities is expected to be difficult to justify and more difficult to implement. Nevertheless, some programs would certainly benefit from consolidation, "piggybacking", or at least close coordination, of their respective monitoring activities. Any effort in this direction should be preceded by a thorough and detailed tradeoff analysis of the benefits and costs of consolidation and a plan to overcome the institutional impediments.

EPA should seek to have each state review biennially and report on the desirability of consolidating in some form selected water quality monitoring activities within its borders.

EPA regions should seek to have various states consolidate in some form selected water quality monitoring activities in the water bodies which they share.

EPA should review biennially its water quality monitoring activities to determine the desirability of consolidating some of these operations within one office.

E. UTILIZATION OF MONITORING DATA

Analysis and utilization of water quality monitoring data will be encouraged substantially through implementation of our recommendation in Section B. Additional assurance can be sought by requesting that states analyze their data in compliance with Sections 106(e) and 305(b).

EPA should seek to have each state monitoring program emphasize the analysis and application aspects to the full extent commensurate with the program objectives and the quality and quantity of data collected.

REFERENCES

1. American Public Health Association, Standard Methods for the Examination of Water and Wastewater, 13th Edition, 1970.

2. Pauszek, F. H., Digest of the 1972 Catalog of Information on Water Data, U. S. Department of the Interior, Geological Survey, Water Resources Investigations 63-73, December 1973.

3. Interstate Electronics Corporation, A National Overview of Existing Coastal Water Quality Monitoring, U. S. Environmental Protection Agency, December 1972.

4. Ozolins, Guntis, Personal Communication, 20 August 1974.

5. U. S. Department of the Interior, Bureau of Sport Fisheries and Wildlife, Biological Services, May 1973.

6. Weber, C. I., Biological Monitoring of the Aquatic Environment, U. S. Environmental Protection Agency, 1973.

7. U. S. Environmental Protection Agency, Model State Biological Monitoring Program, 1974.

8. Earth Satellite Corporation, Study of Benefits and Costs of a Continuing ERS Mission, U. S. Department of the Interior (in press).

9. U. S. Environmental Protection Agency, Proceedings, Second Conference on Environmental Quality Sensors, December 1973.

10. Federal Advisory Committee on Water Data, Design Characteristics For a National System to Store, Retrieve, and Disseminate Water Data, October 1971.

11. U. S. Department of the Interior, Geological Survey, Support in the Overall Design Development of a National Water Data Exchange (NAWDEX), January 1974.

12. U. S. Congress, Federal Water Pollution Control Act Amendments of 1972 (PL 92-500), 18 October 1972.

13. U. S. Congress, Marine Protection, Research, and Sanctuaries Act of 1972 (PL 92-500), 23 October 1972.

14. U. S. Environmental Protection Agency, "Water Quality and Pollutant Source Monitoring - Proposed Rules", Federal Register, V. 30, No. 168, 28 August 1974.

15. U. S. Environmental Protection Agency, "Ocean Dumping - Final Regulations and Criteria; Part 228 - Guidelines for Management of Disposal Sites," Federal Register, February 1974.

16. U. S. Water Resources Council, Coordination Directory, August 1971 (updated).

17. Rosinoff, Bruce, Personal Communication, December 1974.

18. Daniels, Warren S., Personal Communication, 16 August 1974.

19. Crim, Robert L., Personal Communication, 21 August 1974.

20. Wastler, Linda, Personal Communication, October 1974.

21. Parish, John V., Jr., Water Quality Improvement Planning and Monitoring Activities Accomplished Through Civil Works Funding, U. S. Army, Office of the Chief of Engineers, 19 March 1974.

22. Berger, Bernard, Personal Communication, 21 August 1974.

APPENDIX A LIST OF INTERVIEWEES

Agency	Official	Topics
National Aeronautics and Space Administration		
• Applications Directorate	Dr. Stan Freden, Chief Missions Utilization Office	ERTS water quality monitoring experiment:
U. S. Army		
• Corps of Engineers	Col. Wall	Corps of Engineers wa quality monitoring program
U. S. Atomic Energy Commission		
• Division of Operational Safety	Arthur Schoen, Chief Environment Branch	AEC monitoring budget
U. S. Department of Agriculture		
• Soil Conservation Service	Eugene Highfill Charles Fogg Gerald Lanman	SCS water quality monitoring programs
U. S. Department of Commerce		
• National Oceanic and Atmospheric Administration	Robert Knecht, Chief Coastal Environment Branch Joseph Gardner Coastal Environment Branch	NOAA coastal monitori program, ENDEX
• National Oceanographic Data Center	Chris Noe, Chief Data Index Branch	
U.S. Department of the Interior		
• Bureau of Sport Fisheries and Wildlife	Dr. E. Kinney, Chief Biology Section Bernard Berger, Division of Ecological Services	BSFW biological monitoring program
• Geological Survey, Water Resources Division	Warren S. Daniels, Chief Planning Section Richard O. Hawkinson Quality of Water Branch J. Ficke Quality of Water Branch J. K. Culbertson Quality of Water Branch	USGS water quality monitoring programs
	J. E. Wagar, Chief Program Coordination and Information Unit F. P. Kapinos Office of Water Data Coordination George Chase Office of Assistant Chief Hydrologist for Research and Technical Coordination	Circular A-67
	M. D. Edwards Office of Water Data Coordination	WATSTORE
	Solomon Lang Staff Hydrologist George Whetstone Assistant Chief Hydrologist	NAWDEX

APPENDIX A LIST OF INTERVIEWEES (Cont'd)

U. S. Department of Transportation		
• Coast Guard Division of Marine Environmental Protection	Capt. S. A. Wallace, Chief	CG coastal monitoring program
U. S. Environmental Protection Agency		
• Office of Air and Water	Robert Crim, Supervisor Monitoring and Data Support Div. Linda Wastler Norman Lovelace	NWQSS, EPA monitoring program
	Charles S. Conger, Chief of Information Access and User Assistance Branch Robert T. Adams, Program Management Officer Lee Manning, STORET User Assistance Branch	STORET, STORET budget
• Office of Research and Development	Guntis Ozolins, Director Quality Assurance Division Thomas Stanley, Quality Assurance Division	EPA quality control programs
• Office of Water and Hazardous Materials	William T. Musser, Marine Protection Branch	EPA coastal monitoring
• Office of Enforcement and General Counsel	Murray Felsher	EPA remote sensing programs
• Office of Research and Development	John D. Koutsandreas, Equipment and Techniques Division	EPA remote sensing programs
• Region I	Arthur Johnson, Senior Regional Biologist	State biological monitoring programs
• Region II	Dr. Royal Nadeau, Senior Regional Biologist	State biological monitoring programs
• Region III	James Labuy, Senior Regional Biologist	State biological monitoring programs
• Region IV	Lee B. Tebo, Senior Regional Biologist	State biological monitoring programs
• Region V	Max Anderson, Senior Regional Biologist	State biological monitoring programs
• Region VI	John Matthews, Senior Regional Biologist	State biological monitoring programs
• Region VII	Stephen Bugbee, Senior Regional Biologist	State biological monitoring programs
• Region VIII	Loys Parrish, Senior Regional Biologist	State biological monitoring programs
• Region IX	Dr. Milton Tunzi, Senior Regional Biologist	State biological monitoring programs
• Region X	Ronald Kreizenbeck, Senior Regional Biologist	State biological monitoring programs

APPENDIX A LIST OF INTERVIEWEES (Cont'd)

State of Michigan		
• Department of Water Management	W. D. Marks, Chief Basin Studies	"Piggybacking"
State of New Mexico		
• Environmental Improvement Agency	John W. Right, Director	"Piggybacking"
State of New York		
• Department Environmental Protection	William Berner, Monitoring Section	"Piggybacking"
State of North Dakota		
• Department of Health	N. Peterson, Director	"Piggybacking"
State of Oklahoma		
• Department of Health	Charles Newton, Director	"Piggybacking"
State of Oregon		
• Natural Resources Commission	K. R. Cannon, Director	"Piggybacking"
State of Virginia		
• Water Control Board	Michael Ballanca, Director of Technical Services	"Piggybacking
State of Wisconsin		
• Division of Environmental Standards	Russell Pope, Water Planning Section	"Piggybacking"