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208 AREAWIDE WATER QUALITY MANAGEMENT PLANNING

CASE HISTORIES

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NOTICE

The mention of trade names or commercial products in this publication is for illustration purposes, and does not constitute endorsement or recommendation for use by the Environmental Protection Agency.

INTRODUCTION

With the advent of grants to areawide water quality planning agencies under Section 208 of Public Law 92-500, many agencies have been designated to undertake water quality planning. While many such programs are in the early phases of the planning period, others have completed significant portions of their studies and are implementing the planned programs. The case histories discussed in this publication are examples of work done by certain agencies which may be useful to other agencies just beginning their water quality planning.

This publication presents case histories of five planning agencies which illustrate approaches to water quality planning as noted:

- Salt Lake County 208 - The implementation of a plan to regionalize seven treatment facilities into one centralized facility under a single management agency.

- Ohio-Kentucky-Indiana Council of Governments - The development of a rural nonpoint source model to characterize rural nonpoint contributions as they relate to major land use types.

- Southcentral Michigan Planning Council - The development of a methodology to assess water quality conditions in lakes utilizing remote sensing techniques.

- Triangle J Council of Governments - A comprehensive nonpoint source analysis program based on instream sampling and monitoring and receiving stream modeling to assess the nonpoint source contributions and magnitude of the problems specific to land use types in the study area.

While the methodologies suggested in these case studies have not been approved by the EPA, and the publication here does not constitute such endorsement, it is felt that the techniques outlined in these cases may be applicable for other agencies.

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Chapter I

REGIONALIZATION OF MUNICIPAL WASTEWATER TREATMENT PLANTS IN SALT LAKE COUNTY, UTAH

As a result of organized efforts to upgrade the aquatic environment of the surface waters in Salt Lake Valley, and to provide needed recreational facilities for a rapidly growing urban area, water quality planning for Salt Lake County has evolved in a manner unlike that in many other areas of the country. The Jordan River receives practically all drainage from Salt Lake County and consequently, is of critical importance to the proper development of water related recreational facilities. Inital planning for upgrading water quality in the Jordan River began with basin plans in which point source discharges were identified as major contributors to pollution levels in the river. The basin plan made recommendations for regionalized wastewater treatment in Salt Lake County and emphasized the need for a coordinated approach to implementing the plan.

With implementation as a goal, the Salt Lake County Council of Governments was designated an areawide water quality planning agency, and has conducted a thorough analysis of the needs of the County and alternative approaches to regionalization and implementation. The study has concluded that the seven existing municipal treatment plants in the Jordan Facilities Planning Area should be consolidated into one regional facility to provide polished secondary treatment by 1980. Polished (filtered) secondary treatment will be required to meet the 1980 State of Utah effluent limitations and water quality standards and to maintain a level of water quality suitable for proposed recreational activities on the Lower Jordan.

It has been proposed that the regional system be managed by a Special Service District, or regional management agency, incorporating the existing municipalities and improvement districts for the purposes of wastewater treatment only. Wastewater collection systems would continue to be controlled by the local agencies. Modifications to the Utah Special Service District Act will facilitate the implementation of the regionalized concept in Salt Lake County, both politically and financially. Proposed amendments to the Act, as developed by the areawide planning agency, are now before the Utah state legislature.

Existing secondary treatment plants will be purchased by the Special Service District initially, but will remain in operation until they can no longer provide an acceptable level of secondary treatment economically. The first phase of construction of the regional facilities will consist of major interceptors connecting the existing plants, polishing units, and some initial biological treatment capacity. Secondary effluent will be conveyed from the existing plants to the regional plant for polishing before discharge. As the existing plants are abandoned in the future, complete treatment will be provided at the regional site.

It is anticipated that in 1977, the regionalization program will move into the design phase, or Step 2 of the federal construction grant program. The areawide planning study has essentially completed Step 1 of this process, although local agencies have obtained individual 201 grants to perform infiltration/inflow analyses. Step 2 will begin with sewer system evaluation surveys and design of facilities. When Step 3, construction of facilities, is complete and the regional plant is operational (scheduled for late 1980), the on-going water quality planning program to control municipal point sources in Salt Lake County will be completed. It is important to note that water quality planning began with basin studies and is progressing in a logical manner toward facilities design and construction. In this particular case, areawide planning played a major role in assuring that recommendations made on the basin level were actually carried out on the local facilities level.

INTRODUCTION

The Salt Lake County 208 area is located in northen Utah, bordering on the south shore of the Great Salt Lake. Salt Lake County lies in a valley between two mountain ranges, the Wasatch Mountains to the east and the Oquirrh Mountains to the west. The county is essentially a self-contained drainage basin, with only one major hydrologic input, the Jordan River.

As can be seen in Figure I-1, the Jordan River flows north from Utah Lake, through the Jordan Narrows and subsequently, through the valley portion of Salt Lake County, prior to discharging to Farmington Bay in the Great Salt Lake. Other major streams in Salt Lake County are those which arise in the Wasatch Mountains and flow from east to west, generally traversing built-up or urbanized areas in Salt Lake Valley before joining the Jordan River. It is in these mountain streams, particularly to the east, that emphasis on surface water quality has been placed in the past. However, rapid urbanization of the flatter portions of Salt Lake County has renewed attention on the valley surface waters, and in particular, the Jordan River.

Through the efforts of the Utah Division of Health and the Utah Water Pollution Control Committee, many of the acute water pollution and public health problems that Salt Lake County faced in the 1950's have been brought under control. However, due to the rapid growth in the valley and the demand for water related recreational activities, plans for upgrading the entire aquatic environment of the Jordan River system have been developed around a concept known as the Jordan River Parkway. These plans require a concerted effort on the part of the State, county and local agencies to work together in creating a level of water quality in the Jordan River which will permit the needed recreational water uses to take place. Planning in this direction began with the development of basin plans in which recommendations for wastewater treatment in Salt Lake County were formulated. Areawide water quality planning efforts have focused on refinement and implementation of these recommendations.

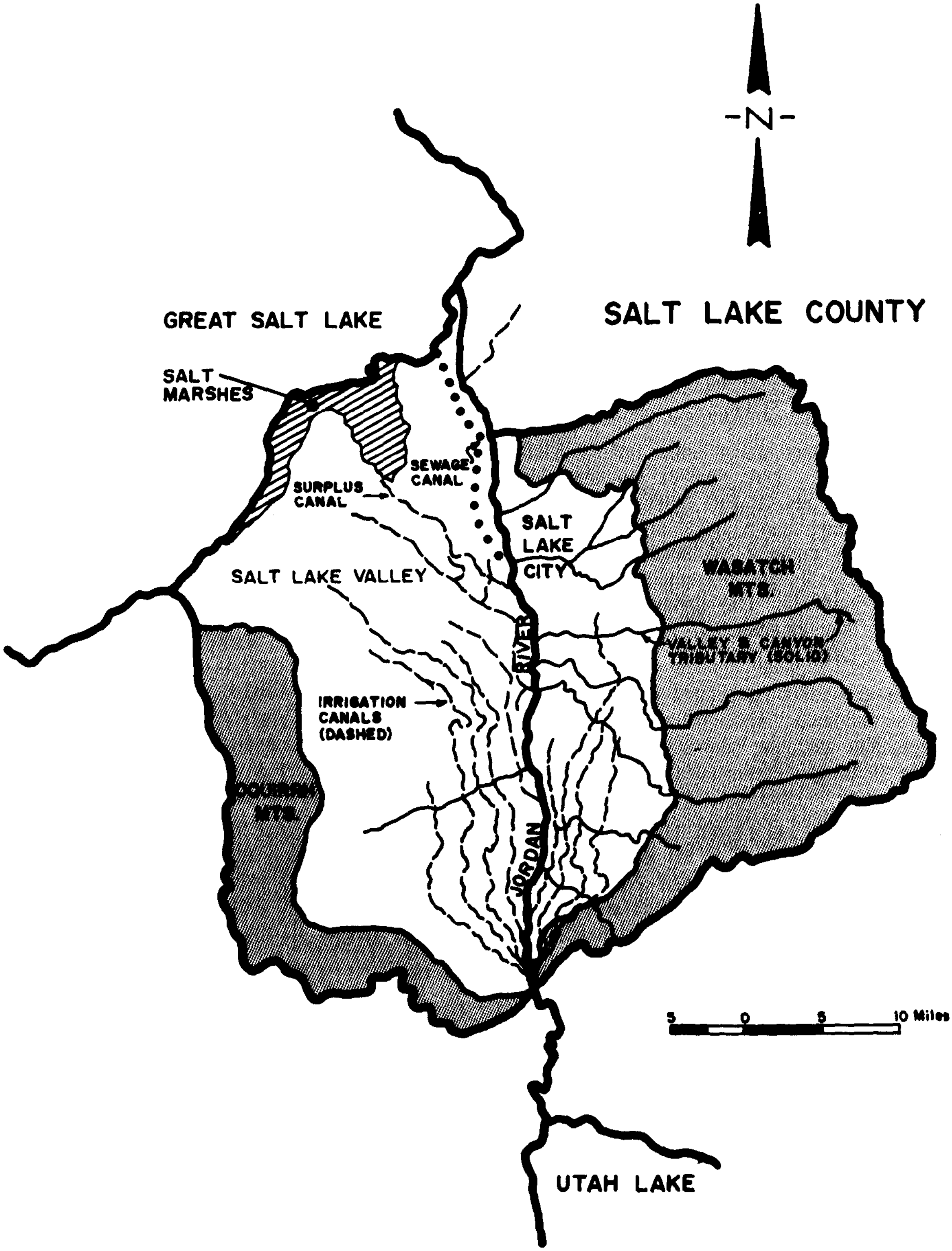

Figure I-1. The Salt Lake County 208 Study Area

THE JORDAN RIVER

The Jordan River begins at Utah Lake and meanders approximately 55 miles northward to the Great Salt Lake. The river gradient is slight, averaging about 5.2 feet per mile and consequently, velocities are low. River flows are supplemented by many tributaries entering from the east and are depleted during the summer by diversions into irrigation canals (illustrated in Figure I-1).

During the warm summer months, dissolved oxygen levels in the Lower Jordan River are well below the 6.0 mg/l standard, as set by the State of Utah for Class C waters and established as an objective for Jordan River water quality. Characteristic dissolved oxygen levels are about 3.5 to 4.5 mg/l in most instances. In addition, high total coliform levels, on the order of 50,000 to 100,000 MPN per 100 ml are characteristic of the Lower Jordan. Stream modeling has indicated that wastewater treatment plant effluents account for at least 40 percent of the dissolved oxygen deficit and sampling programs have led to the conclusion that a major fraction of the coliforms are attributable to these discharges as well.

Salt Lake City does not discharge municipal wastewater effluent to the Jordan River, but rather to the Sewage Canal, shown in Figure I-1. This watercourse was developed over 100 years ago as a means of transporting wastewaters to the Great Salt Lake as quickly as possible. The Sewage Canal is highly polluted as a result of both municipal discharges and industries which discharge wastes with high oil and grease contents. Because of its major use as a discharge channel, the Sewage Canal is not considered a part of the Jordan River system, but rather an independent aspect of water quality management planning in Salt Lake County.

THE JORDAN RIVER PARKWAY

Out of the plans to upgrade the aquatic environment of the Jordan River, grew a concept known as the Jordan River Parkway. When completed in the early 1980's, the Parkway will be a strip park running along the Jordan River and some of its major tributaries throughout the length of Salt Lake County. Ultimately, the Parkway will include recreational areas along the entire Jordan-Provo River system.

Parkway development is under the direction of the Provo-Jordan River Parkway Authority, established by the Utah State legislature in 1973. Under existing agreements, the cost of land acquisition and construction is being shared equally by the State and local communities. The U.S. Army Corps of Engineers is also participating in the project, particularly in the area of stormwater management. The first phase of the Parkway will be developed on the lower Jordan River in the Salt Lake City area, due to the need for recreational activities in that rapidly growing urban area. Primary emphasis will be on park areas and facilities for boating, fishing, and aesthetic enjoyment.

While the Parkway project is being implemented locally, the areawide planning agency has given it full support and has worked toward its development. Of particular importance to water quality planners has been the level of water quality in the Lower Jordan required to meet the recreational needs of those using the Parkway. The Lower Jordan is heavily impacted by municipal wastewater treatment plant discharges, and one of the major efforts undertaken to date in the Salt lake County water quality management program has been in analysis of the best method available to treat municipal wastewaters to the level required to maintain suitable water quality conditions in the Lower Jordan River for recreational purposes.

MUNICIPAL WASTEWATER TREATMENT FACILITIES IN SALT LAKE COUNTY

Within the Salt Lake County 208 area, there are three facilities planning areas and a total of nine municipal wastewater treatment plants, as illustrated in Figure I-2. The Salt Lake City treatment plant discharges to the Sewage Canal and the Magna treatment plant discharges to Kersey Creek, both of which ultimately drain into the Great Salt Lake. The remaining seven plants discharge directly to the Jordan River and therefore become critical to the overall plan for meeting effluent limitations and for upgrading water quality to meet the needs of the Jordan River Parkway.

Table I-1 summarizes basic information on the operation of municipal treatment facilities in Salt Lake County. It can be seen that virtually all municipal plants are currently providing secondary treatment according to federal guidelines. However, the Salt Lake Valley is developing extremely rapidly and many of these plants are becoming overloaded hydraulically. Even if effective secondary treatment can continue to be provided in the future, the increased loadings will continue to preclude the level of water quality desired.

It has been estimated that in order to achieve a level of water quality in the Jordan River, suitable for recreational purposes, municipal dischargers will be required to meet a 10 mg/l BOD and 10 mg/l suspended solids effluent limit by 1980. Such a requirement will mean that secondary effluents must be "polished" using some form of tertiary filtration process to further reduce pollutant loadings to the stream.[1] The 10/10 effluent limitations coincide with 1980 standards established by the State of Utah prior to the development of the 1977 and 1983 federal guidelines. The Utah effluent limitations for 1977 and 1980 are summarized in Table I-2.

For the most part, existing plants in Salt Lake County are meeting or are close to meeting both the 1977 Utah standards and the 1977 federal effluent guidelines for secondary treatment. On-going plant expansion in several of the towns (planned prior to 208 designation) should assure compliance with these requirements. These interim upgrades, however, do not include any polishing facilities and therefore, water quality planning with regard to municipal point sources, has concentrated on developing and implementing the most cost-effective plan to meet the 1980 Utah standards and provide an adequate level of water quality in the Jordan River for recreational purposes.

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[1]Polished secondary treatment, in this study, refers to treatment above the normal secondary level, but not as complete as full tertiary treatment, which might involve chemical addition and/or nutrient removal.

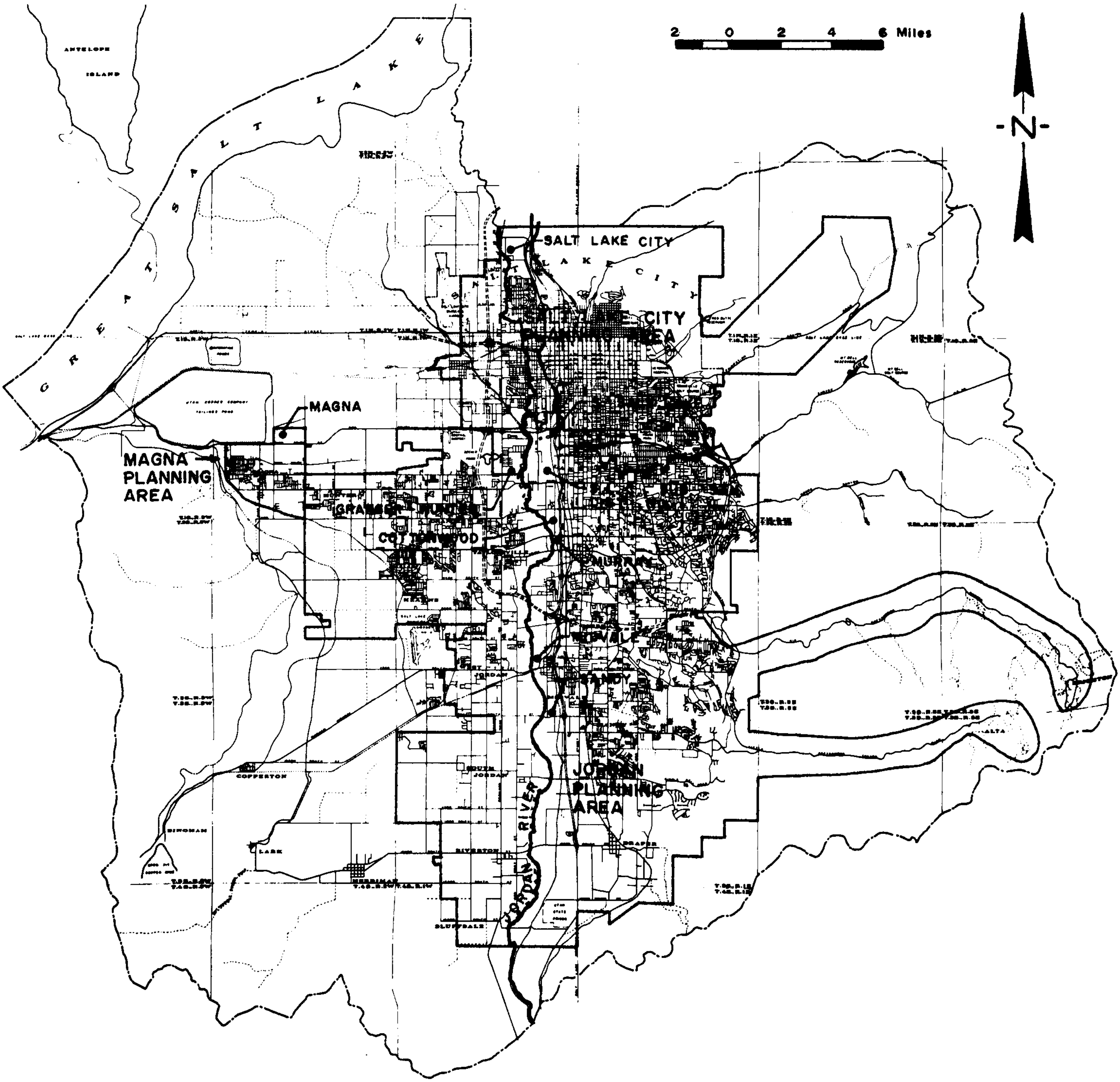

Figure I-2. Facilities planning areas and existing municipal wastewater treatment plants in Salt Lake County

Table I-1.—*Summary of existing municipal treatment plant operations in Salt Lake County*

Treatment Plant	Type Treatment	Design Flow (mgd)	Average Flow[1] (mgd)	BOD_5 (mg/l)[2] Influent	Effluent	SS (mg/l)[2] Influent	Effluent
Salt Lake City	Trickling Filter	45.0	37.0	140	19	122	30
South Salt Lake	Trickling Filter	4.5	5.0	170	20	165	16
Granger-Hunter	Trickling Filter	7.3	7.3	190	29	190	21
SLC Suburban Sanitary District #1	Trickling Filter	16.0	15.0	150	22	160	18
Cottonwood[3]	Trickling Filter	8.0	6.7	190	33	190	24
Murray	Trickling Filter	4.0	3.8	200	28	195	21
Midvale[3]	Trickling Filter	3.8	5.4	174	33	175	22
Sandy[3]	Activated Sludge	1.5	3.0	(data not available)			
Magna	Trickling Filter	1.3	1.0	175	22	180	19

[1]Average flows based on 1975 records

[2]BOD_5 and SS concentrations indicative of highest levels (winter or summer) at each plant.

[3]Interim upgrading procedures are being completed to meet the state and federal effluent limitations by June 30, 1977.

Table I-2.—*State of Utah effluent limitations for municipal wastewater treatment plants*

Parameter	1977	1980
BOD_5 (mg/l)	25	10
Suspended Solids (mg/l)	25	10
Total Coliform (MPN/100 ml)	2000	200
Fecal Coliform (MPN/100 ml)	200	20
pH	6.5-9.0	6.5-9.0

WATER QUALITY PLANNING FOR SALT LAKE COUNTY

Planning to meet the future needs for wastewater treatment in Salt Lake County began with the preparation of a basin plan prepared in conjunction with the Utah State Division of Health and completed in 1975. In this study, existing water quality conditions and waste treatment facilities in Salt Lake County were analyzed, waste load allocations developed, and recommendations for future water quality management schemes made.

One of the major findings to come out of the basin study was the estimated waste loads from the various categories of point and nonpoint sources in Salt Lake County. Point sources were broken down into municipal and industrial categories, and nonpoint sources into irrigation return flow and urban runoff categories. Irrigation return flows include rural and agricultural runoff as well as any water originally diverted for irrigation purposes, but returned to the stream as excess. The percentage contributions of these four discharge categories are summarized in Table I-3.

Table I-3.—*Breakdown of waste loads imposed on the surface waters of Salt Lake County*

Source Category	% Flow	% BOD	% TDS	% Total N	% Total P
Municipal	31	59	24	80	67
Industrial	33	15	54	5	29
Irrigation Return Flows	18	2	8	8	1
Urban Runoff	18	24	14	7	3
	100	100	100	100	100

From the data presented in Table I-3, it can be seen that point source dischargers contribute the majority of the BOD, TDS and nutrient loandings to the surface waters of Salt Lake County. Furthermore, it can be seen that municipal treatment plants are contributing the major portion of the overall pollutants load. This is not to say that nonpiont source discharges are insignificant, since they are not in many cases. However, the analyses performed in the basin planning study indicated that the magnitude of municipal point source waste loads in Salt Lake County warranted the major focus of areawide water quality planning efforts.

In regard to future wastewater treatment in Salt Lake County, a number of alternative strategies were developed in the basin study, ranging from individual upgrading of existing plants to a series of regionalized approaches applying various treatment levels. The plan recommended in the basin study called for two regional treatment facilities, one at Salt Lake City to serve that facilities planning area and one at Salt Lake City Suburban Sanitary District No. 1 to serve the Jordan Facilities Planning Area. The plants would provide polished secondary treatment by 1980 and the capability of providing full nitrification in the future, if conditions so warrant. The basin study did not incorporate the Magna Facilities Planning Area into the recommendations for the County.

As a means of developing a plan of implementation for the recommended regionalization program, Salt Lake County was designated as a 208 area in July, 1975. In order that a comprehensive areawide water quality management plan be developed, the Salt Lake County 208 Project has evaluated and analyzed the effects of all point and nonpoint sources of pollution, whether or not they affected the Jordan River and its proposed recreational activities. Clearly though, the need for the 208 program evolved from basin planning efforts, which showed the importance of reducing the waste loads emanating from point source discharges, and in particular, municipal treatment plants. Therefore, the focus of the 208 work program for Salt Lake County was on developing a workable program by which the conceptual point source recommendations in the basin study could be applied, implemented and administered.

ALTERNATIVE SELECTION

The initial aspects of the 208 program were directed toward a reevaluation of the cost-effectiveness of the alternatives presented in the basin study. As part of the 208 evaluation of alternatives, municipal wastewater reuse and land application of secondary effluents were investigated along with the various treatment and discharge options. The results of the analyses indicated the following conclusions concerning the most practicable form of treatment in Salt Lake County:

- Treatment and reuse is not a viable alternative at present in Salt Lake County, but may become so in the future. There is no current shortage of good quality water and the costs involved with reuse make this option economically unattractive.

- Treatment and land application is not economically competitive with treatment and discharge at the treatment levels required for the planning period. Land costs are very high in the valley and the distances involved in transporting effluents from urban areas to suitable sites for land application make the costs for such systems excessive.

- Treatment and discharge is the most practicable treatment scheme in all three facilities planning areas in Salt Lake County during the planning period. The existing plant site in Salt Lake City is suitable, but optimum treatment plant siting in the Jordan and Magna planning areas requires further analyses.

Modeling of the Jordan River indicated that there would be little difference in water quality if each existing plant in the Jordan Planning Area was upgraded instead of employing a regional approach. However, the cost of upgrading the existing plants to meet 1980 effluent standards was found to be significantly higher than going to the regional system to obtain the same level of treatment. The three alternative treatment schemes for the Jordan River planning area are illustrated in Figure I-3. Cost estimates for these alternatives are summarized in Table I-4. In addition to cost, the advantages of consolidated management and control over treatment plant operation made the regionalized approach more attractive than the individual plant concept.

Table I-4.—*Summary of costs for wastewater treatment[1] alternatives in the Jordan Facilities Planning Area[2]*

	Equivalent Annual Cost[3] ($ million)					
	Alternative 1		Alternative 2		Alternative 3	
Facility	Local[4]	Total	Local[4]	Total	Local[4]	Total
South Salt Lake	0.49	0.91	0.27	0.73	0.27	0.73
Granger-Hunter	0.70	1.31	0.49	1.32	0.49	1.32
SLC Suburban Sanitary District #1	1.14	2.13	0.93	2.50	0.93	2.50
Cottonwood	0.78	1.46	0.54	1.45	0.54	1.45
Murray	0.42	0.78	0.22	0.58	0.22	0.58
Midvale	0.83	1.55	0.46	1.24	0.77	1.55
Sandy	0.46	0.86	0.29	0.78	0.48	0.97
	4.82	9.00	3.20	8.60	3.70	9.10

[1]Costs shown are for polished secondary treatment

[2]Does not include Salt Lake City and Magna planning areas

[3]Based on present worth analyses using ENR index = 2,200, an interest rate of 6 1/8 percent and a 20 year planning period.

[4]Based on 75 percent federal funding of new grant eligible construction

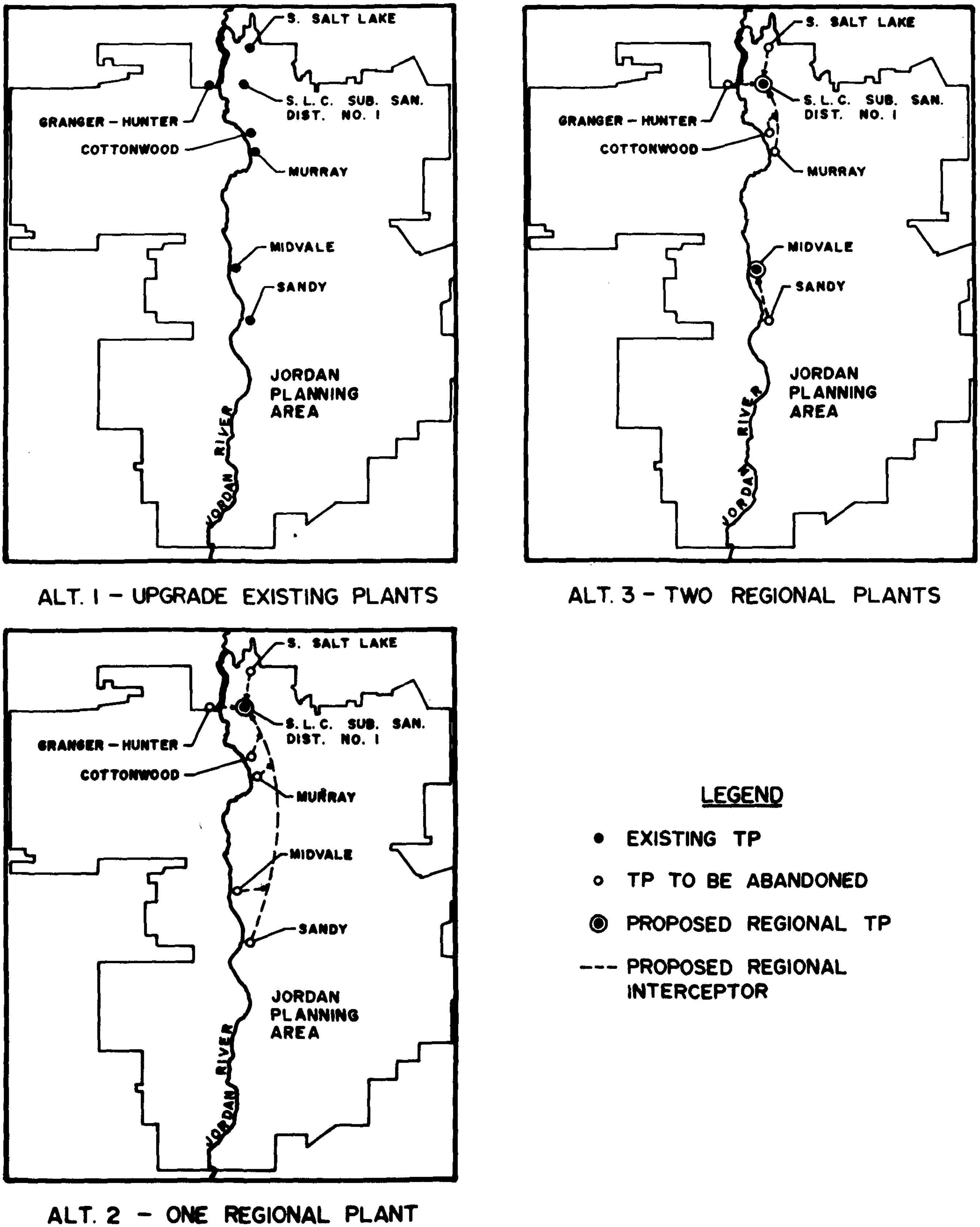

Figure I-3. Municipal treatment alternatives for the Jordan Facilities Planning Area

Based on the cost figures shown in Table I-4, Alternative 2, or the single regional plant configuration, was found to be the most cost-effective for the Jordan Planning Area, given comparable levels of water quality in the Jordan River for each of the alternatives. This analysis verified and confirmed the preliminary recommendations made in the basin study, which also called for a single regional plant at the site of the existing SLC Suburban Sanitary District #1 plant to serve the Jordan Facilities Planning Area.

IMPLEMENTATION OF THE PROPOSED REGIONALIZED WASTEWATER TREATMENT SYSTEM FOR THE JORDAN FACILITIES PLANNING AREA

Operation and Management of the Regional Wastewater Treatment System

Under Utah State law, wastewater collection and disposal services can be provided by individual municipalities or improvement districts. These bodies can own and operate their own facilities or contract for the services from another municipality or improvement district. Of the seven plants in the Jordan Planning Area, three (South Salt Lake, Murray and Sandy) are run by municipalities and four by improvement districts. A total of 14 municipalities and improvement districts are served by the seven plants. With the inception of the Jordan River Parkway and its recreational potential for Salt Lake County, the need for coordinated control of wastewater treatment systems became apparent. In recognition of this need, the areawide planning agency has recommended, with State of Utah concurrence, that the regional treatment system should be owned and operated by a "Special Service District."

The Utah Special Service District Act of 1975 gives special authorities and responsibilities to an agency (or district) whose boundaries may overlap existing improvement districts and municipalities. The Act was specifically designed to provide for adequate, economical, and equitable public works and services in rapidly growing areas. The Act provides that each municipality or improvement district can elect whether or not it wishes to participate in the consolidated Special Service District concept. The Salt Lake County Council of Governments feels however, that by working with each local unit, the substantial cost benefits to each will become apparent and that responsbile cooperation between them can be realized without danger to individual rights or prerogatives. Although no formal agreements have been signed with any of the local municipalities or districts, each has indicated an intent to participate in the regionalization program and to work out the specific elements of the implementation plan.

The general organization structure of the proposed Special Service District is illustrated in Figure I-4. Its principal features are summarized below:

- The organizational structure as shown, would be adopted through resolution of the Salt Lake County Board of Commissioners as set forth in the Act.
- An Advisory Board would have general managerial responsibility for operating the Special Service District. The Board would be composed of representatives from the 14 existing districts and municipalities.

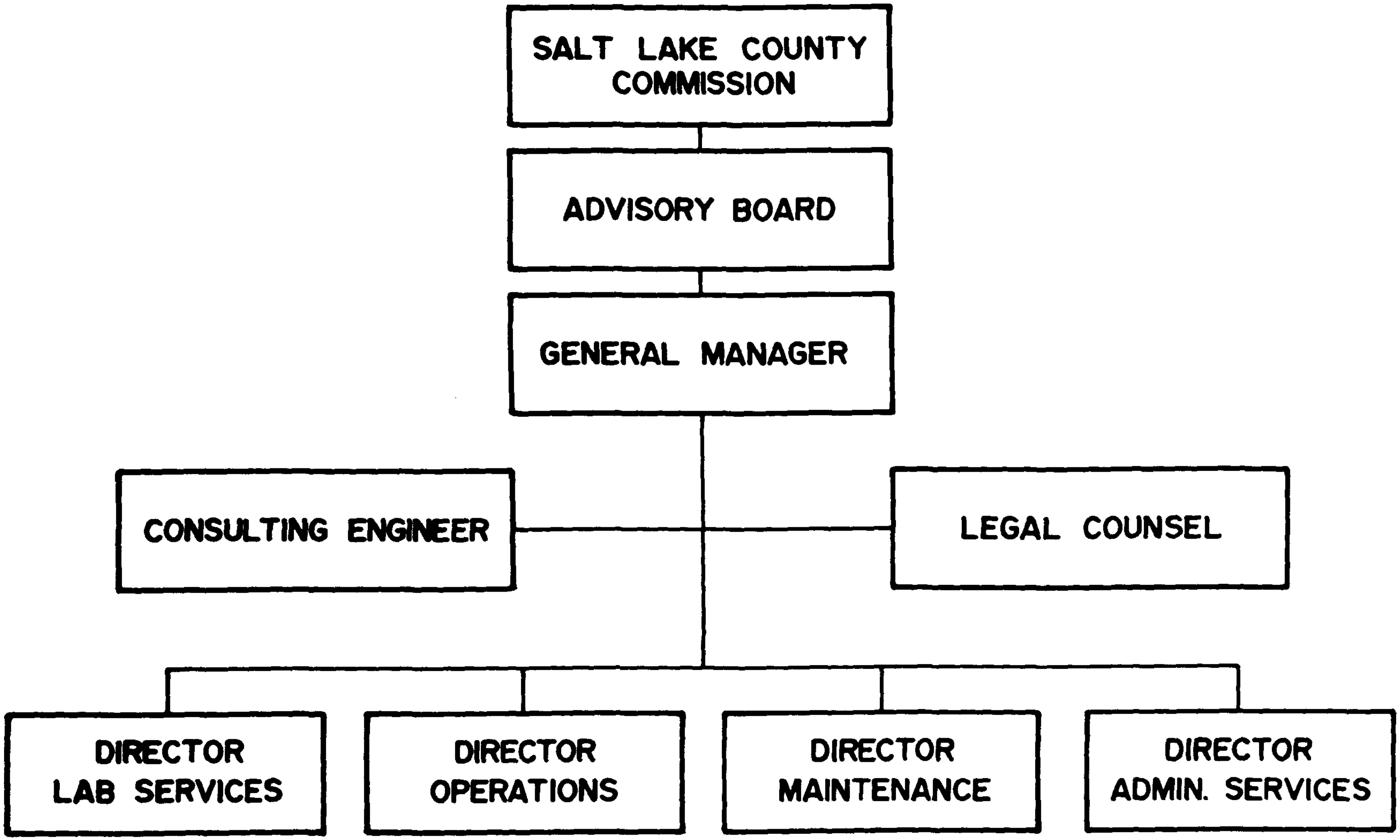

Figure I-4. Organizational structure of the proposed Special Service District

- A general manager would have direct responsibility for operating the Special Service District under the general direction of the Advisory Board.

- Existing districts and municipalities would continue to have the responsibility for wastewater collection and for all of the related administrative and financial functions needed to support the wastewater collection program.

- The Special Service District would be a financially autonomous body and would obtain bonded financing to build the needed regional treatment facilities. Operating costs would be borne by the users of the facilities, according to the amount and type of wastewater treated. This would be governed by contractual agreement between the Special Service District and the individual collection district or municipality.

- The existing seven plants would be equitably purchased by the Special Service District and continued in operation. When it becomes uneconomical to continue their individual operation, they would be phased out of service.

The first phase of regional treatment plant construction will consist of the following elements:

- Major interceptor lines connecting the existing secondary treatment plants with the regional facilities.

- Secondary treatment capacity sufficient to treat raw wastewater from at least two of the existing plants initially. It is envisioned that when the regional plant comes on-line in late 1980, the existing plants at Midvale and Sandy will be abandoned. The other five existing plants will continue to operate until it becomes uneconomical for them to do so or when they can no longer provide an acceptable level of secondary treatment.

- Polishing facilities to treat all flows receiving secondary treatment either at one of the existing plants or at the regional plant. Secondary effluents from those existing plants remaining in operation will be conveyed to the regional facility for polishing prior to discharge to the Jordan River.

Initial purchase of the existing plants will eliminate any competition between the Special Service District and the local agencies and will provide for objective decisions on when to phase these facilities out of service in the future. Initial purchase will also equitably reimburse those districts and municipalities who have made investments in the past, and provide a future for plant personnel in terms of advancement within the Special Service District operations staff.

As the existing treatment plants become phased out of operation, their untreated wastewaters will be collected in the interceptors and conveyed to additional secondary treatment facilities at the regional plant site. This phased construction of regional facilities will provide for maximum use of investments made in existing plants and should be more in line with the anticipated availability of federal construction grant funds.

It has been recommended by the areawide planning agency that only wastewater treatment come under the purview of the Special Service District and that wastewater collection systems remain in control of the local municipalities and districts. The reasons supporting this recommendation are:

- That collection systems are often complex and a detailed knowledge of an area's potential problems and unique characteristics is often required to assure reliable service.

- That customers of a collection system require quick, responsive service if problems do arise, something which can best be provided on a local basis.

Hence, the planning agency has concluded that wastewater collection systems should be operated and maintained on the local level, totally apart from the treatment of those wastewaters by the Special Service District.

The consolidated Special Service District concept for regionalized wastewater treatment in Salt Lake County also has potential benefits to the area which go beyond initial operation and management of regional wastewater treatment facilities. In order that water quality problems in the County be addressed in a comprehensive manner, nonpoint sources of pollution, such as urban and agricultural runoff, must be controlled as growth continues and the interface between rural and developed land uses becomes more critical. The Special Service District will be in a position to assist in efforts made to apply best management practices throughout the County. The Special Service District may also be able to assist in the development of adequate future water supplied for the County and to work with adjacent regions to the south and east where much of the surface water in Salt Lake County originates.

Legal and Institutional Aspects of the Special Service District

The Special Service District Act provides that the Special Service District shall be a totally separate body, distinct from each county, municipality or improvement district within its boundaries; but that the governing authority of the County shall supervise and control all activities of the District. The Act further provides however, that the County may delegate the performance of any or all such activities to an Advisory Board, which is the case with the District being proposed for Salt Lake County. This provision in the Act has created some problems since Salt Lake County cannot delegate to the Advisory Board the authority to levy taxes or issue bonds payable from taxes, and therefore, the Special Service District will not be a totally autonomous body. Consequently, some anxiety has developed among local officials concerning the relationships between the Special Service District, its Advisory Board and General Manager, and the Board of County Commissioners.

The planning agency, in cooperation with legal and management consultants, has analyzed and evaluated the existing situation and developed a strategy for better Advisory Board control of District activities through amendment to the Act. For example, it is proposed that it be made mandatory that 1) the Advisory Board become a permanent body made up of one representative from each of the existing districts and municipalities; and 2) that the Special Service District be financially autonomous with no mixing of District funds with moneys for other County activities. At the present time, these provisions are conditional on the part of the county involved, and making them mandatory will ease some of the anxiety on the part of local officials. The Utah state legislature is expected to act on these and other amendments to the Act in early 1977 as a result of the areawide investigations. There has been no organized opposition to the amendments and their approval is expected.

Financing and Schedule for Implementation

It is estimated that purchase of existing secondary treatment facilties will amount to approximately $16.3 million and that construction of the initial phase of the regional plant (interceptors, polishing facilities and some biological treatment units), will cost another $50 million, with $13.5 million the local share. The Special Service District, under the authority of Salt Lake County, will have the power to issue general obligation bonds, revenue bonds or a combination of the two, as might be appropriate. The bonds will be paid from operating revenues generated from charges levied on the local municipalities and improvement districts providing wastewaters to be treated. While not final at this time, it is expected that charges will be made on the basis of flow for wastewaters within a standard strength range. Surcharges would then be made for high strength wastewaters, based on a mutually agreeable formula.

Actual purchase price for existing treatment facilities will be negotiated with each individual owner, based on the facility's assessed value at the time of purchase. Method of payment will also be negotiated individually to best meet the needs of the municipality or improvement district involved, and will be in the form of treatment credit or cash, or derived from some other mutually agreeable formula. Upon abandonment of the existing facilities, ownership of all associated land, buildings and equipment will automatically revert back to the municipality or improvement district originally holding title to them.

Current plans call for the creation of the Special Service District in early 1977 with bond elections being held later in the year. With general agreement from each of the municipalities and districts concerning the regional concept, passage of a bond issue does not appear to be a problem. Upon funding, the design of the initial phases of the regional plant can begin, with construction to start in late 1978 or early 1979. The regional facility should be operational by late 1980.

Chapter II

ASSESSMENT OF RURAL NONPOINT SOURCES IN THE OKI WATER QUALITY MANAGEMENT PROGRAM

As a major element of its areawide water quality managment planning program, the Ohio-Kentucky-Indiana Council of Governments (OKI) developed a methodology for identifying and assessing rural nonpoint source pollution problems. Beginning its program in July, 1974, OKI recognized that, while urban nonpoint source problems had received considerable attention in other areas, information concerning rural contribution and problems was almost non-existent. As a selected course of action, OKI developed the rural runoff model for application in the study area which is 85 percent rural.

The OKI model is based upon the Soil Conservation Services' Universal Soil Loss Equation. The OKI model and the approach for assessing rural nonpoint sources provided for each of the 226 rural watersheds, an estimate of the nonpoint source loadings, an identification of problem uses within watersheds, and a means of evaluating alternative management practices for alleviating identified problems.

Model results indicated that gross erosion ranged from 0.02 to 32.5 tons per acre per year under existing conditions and provided estimates of sediment, nutrient and organic matter loads. To determine the relative magnitude of the erosion problems, criteria were established for cropland, grassland, and woodland uses, based upon "allowable soil loss." Using the OKI model, watersheds with particular problems were identified and alternatives for reducing erosion through improved management were tested. Reductions in erosion were calculated and public costs to implement the tested control measures were estimated.

The model results and supporting information were used to develop a rural nonpoint source control program which keys on the effective application of management practices in prioritized problem areas, and demonstrates the need for an increased Agricultural Conservation Program through local Soil and Water Conservation Districts. Strong support has resulted from the OKI program for sediment control legislation in Ohio and Indiana and such legislation is pending. Prior to the OKI water quality management planning efforts, supporting documentation in regard to rural nonpoint source problems and abatement alternatives had not been available.

The OKI model was the culmination of much original research and its development and application cost approximately $200,000. The OKI model has proven its effectiveness and will be utilized as a continuing planning and evaluation tool.

OVERVIEW OF AREA

The Ohio-Kentucky-Indiana Regional Council of Governments (OKI) was organized in 1964 and functioned as a single purpose transportation and development planning agency. OKI broadened its responsibilities in 1973-1974 to include all aspects of regional planning in the form of a Council of Governments. OKI is governed by a one hundred member Board of Trustees composed of elected officials and appointed representatives. Policy is established by the Executive Committee which is formed from members of the Board of Trustees. The continuing objectives of OKI are to promote cooperation among local agencies, to conduct studies, perform planning services, and function as the regional project review and comment agency.

OKI was designated by the Governors of Ohio, Kentucky, and Indiana to undertake the areawide water quality planning effort. The water quality management process at OKI was begun in July, 1974 and is guided by the ninety member Water Quality Advisory Committee. Serving on the Committee are elected officials, local and State agencies, technical representatives, private citizens, and representatives of citizens groups.

From the beginning, the areawide water quality planning process addressed all aspects of water quality. With regard to nonpoint source problems, OKI recognized that considerable attention in other areas had focused on urban nonpoint source problems. By comparison, information on rural nonpoint source pollution was found to be almost non-existant. OKI, because of the strong rural influence in the region, undertook to develop a rural nonpoint source methodology and model as a major input to the overall areawide water quality planning process.

The 3,000 square mile planning area includes nine of the Council of Governments' ten counties. As shown in Figure II-1, four of these counties are in Ohio, three in Kentucky and two in Indiana. At the center of the study area is the urban core represented by the cities of Cincinnati, Covington and Newport. There are over one hundred municipalities in the area and numerous special purpose districts. Population of the planning area was 1.6 million in 1970 and is projected to increase to 2.2 million by the year 2000. Employment in the region is industrially based. Hydrologically, the area is dominated by the Ohio River and the tributary basins of the Great Miami River, Little Miami River, Licking River, and Mill Creek. More than eighty percent of the region's population lives on fifteen percent of the land. In contrast to the urban core, eighty-five percent of the region is rural. The rural areas are characterized by cropland and grazing activities, although much of the land is steep and wooded.

NONPOINT SOURCE ASSESSMENT: PROGRAM

Because of the strong influence of rural land uses in the OKI region, particular emphasis was directed toward determining the rural contribution to nonpoint source pollution problems. Urban runoff was assessed utilizing modeling techniques developed by the Corps of Engineers in STORM. The staff of OKI was interested in developing a model to assess the rural nonpoint source contribution.

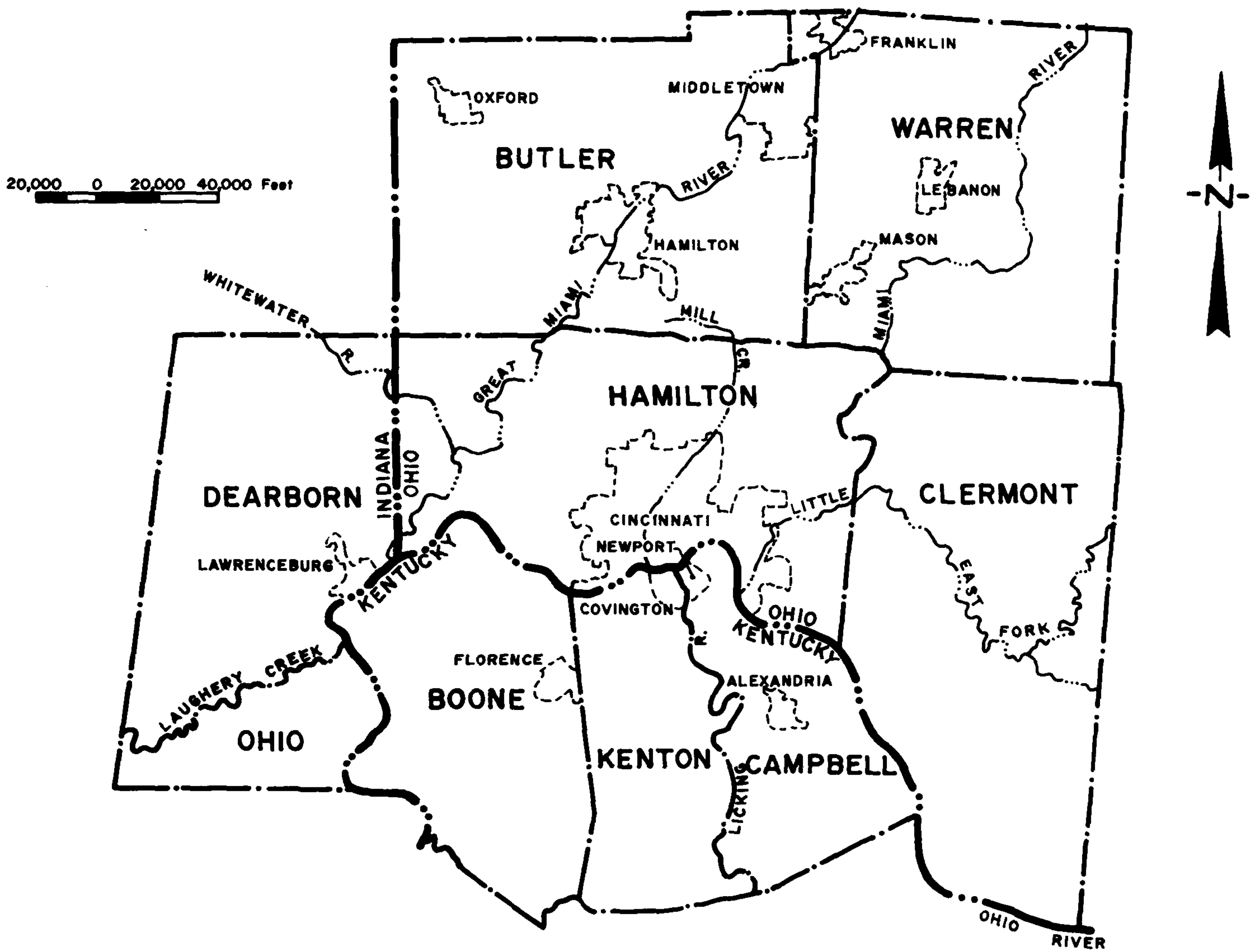

Figure II-1. Ohio-Kentucky-Indiana 208 Study Area

Selecting a Methodology

Considerations of an OKI rural nonpoint source assessment strategy were based on several objectives which included:

- assess the pollutant loadings from rural watersheds
- determine the relative magnitudes of point and nonpoint sources in a stream segment
- assess the impacts of nonpoint source pollution on water quality
- select alternative management combinations to control significant nonpoint sources from rural areas.

In selecting the desired course of action, OKI considered three general approaches for estimating the quantity and quality of runoff from rural areas. One approach was to use extensive sampling and monitoring to assess runoff from watersheds. Even if the approach were carried out on selected watersheds, OKI concluded that such a methodology had several limitations not the least of which were time consumption and expense. Another approach considered was the use of a "black-box" predictor to multiply acreage values for various land uses by previously established unit runoff values to derive total loads. Limitations of this approach were considered to be the lack of flexibility in taking into account the numerous other factors, particular to the region, which exert an influence on nonpoint source pollution. The third approach was considered to overcome the limitations of the first two and this selected approach is described in this paper.

The OKI Rural Nonpoint Source Model

To determine the nonpoint source loadings, OKI developed a rural nonpoint source model which focused on the Soil Conservation Services' Universal Soil Loss Equation (USLE). Erosion was recognized as the greatest potential rural nonpoint source pollutant problem, not only because of the delivery of suspended solids but because of the adsorbed nutrients and organic materials that sediments carry to the streams. The USLE was applied to individual watersheds to develop estimates of gross soil erosion. This estimate was then multiplied by a sediment delivery ratio to determine the amount of solids carried out of the watershed. Additionally, nutrients and organic loads were established from reported chemical analyses of sediment or known nutrients levels and enrichment ratios for soils in the region. Because the input values for the OKI model had been developed historically for use in the USLE, literature values were readily available, and since specific physical characteristics of the watersheds could be determined, extensive stream sampling and monitoring were not undertaken. With this methodology, OKI could determine the average annual loadings for certain parameters and use these as a means of estimating water quality conditions. The types of pollutants which were considered included sediments, nutrients (nitrogen and phosphorus), and organic matter.

The OKI region was divided into 233 watersheds, of which 226 were predominantly rural. Watersheds ranged in size from 20 to 100 square miles. As input to the OKI model, data specific to each of the rural watersheds was gathered. In determining the land use in each watershed, three categories were delineated by the interpretation of LANDSAT satellite imagery: cropland, woodland, and grassland. These categories were selected because they were easily interpreted with satellite imagery and were the predominant land uses influencing rural water quality in the OKI region. Acreage data and maps were generated from this analysis.

Data on soil associations (particularly erodibility) were gathered and a matrix was developed for soil/land use mixes using the satellite generated map overlays and Soil Conservation Service soil maps. A mix, such as soil with high erodibility with a woodland land use, would not pose as great a potential water quality problem as a cropland use on the same soil. Information concerning topography, type of crops, crop rotations, and general ground cover conditions for each soil type/land use mix within each watershed was also tabulated. Additionally, information concerning the type and extent of existing conservation practices in each watershed was compiled from interviews with area Soil and Water Conservation District personnel.

Each of these factors has its particular influence on runoff quality and quantity from rural areas. By using the OKI model, specific characteristics of soils, type of land use, and management conditions was combined with drainage characteristics, rainfall data, and hydrograph information to estimate annual loads from each of the 226 rural watersheds.

Through the OKI model, estimates of annual quantity of pollutants for the watersheds were derived by three primary steps: computation of surface erosion; sediment yield; and computation of pollutant loadings. Pollutant parameters for which loadings and concentrations were calculated consisted of chemical oxygen demand, biochemical oxygen demand, total nitrogen, and total phosphorus.

The development of the OKI rural nonpoint source model was the culmination of considerable original research and development. Development of the model, obtaining the input data, testing and refining the model, and generating the output data involved approximately $200,000 of the OKI water quality planning funds. A specific description of the OKI model computational procedures is available in the 1975 publication, "A Method for Assessing Rural Nonpoint Sources - Interim Report V." This publication is available from the Water Planning Division (WH-554), EPA, Washington, D.C. 20460.

NONPOINT SOURCE ASSESSMENT: RESULTS

The OKI model and the approach for determining rural nonpoint source pollution problems were developed to provide an estimate of the nonpoint source loadings, to identify problem watersheds, and to evaluate alternative best management practices for alleviating identified problems.

Ranges for Parameters Modeled

Model results for each of the 226 rural watersheds indicated that the estimated erosion rates ranged from 0.02 to 32.5 tons per acre per year under existing conditions. Ranges for average annual loadings to area streams for the parameters under consideration are shown in Table II-1. These calculated average annual loadings were compared with reported values in the region and the literature, and were found to be in general agreement with them.

Table II-1.—*Ranges for average annual loadings*

Parameter	Range over Watersheds
Sediment Yield	0.16 to 1.72 tons per acre
Total Nitrogen	0.96 to 10.3 lbs per acre
Total Phosphorus	0.1 to 1.22 lbs per acre
Organic Matter	1.77 to 20.68 lbs per acre

Source: OKI, Staff Working Paper, 1976.

Establishing Criteria

Since no State standards for nonpoint source parameters existed, it was necessary to establish a basic set of criteria on which the relative magnitude of nonpoint source problems could be based. Considerations in establishing the criteria focused on the technical feasibility of meeting the criteria, and the ability to implement the various control measures. After analyzing the alternative strategies which could be applicable in a rural setting, OKI decided that a single criterion governing sediment was desirable. In rural areas, the control of sediment was considered to be feasible, in terms of implementation, because farmers could identify with economic benefits of decreasing topsoil loss. Water quality improvements could also be realized with a reduction of sediment yield and the associated nutrients and organic matter being carried to streams by the sediment.

Therefore, the criterion selected was the "allowable soil loss" as established by the Soil Conservation Service. This gross erosion rate criterion is specific to soil type and soil/land use factors which were being used in the OKI model. The allowable soil loss is generally defined as the maximum rate of soil erosion that would allow a high level of crop production to be sustained economically and indefinately. Although the criterion is based on crop production, water quality benefits would be realized by meeting the allowable soil loss limits. OKI was aware that farmers were more likely to implement control measures which would improve their crop yields than to support measures solely directed toward improved water quality.

For cropland, the allowable soil loss was established as a range from one to five tons per acre per year gross erosion. For other land uses in rural areas, values were determined from literature review and were established to be one ton per acre per year for grassland and 0.5 tons per acre per year for woodland. With these criteria set, each watershed was analyzed, those areas not meeting the criteria were identified, and total acres of each land use requiring conservation measures were calculated. In this manner, the OKI model enabled potential water quality improvements to be maximized by concentrating implementation efforts in identified problem watersheds.

To carry the analysis of rural nonpoint source problems a step further, relative magnitudes of pollution from point sources, rural nonpoint sources, and urban nonpoint sources were compared. Such analyses provided insight into which source represented the most significant contribution to water quality problems. The analyses were carried out by modeling stream segments, and the results indicated the relative importance of each source in a particular segment. Average annual loads for sediment yield, BOD_5, nitrogen, and phosphorous were calculated and compared. An example of this output for Segment I of the Great Miami River Basin (from the Ohio River to river mile 10) is presented in Table II-2.

Table II-2.—*Comparison of annual loads by source — Segment 1, Great Miami River Basin*

Source	Annual Loads (Tons)							
	Sediment	% of Total	BOD_5	% of Total	Nitrogen	% of Total	Phosphorus	% of Total
Nonpoint Rural	13,754	94	75.7	27	41.26	55	8.38	43
Nonpoint Urban	826	5.5	13.5	5	5.07	7	1.68	9
Industrial	42	0.3	168.4	60	17.35	23	5.00	25
Municipal	35	0.2	23.5	8	11.03	15	4.42	23

Source: Chapter VI, OKI Draft Water Quality Management Plan.

Within the urban watersheds it was determined through the use of STORM, that nonpoint source runoff from urban areas was not as significant a water quality problem as the industrial and municipal point sources. In rural watersheds, varying degrees of nonpoint source problems, related to sediment, were identified under existing land use conditions. Figure II-2 illustrates average annual sediment yield for the watersheds within the Great Miami River Basin as determined by the OKI model.

APPLICATIONS OF DATA IN DEVELOPING BEST MANAGEMENT PRACTICES

Through the analysis of nonpoint source pollution problems in rural areas, watersheds with existing problems (gross erosion in excess of the allowable soil loss criterion) were identified. Relative contribution with regard to soil/land use mix were determined so that potential controls to abate the nonpoint source pollution could be related to the contributing source. Consequently, alternative control measures or best management practices were developed as

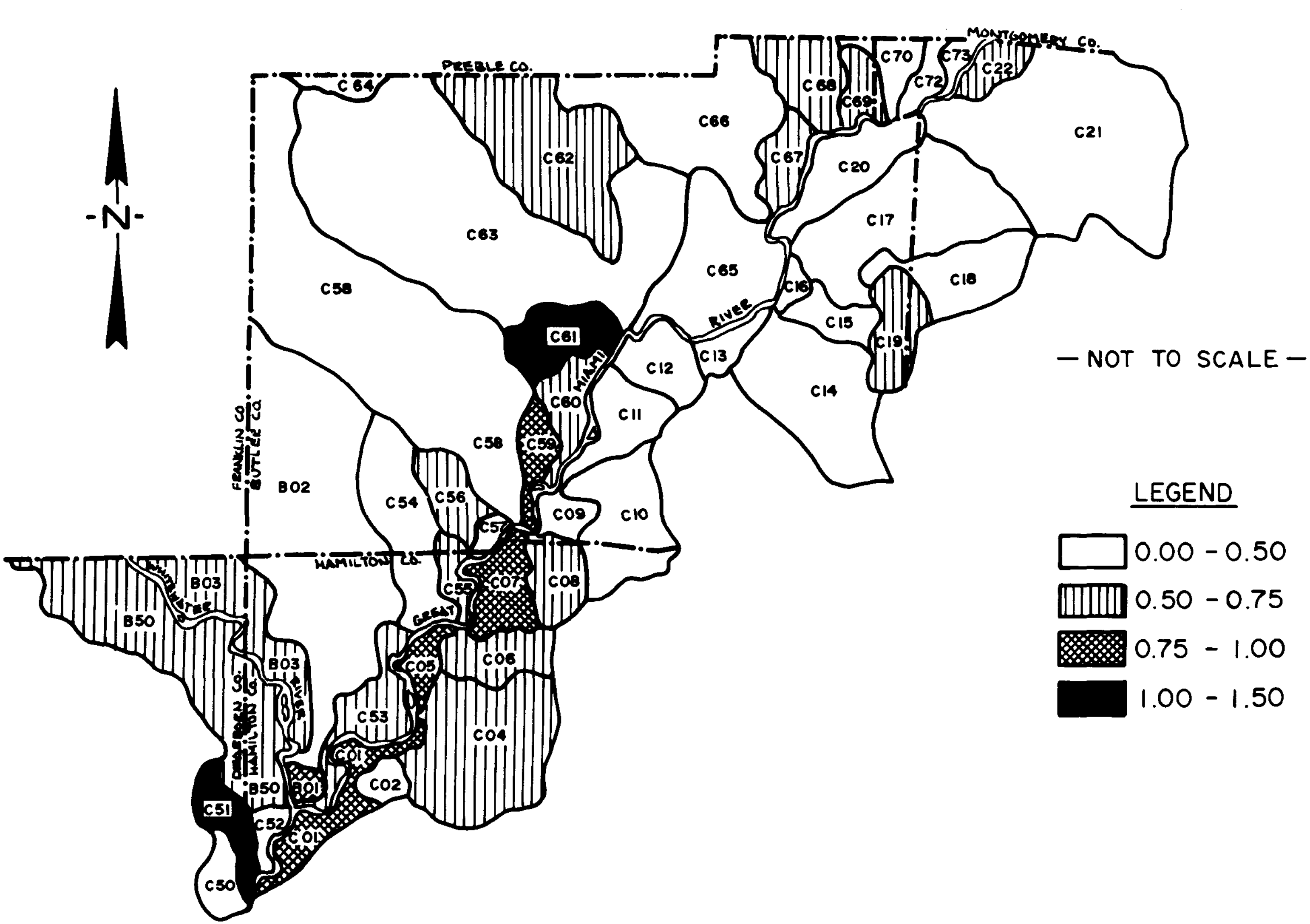

Figure II-2. Average annual sediment yield in tons per acre for existing conditions — Great Miami River they related to reducing the erosion rate and soil loss under cropland, grassland, and woodland uses.

Testing Alternative Management Approaches

The strategy was to apply and test alternative control measures in problem watersheds through the use of OKI's rural nonpoint source model. With control measures in place, differences in gross erosion were calculated and relative improvements in the nonpoint source problems were determined. The application of the best management practices for rural uses was not undertaken to produce site specific, detailed control measures which would be required, but rather to exemplify the utility of best management practices and demonstate the benefits which could be derived. Data and results were utilized to support the need for and encourage the implementation of management practices.

For cropland areas, three alternatives were tested to demonstrate the effectiveness of control measures in reducing erosion. These management practices were established, though not uniformly applied, in area farm operations. For cropland areas which were identified by the OKI model as having very high erosion rates, the tested alternative was a change in land use (i.e., change from cropland to woodland). In cropland area with less severe rates, management practices included minimum tillage and improved crop rotation. Similarly, in woodland and grassland areas with erosion problems, improved management practices such as increased brush cover, reforestation, and better grazing practices were tested. Depending on the degree of the problem, extent of the particular land use, and level of treatment considered appropriate, the management practices being tested were applied in each watershed within a river basin. The OKI model predicted the effectiveness of the management practices in terms of the reduction in gross erosion.

An example of the application of best management practices is illustrated in the case of the Great Miami River Basin. Applicable land treatment measures were applied to the 49 watersheds of the Great Miami and Whitewater River Basins based upon the acreages of the three land uses in each watershed identified as needing treatment. For those land uses needing treatment within the Great Miami Basin, 70,400 acres were cropland, 41,700 were grassland, and 20,300 were woodland. It was estimated that within the Great Miami Basin, 61 percent of the gross erosion was from cropland, 35 percent from grassland, and 4 percent from woodland. By applying best management practices to the aggregate basin, the overall reduction in gross erosion was calculated for two alternatives.

Figure II-3 shows the findings of this analysis in the Great Miami and Whitewater Basins of the Great Miami River. For the Great Miami Basin, it can be noted that, by applying alternative 1 (woodland improvement, grassland improvement, and cropland practices improvement), a greater reduction in gross erosion could be realized than with alternative 2 (changing from cropland improvement to minimum tillage). Under the management practices of alternative 1, gross erosion could be reduced by approximately 35 percent. It is of significance that in the Whitewater basin, improvements in grassland management alone would greatly reduce the gross erosion.

For those management practices which were analyzed in the Great Miami Basin, total annual public costs were calculated. Public costs are those which

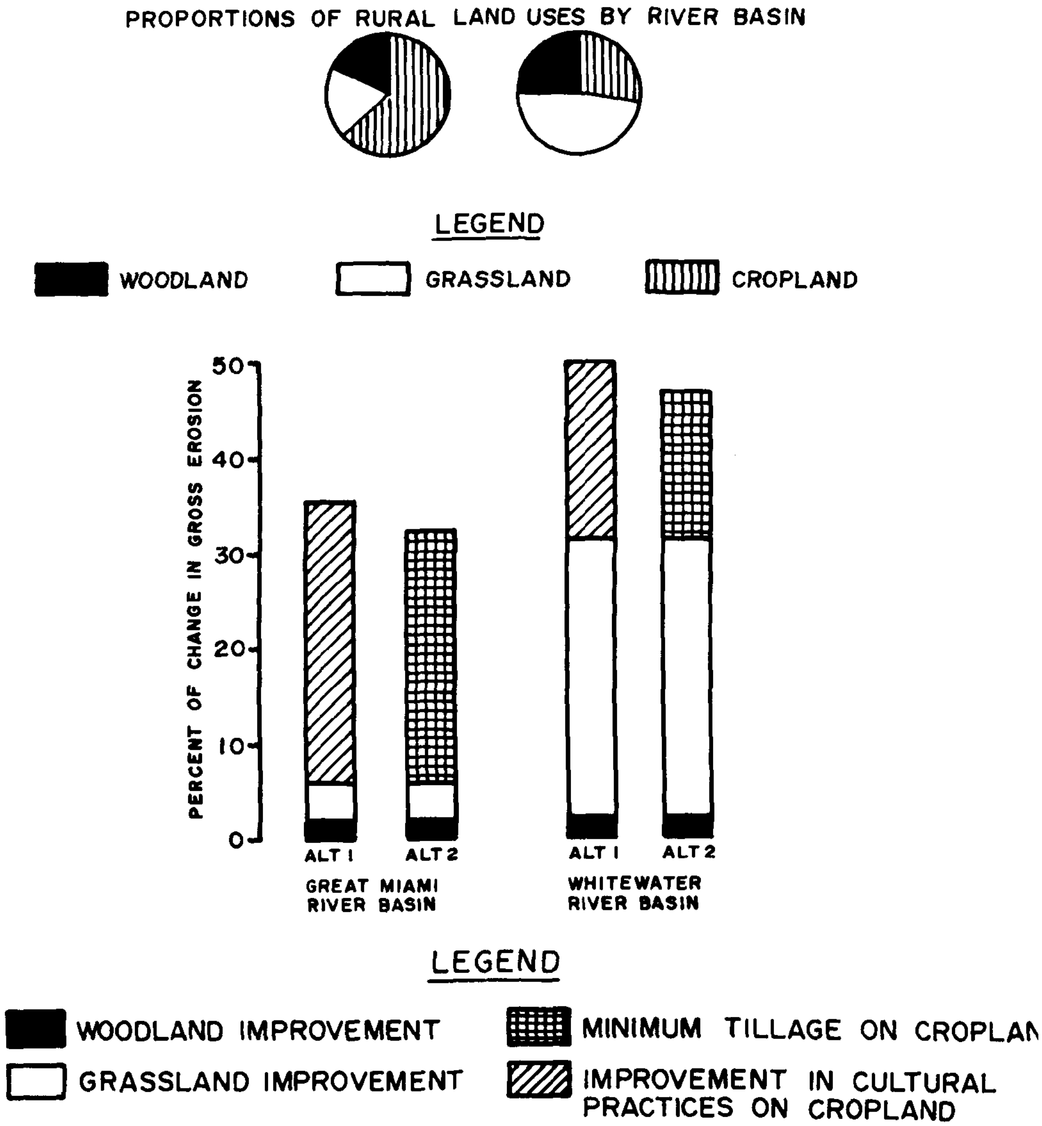

Figure II-3. Reduction in annual gross erosion rate with application of best management practices — Great Miami River would be borne by the federal government under the existing cost-sharing program. As shown in Table II-3, these costs were subdivided according to management techniques. When applied to the Great Miami Basin as a whole, the total annual cost approaches $685,000 (Table II-4). This figure represents the cost for the basin controls associated with the cost-sharing program of the federal Agricultural Conservation Program. This program is administrated through the Agricultural Stabilization and Conservation Service in the U.S. Department of Agriculture. Direct costs to individual farmers were not calculated because of the complexities of dealing with a variety of potential conservation practices for a particular tract of land.

Table II-4.—*Summary of nonpoint source control costs for Great Miami River Basin*

Land Use	Acres Needing Treatment	Weighted Average Annualized Cost	Total Annual Cost
Cropland	70,400	$6.52/ac/yr	$459,000
Woodland	20,350	$1.77/ac/yr	$ 36,000
Grassland	41,700	$4.53/ac/yr	$188,900
			$683,900

Source: Chapter VI, OKI Draft Water Quality Management Plan.

It should be noted that only a portion of the $685,000 is an expenditure for the direct benefit of pollution abatement. As stated earlier, meeting the allowable soil loss criterion is already an established agricultural objective, so cost savings and increased crop yields would benefit area farmers. Other cost savings resulting from the management practices analyzed would be a reduction in flood damages and dredging costs associated with sediment build-up in streams.

Strategy for Developing Management Practices

In the nonpoint source analysis undertaken for the Great Miami Basin, a limited number of specific management alternatives were considered in the OKI model. The approach utilized for the other river basins in the region was similar. The objective of this analysis was to demonstrate the potential reduction of rural nonpoint sources through the application of best management practices rather than to develop a detailed conservation plan for the basin. OKI determined that a reduction in gross erosion could be accomplished by the sound application of other management practices on specific tracts of land with specific characteristics and problems.

Table II-3.—*Rural nonpoint source control costs by management technique for Great Miami River Basin*

Management Technique	Unit Cost[1] ($/acre)	Practice Life (years)	Annualized Cost ($/acre)
Cropland			
Annual Cover	3.89	1	3.89
Sod in Rotation	24.34	3	8.11
Terraces	12.61	10	1.26
Permanent Cover	51.05	5	10.21
Weighted Average			6.52
Woodland			
Livestock Exclusion	20.00	25	0.80
Woodland Improvement	20.00	10	2.00
Weighted Average			1.77
Grassland			
Pasture Management	18.00	4	4.50
Pasture Planting	70.00	10	7.00
Weighted Average			4.53

[1]Represents average cost of practice as cost-shared by Agricultural Stabilization and Conservation Services.

Source: Chapter VI, OKI Draft Water Quality Management Plan.

To assist agricultural interests in implementing management practices to reduce erosion, several more specific practices were described and assessed as part of the water quality management plan. The range of management practices which was developed is shown in Table II-5. Since these best management practices are basically variations of the modeled practices, costs and effectiveness associated with them on a regional basis would be similar to those of the modeled practices.

IMPLEMENTATION OF NONPOINT SOURCE RECOMMENDATIONS

Throughout the assessment process for rural nonpoint source pollution, very close coordination was maintained with the various Soil and Water Conservation Districts, Soil Conservation Service representatives, and agricultural extension agents in the region. These groups assisted in supplying the required information to OKI in developing the rural nonpoint source assessment procedure, and participated in discussion and deliberations of the significance of the data and model results including potential measures for control.

Basis of the Implementation Approach

The focus of OKI was to address rural nonpoint source problems on an area-wide basis, provide estimates of pollutant loadings, establish broad recommendations for control measures or best management practices to reduce erosion from rural land, and estimate the public or federal cost to implement these control measures.

The overriding conclusions of the OKI rural nonpoint source program was that erosion poses significant problems, it can be controlled, and multiple benefits could be derived from the application of best management practices to rural land uses. Through institutional analyses, it was determined that existing groups and agencies had the capacity to implement rural nonpoint source control practices. These organizations, however, needed background data for prioritizing approaches to solve the problems and needed funding at a greater level than currently existed.

Traditional rural conservation programs in the OKI planning area have dealt with the problem through education and technical assistance. Through these means, agricultural extension agents and district conservationists demonstrated the effects of erosion and described various control measures. To encourage the application of management practices qualifying land owners can receive financial assistance through the cost-sharing program. This program is currently administered at the local level on a first come first served basis and the level of funding is small, ranging from $10,000 to $15,000 per county. As a means of implementing the rural nonpoint source program, OKI is working closely with the County Soil and Water Conservation Districts to encourage the allocation of existing cost-sharing monies on a problem area priority basis which includes the objectives of improved water quality. Prior to the water quality management planning effort, no supporting data which pin-pointed problem areas and demonstrated the effectiveness of control measures for a particular basin had been available. Increased funding for cost-sharing programs on a long-term basis is being actively encouraged through the U.S. Department of Agriculture.

Table II-5.—*Best management practices developed for rural nonpoint source control*

Cropland Management	Grassland Management
Tillage Alternatives	Grassland Planting
Terraces	Grassland Management
Diversions	Grazing
Stripcropping	
Contouring	**Woodland Management**
Grassed Waterways	Livestock Exclusion
Pipe Outlets	Improved Management
Crop Rotations	
Cover Crops	**Livestock Management**
Timing Field Operations	Feedlots
Sod-based Rotations	detention ponds
Other Practices	settling areas
	grass filters
Agricultural Chemicals	Pastureland
Chemical Registration	animals per land ratio
Approval of Application Methods	productive forage
Applicator Licensing	limited access to streams
Alternatives to Chemicals	erosion control

Source: Outline for Chapter V, OKI Draft Water Quality Management Plan.

In addition to encouraging conservation programs on a problem area priority basis, OKI realized that the cost-sharing program needed to be more than voluntary to effectively reduce erosion. The adoption of a mandatory program had more far-reaching impacts than just those counties in the OKI planning area. Such programs must have a legal basis at the state level and need sufficient funding to implement the program. Within the three states of the OKI planning area, Indiana and Ohio have begun work on state-wide sediment control legislation. Legislative action on the Ohio bill is expected in 1977 and this bill is further along the legislative process than the Indiana bill. Both, however, provide for greatly expanded Soil and Water Conservation District programs in terms of authority and staff funding. OKI is actively supporting the legislation of both states. Position papers in conjunction with area district conservationists have been prepared, and the OKI staff has joined with other water quality planning areas in Ohio to strongly support passage of the bill as a cornerstone in their efforts to implement the nonpoint source control program.

To provide assistance to individuals and organizations in carrying out the best management practices, OKI developed within the Water Quality Management Plan a more specific list and explanation of available management practices which could be used. Each of the major river basins in the planning area has a chapter of the plan devoted to that basin's characteristics, existing water quality, assessment of pollutant loads and contribution of sources, a review of alternatives to correct the identified water quality problems, and a recommended plan specific to that basin.

Recently, meetings have been conducted with each of the six Soil and Water Conservation Districts to discuss the findings of the rural nonpoint source assessment and demonstrate the benefits of land conservation techniques. These groups have been provided with presentation materials which they could use in their meetings with district farmers. Similar meetings have been held with the various 208 advisory committees concerning the recommendations of the full Water Quality Management program and with a key organization, the OKI Regional Conservation Council. This citizens council acts as a mechanism to coordinate the activities of Soil and Water Conservation Districts with the various county governments. Also, public hearings are being scheduled (beginning in March) for the full Water Quality Managment Plan recommendations for each of the five river basin plans being drafted.

The final Water Quality Management Plan is scheduled for completion in July, 1977. Of prime importance in implementing the rural nonpoint source program, as well as other water quality considerations, is the continuing planning functions at OKI. In regard to the rural nonpoint source program, functions of the continuing planning agency will include:

- Monitoring the implementation of rural nonpoint source program.
- Working with agencies, groups, and individuals in support of state erosion control legislation.
- Providing technical assistance and developing best management practices demonstration projects.
- Determining the success of management practices.
- Analyses of water quality problems which could not be adequately addressed in the initial planning effort.

The primary means of implementing the best management practices for rural areas is through a strengthening of existing mechanisms. OKI has demonstrated the utility of various broad management practices toward conserving valuable land resources for agricultural use and improving water quality by reducing sediment loads. An understanding of the benefits which could be derived through best management practices has been developed with agricultural extension agents, SCS district conservationists, area Soil and Water Conservation Districts, and the farmers they represent. The need for developing soil conservation plans has been well established and costs to implement management practices have been estimated. Implementation of the rural nonpoint source program hinges on the availability of money, particularly through the State and federal allocations for local cost-sharing programs. Agricultural interests and OKI staff feel they now have the data to strongly support requests for additional allocations for conservation plans, and can adequately show the benefits for water quality as well as agricultural production from such rural nonpoint source control mechanisms. The OKI rural nonpoint source model will have continuing input through the program implementation period. It will be utilized to assess the effectiveness of specific management practices and will be refined as a planning and evaluation tool.

Chapter III

THE SOUTHCENTRAL MICHIGAN PLANNING COUNCIL ASSESSMENT OF WATER QUALITY IN LAKES

The Southcentral Michigan Planning Council (SMPC) has identified water quality in lakes as one of the major problems to be addressed in its areawide planning program. In addressing this problem, the SMPC saw a need to develop a methodology for water quality assessment which could be used in working with local lake associations and governmental units both now and on a continuing basis. Toward this goal, a system utilizing LANDSAT 2 satellite imagery has now been established to indicate bio-indices which reflect overall water quality conditions throughout a given lake.

The information developed by the lake assessment program does not provide quantitative water quality data. The purpose of the remote sensing approach is to identify indicators of various water quality conditions which in turn, are being used in conjunction with soils, topographic and land use information to delineate specific problem areas and probable causes. This tool, the end product of the water quality assessment program, has been used to establish alternative strategies for best management practices (BMPs) on a local level.

As a continuing planning tool, the system will allow the SMPC to work with local lake associations and governmental units in monitoring the progress of programs designed to improve water quality. By using water quality conditions identified over time in conjunction with changing land use patterns and improved agricultural practices, the relative success or failure of alternative BMP strategies can be evaluated. In this way, the beneficial impact of the water quality management program on the region can be realized on a continuing basis.

BACKGROUND

In 1973, the Southcentral Michigan Planning Council (SMPC) was formed as the regional planning agency for the Counties of Barry, Branch, Calhoun, Kalamazoo and St. Joseph and in June, 1975 was funded to develop an areawide water quality management plan under Section 208 of the Federal Water Pollution Control Act Amendments of 1972. The region includes two major urbanized areas: the Cities of Kalamazoo and Portage with a combined population of about 130,000; and the City of Battle Creek with a population of about 40,000. The present overall population in the region is estimated to be approximately 500,000 persons. Land use in the region varies considerably, from downtown urban and industrial areas to rural, agricultural and recreational areas. Overall, however, the region is dominated by non-urban land use categories.

The SMPC region forms a part of the Lower Lake Michigan drainage basin and contains portions of three major contributing river systems. These rivers are the Thornapple, Kalamazoo, and St. Joseph. In addition to the major river systems, there are several hundred lakes within the region, ranging in size from several acres to several square miles. While most of these lakes are natural or man-made parts of river systems, many are self contained with no significant tributary flow. Figure III-1 illustrates the existing land use, the major river systems, and the predominance of lakes throughout the five county planning area.

Over the years, a considerable amount of water quality information has been collected on the various river systems, in order to monitor the discharge of municipal and industrial wastewater effluents. This effort has been intensified in recent years as a result of on-going 201 facilities planning studies. Specific localized water quality data, primarily of a biological nature, has also been collected by various institutional and private organizations on many individual lakes in the region. However, none of the information generated has been comprehensive enough for regional purposes, and with but a few exceptions, has not identified any contributions from nonpoint source pollutants.

In developing the areawide planning program for the region, the SMPC saw the need to focus on water quality problems felt to be of most importance by the people living in the region. Two basic objectives were identified and addressed by the planning agency. One of the basic objectives was to tie the various on-going 201 planning studies into a comprehensive plan for point source wastewater management. The other objective was to more clearly identify water quality in the region's lakes, and to formulate plans for improving water quality where problems were seen to exist. Water quality in lakes is considered to be the biggest unresolved water quality problem in the region. It is in this area that the SMPC has developed a unique method for assessing water quality in lakes and a tool with which the impact of applying best management practices (BMPs) on the local level can be monitored over time on an individual lake basis.

THE SMPC APPROACH TO ASSESSMENT OF WATER QUALITY IN LAKES

The largest source of existing water quality information in the region is maintained by the Michigan Department of Natural Resources (DNR). The State has set up and operated a series of permanent monitoring stations which have generated a wide ranging data base for use in overall water quality planning efforts. These monitoring stations are predominantly located on the major river systems. While numerous studies have been undertaken by DNR and other institutional and private agencies on specific lakes in the region, the data generated has not been comprehensive enough for areawide application. Consequently, the development of a procedure for assessing general water quality in lakes was necessary to identify potential problem areas associated with them.

The basic problems with regard to lake water quality in the region are residential development and surface runoff. Many of the lakes having recreational potential have recently had homes built around their periphery. The majority of these lake developments are not included on municipal sewerage systems and therefore, must rely on subsurface systems for wastewater treatment and disposal. As a result of high groundwater levels, these disposal systems have not

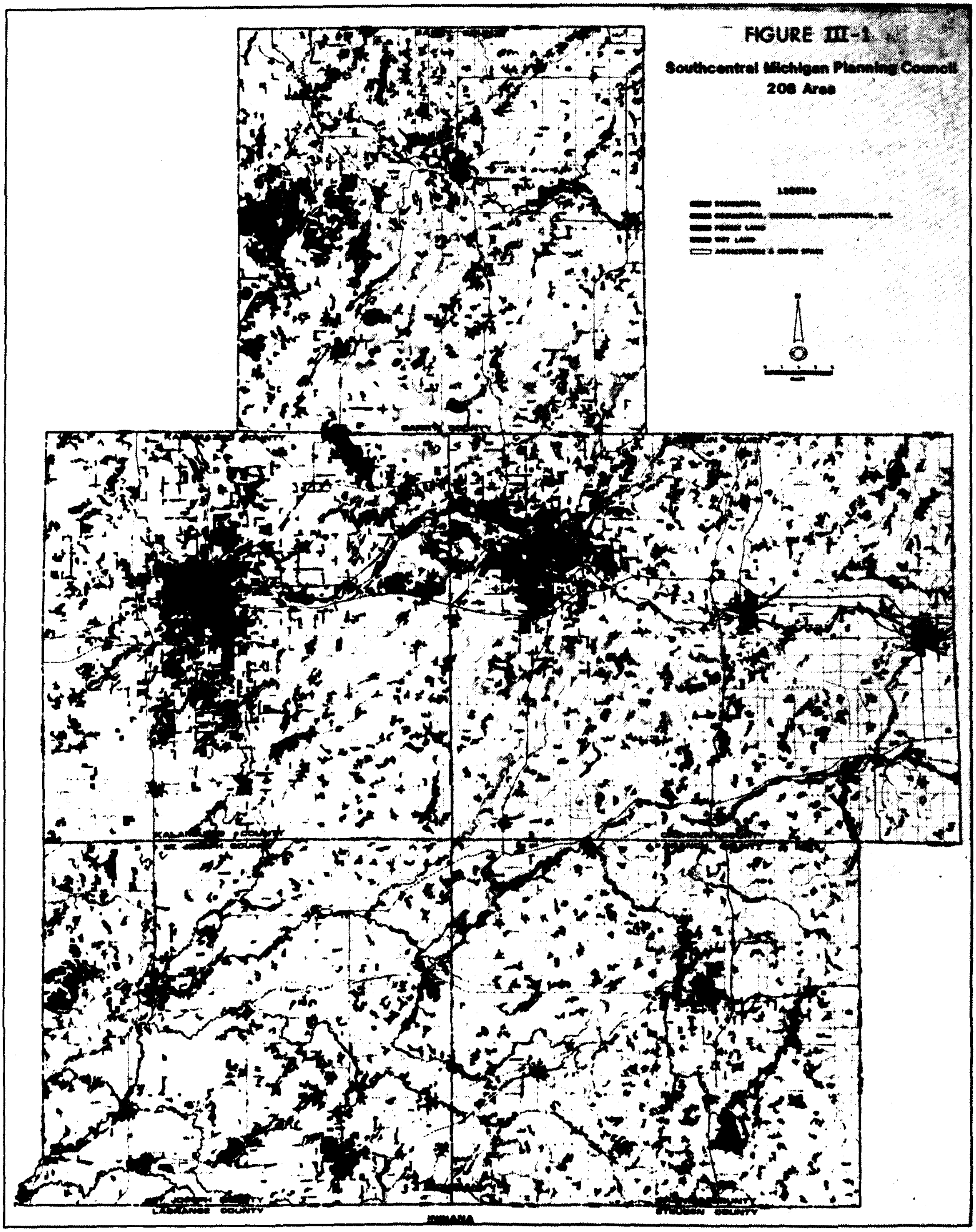
FIGURE III-1
Southcentral Michigan Planning Council
208 Area
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been adequate in many instances and have contributed significantly to increased nutrient loadings to some lakes. In addition, runoff from nearby agricultural lands and fertilized residential lawns has created increased nutrient levels in many lakes, and stormwater runoff from newly developed and agricultural areas around the lakes has led to increasing sediment loads as a result of land disturbing activities.

Given the large number of lakes in the region and the time and financial constraints of the SMPC water quality management program, it would have been impossible to sample and generate laboratory data for each specific lake. It was also felt that water quality sampling data per se, would not be of substantial benefit in identifying problems and developing potential solutions. While sampling and laboratory analysis would generate specific constituent levels at the sampling point, it would not necessarily depict the overall condition of water quality in various sections of the lakes unless each section was sampled. In addition, the sampling approach would be cost prohibitive on a continuing basis and therefore, could not be used as a continuing method of developing and evaluating the success or failure of local best management practices utilized to up grade water quality. It became apparent that a system was needed to assess general water quality in a lake, not necessarily through the use of parametric data, but through the use of bio-indices which could lead to the identification of particular problem zones throughout a lake, and ultimately to the potential causes of the problems.

Toward this objective, the SMPC staff and their consultants worked with the Bendix Company, Aerospace Systems Division, in developing a methodology for identifying different aquatic biological community types using LANDSAT 2 satellite imagery. Multi-spectral scanners in the satellite record reflected light from the earth's surface at an altitude of 570 miles. Land and water features exhibit different light reflectance characteristics and a particular feature will exhibit a particular reflective index. Shallow water for example, has a different reflective index than deep water or water with emergent vegetation. Some features may have similar reflective indexes and consequently, computer analysis of the satellite imagery is required to separate or categorize the particular features into the desired classifications.

Using multi-spectral analysis techniques, it was possible to interpret the satellite imagery to delineate bodies of water and then separate various aquatic classifications within them. These classifications were categorized (or calibrated) according to known biological communities and available water quality information on specific lakes. By classifying these communities according to their reflective index, a number of biological index categories were developed for use in defining water quality. Six biotic communities were established as indicators of general water quality in lakes throughout the region. The six bio-indices chosen were interpreted to be indicative of the water quality conditions illustrated in Table III-1.

The categories noted in Table III-1 are the predominent bio-indices in the lakes of the region as determined by computer interpretation of LANDSAT 2 data. It is not possible to determine relative concentrations using this procedure, and therefore, only the predominant feature is indicated by computer interpretation. Interpretation of a lake is done by analysis of 1.1 acre grids to provide a complete water quality profile over the lake area.

Table III-1.—*Bio-indices identified using LANDSAT 2 imagery*

Water Quality Category	Explanation
Shallow clear water	Water generally considered to have a low algal, silt and sediment content. The water may be shallow or appear so because of submergent vegetation or some other factor limiting light penetration.
Blue-green algae	Water considered to have blue-green algae concentrations in excess of levels normally found in cold water plankton populations. It generally is an indicator of high nitrate and phosphorous levels and warm water temperature, resulting in eutrophication.
Green algae	Water considered to have green algae concentrations in excess of those normally found in cold water plankton pupulations. It is an indicator of nutrient rich wates, containing high phosphorous levels as well as high levels of nitrates, which may be somewhat cooler but nonetheless, subject to eutrophication.
Emergent vegetation	Waters generally dominated by plant life covering much of the surface. It may also indicate organic bottoms or very shallow waters exhibiting such characteristics as algal blooms.
Silts and sediments	Waters dominated by high levels of soil particles or organic matter in suspension. Included in this category would be suspended benthic materials, heavy detritus, zooplankton having a large percentage of debris and possibly heavy concentrations of bacteria and other non-algal organics. It may be indicative of heavy organic or nutrient loads where conditions are not favorable to algal or plant growth.
Deep clear water	Waters not nutrient enriched beyond normal levels for a cold water lake. The waters may be naturally eutrophic, but do not contain heavy concentrations of phytoplankton or zooplankton. This category is an indicator of generally good water quality as based on records and opinions of the Michigan Department of Natural Resources.

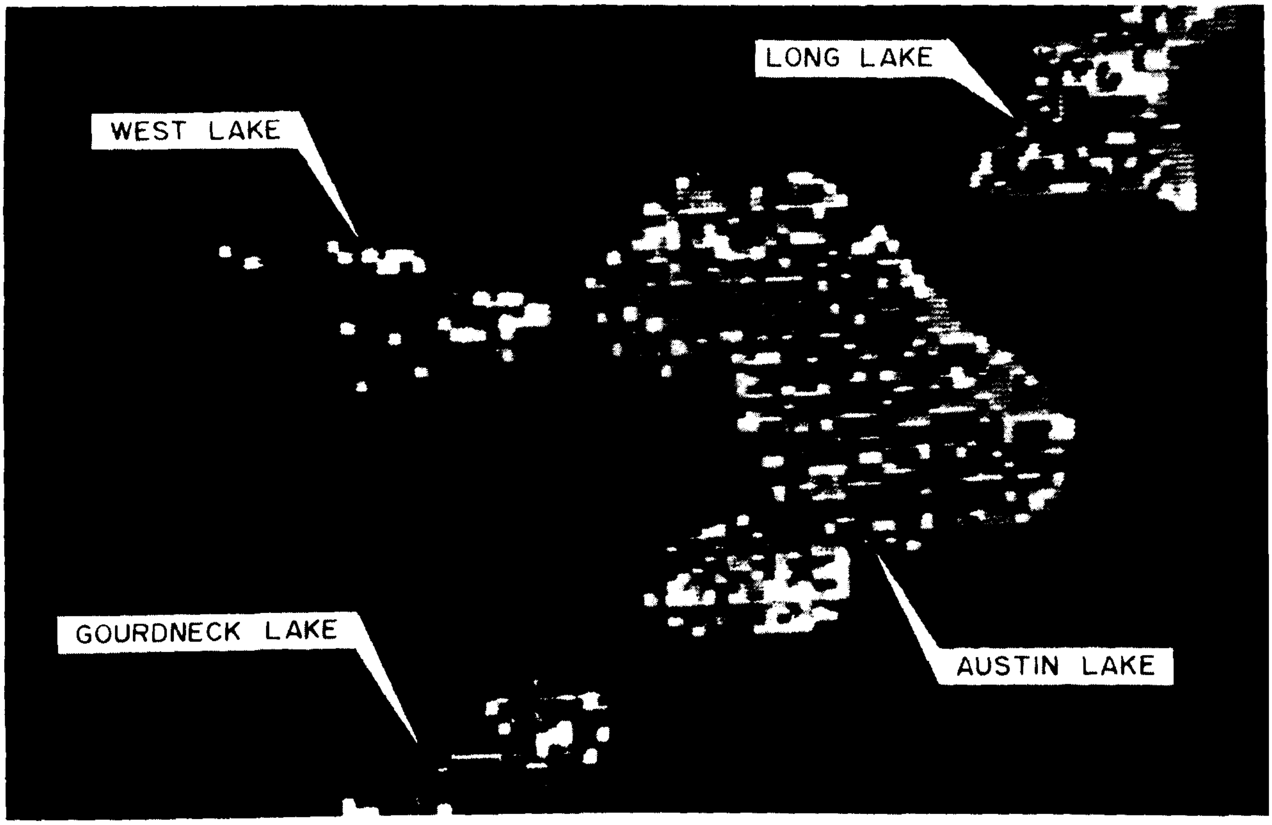
In order that the public become involved in the lake assessment program and become aware of its value as a continuing planning tool, the assistance of the SMPC Water Quality Commission's Citizens Advisory Committee was solicited. Twenty lakes of specific interest to members of the committee or of known water quality were used for testing the validity and benefit of the procedure. Color photographs of the computer video display unit, indicating the nature of water quality in these lakes, were prepared and distributed to the local lake associations involved. These lake associations are made up of local residents who nave specific interest in maintaining the integrity of lakes in their area and have detailed knowledge of water quality conditions in the lakes. The lake associations were informed of what the photographs depicted and for what use they were intended. They were asked to verify the information shown, based on their knowledge and visual inspection of the lake systems. Replies were received from the lake associations and for the most part, the water quality information depicted on the color photographs was verified as being accurate. Furthermore, acceptance of the program was widespread and its usefulness in identifying potential problem areas was established.

Figure III-2 is an example of the color photographs taken of the computer video display unit. Shown in this particular figure are Austin and West Lakes, both of which are located in the SMPC region and serve as contrasting illustrations of the information which can be derived from the water quality assessment program. The colors in the figure indicate bodies of water, with the black background constituting land. Each colored block, as indicated earlier, represents an area of approximately 1.1 acres. Austin Lake is the lake to the right in the figure with West Lake shown to the left.

Austin Lake appears to be a shallow lake with areas of green and blue algae problems, particularly in the northwest, east and southeast portions of the lake. These areas probably indicate the presence of inadequate subsurface disposal systems adjacent to the lake. Scattered areas of silt and sediment indicate some potential problem with stormwater drainage systems discharging into the lake. West Lake contrasts with Austin Lake in that its major water quality problem appears to be silt and sediment. Nutrient loadings to West Lake do not appear to be nearly as high as in Austin Lake, but stormwater runoff, from adjacent residential development and nearby agricultural lands, is causing significant amounts of sediment to be washed into the lake.

As illustrated in Figure III-2, the information developed from the program has been directed toward a qualitative comparison of lake water quality throughout the region. The program has not attempted to provide a quantitive analysis of the biological or chemical constituents of a specific lake water. However, the bio-indices identified can be compared on the basis of percent area classified in each category to provide a method for ranking the significance of various water quality problems in a given lake system. The conceptual approach of the program has the limitation of not being able to consider the intensity of localized problems (i.e., relative density of algal populations or relative concentration of silt and sediment). It is able to examine broad problems, however, and is suitable for correlation with existing land use data to aid in the identification of potential causes of those problems. The result of the assessment program is an overall evaluation of water quality problems in lakes with respect to soils, topographical features and land use patterns. The information can then be used in working with local lake associations and governmental units, such as municipalities and townships, to develop alternative strategies for solving specific water quality problems.

The key to the development of this water quality assessment program was public participation, both for political and financial reasons. Obviously, it took a great deal of work on the part of the SMPC staff and consultants to synthesize existing water quality data for use in calibrating and categorizing



LEGEND

COLOR	WATER QUALITY CATEGORY
BLUE	SHALLOW, CLEAR WATER
LIGHT BLUE	BLUE - GREEN ALGAE
GREEN	GREEN ALGAE
RED	EMERGENT VEGETATION
YELLOW	SILT AND SEDIMENT
DARK BLUE	DEEP, CLEAR WATER

Figure III-2. Example of LANDSAT generated color photograph for Austin and West Lakes computer interpretations of the LANDSAT 2 imagery. However, the role of the public sector in verifying the results and accepting the program as a beneficial tool, with which problems could be identified and solutions sought, was critical in making the approach effective.

REFINEMENT OF WATER QUALITY INFORMATION

The initial remote sensing work was performed to evaluate the viability of using satellite imagery for assessing general water quality conditions in lake systems. The use of the categorized imagery also provided a means of obtaining field verification of the information and promoting public participation in the program. However, in order to make use of the information for technical purposes in identifying and solving problems, it became apparent that refinement of the satellite imagery interpretations would be needed to estimate the intensity of local water quality problems. As noted earlier, the refinement analysis was not possible through the use of color photographs and was not an initial objective of the lake assessment program. The need for refinement evolved during the initial phases of the program however, and brought a research oriented element into the work effort.

Discussions with the Laboratory for Applications of Remote Sensing (LARS) at Purdue University indicated that potential refinement of the water quality information was a possibility. The LARS system, known as LARSYS, utilizes the same satellite technology and a similar computer interpretation system to that of the system at Bendix. The main difference in the way the two systems are being used by SMPC is that LARSYS will generate the water quality information in standard computer output form, instead of color photographs. A LARSYS printout provides a line-column designation for each grid in a body of water, thereby allowing surface cross-sectional analyses to be performed and the accuracy of the information to be better determined.

An example of a LARSYS printout, showing ten water quality categories, is shown in Figure III-3. The lakes shown are again Austin and West Lakes, shown in color in Figure III-2, and based on the same satellite imagery (June, 1973) used in the Bendix interpretation. However, the LARSYS interpretation provided ten water quality categories, within acceptable confidence limits, where initial analyses provided only six.

Based on the LARSYS interpretation, Austin Lake shows large areas of submerged vegetation throughout the west, central and south portions, and appears to be severely eutrophic. However, the pockets of blue-green algae are isolated and apart from the submerged vegetation. It appears that the submerged plants may be serving to tie up nutrients and thus limit algal growth. Isolated areas of organic sediments, due predominantly to local drainage, can also be seen in Austin Lake. West Lake appears to have heavy organic sediment loads as well as a large amount of submerged plants. The problems with this lake appear to be associated with drainage from surrounding bog-type lands which are easily disturbed by development and other human activities.

While the analyses derived from the LARSYS interpretations of the June, 1973 satellite imagery are not significantly more detailed than those derived from the Bendix interpretations, LARSYS has the additional capability of being

LEGEND

SYMBOL	CLASS
-	EMERGENT VEGETATION
•	EMERGENT VEGETATION & SHORE EFFECTS
=	MARL & LOAM SILT
/	GREEN ALGAE
*	BLUE-GREEN ALGAE
S	EMERGENT & SUBMERGENT VEGETATION
O	PLANKTON (ZOOPLANKTON)
X	DETRITUS & ORGANIC SEDIMENTS
+	SUBMERGED VEGETATION
W	CLEAR WATER

Figure III-3. Example of LARSYS printout for Austin and West Lakes used in conjunction with a mobile, truck mounted spectrophotometer to increase resolution to an area as small as an eight-inch diameter circle. This means that by using the truck mounted unit at the same time the satellite is passing, more detailed information within the standard 1.1 acre grids can be obtained. This information, combined with selective sampling and laboratory analysis can result in relative compositions and concentrations of bio-indices and a greater number of water quality categories in future efforts.

Of major concern to the SMPC staff was the cost of providing water quality information on the many lakes throughout the region. A comprehensive sampling and laboratory analysis program would have cost hundreds of thousands of dollars and would have been cost prohibitive. On the other hand, the initial work at Bendix, to evaluate the potential for examining water quality using satellite imagery, cost approximately $2,000 for an analysis of about 40 lakes. The work at LARS, in refining the computer interpretations and providing more detailed information regarding relative compositions and concentrations, will amount to about $22,000 for the analysis of approximately 300 lakes. It should be emphasized that much of this cost is related to development of a system to provide the specific information desired by SMPC. Once the system is set up, the major costs will be in the area of computer time, which amounts to about $250 per hour. Representative runs indicate that a printout of water quality categories for five lakes can be accomplished in less than ten seconds of computer time. This corresponds to a cost of less than one dollar per lake. While the cost of operating the truck mounted unit must also be included in some cases, it can be seen that the overall approach of using satellite imagery to analyze lake water quality in the SMPC planning area is cost-effective on a continuing basis and was a positive factor in its development.

USE OF THE WATER QUALITY INFORMATION IN DEVELOPING POINT AND NONPOINT SOURCE CONTROL STRATEGIES

As an areawide planning tool, the remote sensing of lake water quality has been used, in conjunction with storm runoff and stream modeling, to generate BMPs on a sub-basin level. In a sense, areawide BMPs are being defined on a broad conceptual basis, with actual point and nonpoint source control measures being developed and implemented on a local basis. This type of analysis was made possible by the nature of the water quality information generated by LARSYS. Since the drainage areas of many of the lakes constitute major portions of sub-basins, the information generated on water quality can be used to assess the overall impact of stormwater runoff from those sub-basins.

The most important use of the remote sensing water quality information as a planning tool is in the assessment of the impacts of changing land use around the lakes. The original satellite imagery, used to develop the color photographs, was taken in June, 1973. More recent information, to be generated by LARSYS, will be based on satellite imagery taken in July, 1976. The changes in land use during that period are expected to indicate resulting changes in water quality, based on the results of other on-going studies dealing with water quality in specific lake systems. These changes in land use are most prevalent where residential development around the periphery of lakes has accelerated in recent years. The water quality information generated to date has also been used by facilities planning agencies in establishing the fact that water quality in the region's lakes has changed due to the increasing number of septic tank systems in close proximity to them. Where the replacement of subsurface disposal systems by sewerage systems may be viable in some cases, the SMPC has shown, using the same water quality information, that sewers may not be the answer in all cases and that there are other nonpoint sources of pollution which could be controlled to produce viable alternative solutions.

Several specific nonpoint source pollution problems have been verified on lakes in the region as a result of the water quality assessment program. For example, Goquac Lake has been verified as being severely impacted by stormwater runoff from surrounding residential development. Gull Lake has been verified as being impacted by septic tank discharges and fertilizers from residential lawns. Barton Lake has been verified as being impacted by the discharge of treated municipal wastewater. Several other lake systems have been shown to be degraded due to agricultural contributions of silt and nutrients.

By using the lake assessment program to identify current and past water quality conditions, and correlating this information with existing and past land use data, SMPC is able to verify problems caused by inadequate control of land use activities. With this information, it will be possible to suggest controls, which might for example, guide development or impose subdivision regulations in the vicinity of lakes.

The initial areawide plan will provide model ordinances, needed sediment control procedures and other forms of control strategies which can be adopted and implemented locally. The SMPC will then monitor land use activities and reassess the lakes annually to provide information either confirming the need for the controls or proving that the controls are not effective and other methods need to be considered. The importance of such a continuing program is emphasized by the fact that the majority of townships surrounding lake areas do not now control land use and/or development activities as they relate to water quality. In some areas, the SMPC will monitor specific lake systems to determine the impact of proposed sewer systems, which are currently in the facilities planning phase. If it is found that lake water quality is continuing to be degraded after these systems have been constructed, the annual updates will serve as evidence that other control measures, besides wastewater collection, are needed.

Since the initial public participation in verifying the water quality information originally developed, support of the program has grown significantly. Two existing lake boards, which were formed by the Michigan legislature, and have the authority to regulate development and assess costs for facilities, are actively involved in facilities planning studies and are investigating the possibilities of obtaining federal lake restoration grants using SMPC information to document problems. At least seven other local lake associations, which do not have the authority to legally regulate or levy assessment, are investigating the possibilities of similar grants through their elected officials. In addition, many other lake associations are actively investigating measures, one of which might be to become a designated lake board, in order to better control water quality related activities.

To date, no specific control strategies have been implemented as a direct result of the water quality assessment program. The water quality assessment program has identified general water quality problems and local water quality priorities are now being established. As each sub-basin is evaluated in detail in terms of land use, surface runoff and water quality, these priorities will be used in establishing specific local control programs. The public has been kept in tune with the water quality assessment, they have verified its accuracy, become aware of its benefit to them on a local level, and now are laying the political groundwork for establishing some of the controls that they and local governments will ultimately implement as a result of the program.

Chapter IV

THE COMPREHENSIVE NONPOINT SOURCE ANALYSIS PROGRAM OF TRIANGLE J COUNCIL OF GOVERNMENTS

The Triangle J Council of Governments (TJCOG) initiated work on their water quality management planning program in May, 1974. The 1,750 square mile planning area is located in the central Piedmont section of North Carolina, and twenty-two units of local government are participating in the water quality management planning process. The three-city urban core contains 68 percent of the region's population and the surrounding area is predominantly rural.

One of the major elements in TJCOG's areawide water quality management program was an in-depth study of nonpoint source pollution in the region. The approach used was a comprehensive pollution source analysis which was designed to assess existing and projected water quality and analyze the source, duration, magnitude and extent of nonpoint sources specific to the planning area.

An extensive water quality sampling and monitoring program was conducted over a twelve-month period. Automatic sampling was conducted under storm event conditions on seven watersheds or catchments, each with a predominant land use, to determine pollutant loading rates particular to each land use type. Larger catchments with many land use types were also sampled. Utilizing the data gathered in the sampling and monitoring program and the selected model, Storm Water Management Model, pollutant loading rates for each of four predominant land use types were determined. To assess in-stream impacts of nonpoint source pollution, these loading rates and stream hydrographs for seventy-eight catchments were input to RECEIV II, the selected receiving stream model. The models were run under existing and projected development patterns and the modeled parameters included BOD, suspended solids, total Kjeldahl nitrogen, and phosphorus.

The results of the model runs were compared to staff developed preliminary 1983 water quality goals for particular pollutants. Specific nonpoint source pollution problems were documented for suspended solids, phosphorus, dissolved oxygen, and lead. The nonpoint source management program was developed to reduce these pollutant levels through immediate control measures for suspended solids and longer range measures such as proposed state-wide legislation for a comprehensive stormwater management act.

The cost for developing and carrying out this extensive sampling, monitoring, and modeling effort was approximately $400,000. In addition to establishing an extensive nonpoint source data base, stormwater runoff and receiving stream models were developed and calibrated specifically to the planning area. The models are now operational and serving as a continuing planning and evaluation tool of TJCOG. The experiences gained and conclusions drawn from this comprehensive nonpoint source assessment approach have provided significant input to the TJCOG areawide program and will provide useful guidance to other agencies undertaking water quality management planning.

OVERVIEW OF AREA

The Triangle J Council of Governments (TJCOG) is the State designated regional planning agency for North Carolina Region J and is located in the central Piedmont section of the State. The Council is governed by locally appointed delegates who are elected officials of member cities and counties. The primary objectives of TJCOG are to prepare regional plans and studies, serve as the project review and comment agency (A-95), provide a forum for discussion of regional issues, and assist member governments in various aspects of planning.

The Governor, in 1973, designated TJCOG as the lead agency to undertake water quality management planning in the region. Twenty-two local governments within the designated area adopted concurrent resolutions "to develop and implement a coordinated water quality management plan for the region." The Triangle J region and the designated water quality planning area are shown in Figure IV-1. The study area, in the Piedmont physiographical region of the State, is within the drainage area of the Neuse and Cape Fear River basins. Two multi-purpose Corps of Engineer reservoirs, the B. Everett Jordan and Falls of the Neuse with a combined project area of 89,000 acres, are proposed for the area.

Three counties (Orange, Durham, Wake) and portions of two others (Chatham and Johnston) make up the 1,750 square mile study area. Seventeen municipalities, including the urban triangle formed by the cities of Raleigh, Durham, and Chapel Hill are within the study area. With the exception of this urban core, the region is primarily rural and is characterized by small towns and agricultural activity. Population of the planning area in 1970 was 428,000 and 68 percent of this population lived in the three-city urban area. Raleigh is the State Capital and although the governmental sector is the largest employer, manufacturing is a close second. The Research Triangle Park, a nationally recognized center for industrial and governmental research facilities, is located between the three cities of the urban core.

NONPOINT SOURCE ASSESSMENT: PROGRAM

One of the major focal points of the Triangle J water quality management program was an in-depth study of nonpoint source pollution in the region. The comprehensive effort in pollution source analysis was the first such effort conducted under the provisions of Section 208, and was designed to assess existing and projected water quality and analyze the source, magnitude, and extent of pollution specific to the Triangle J planning area. In addition to providing direct input to the water quality planning program, the approach also served as a demonstration effort to determine the feasibility of characterizing nonpoint source pollution as it relates to land use through extensive sampling, monitoring, and modeling. Through this analysis, nonpoint source pollution was analyzed and computer models were developed to serve as water quality planning and evaluation tools for the region. Approximately $400,000 was expended to develop and carry out this comprehensive effort. The major objectives of the assessment elements of the program were as follows:

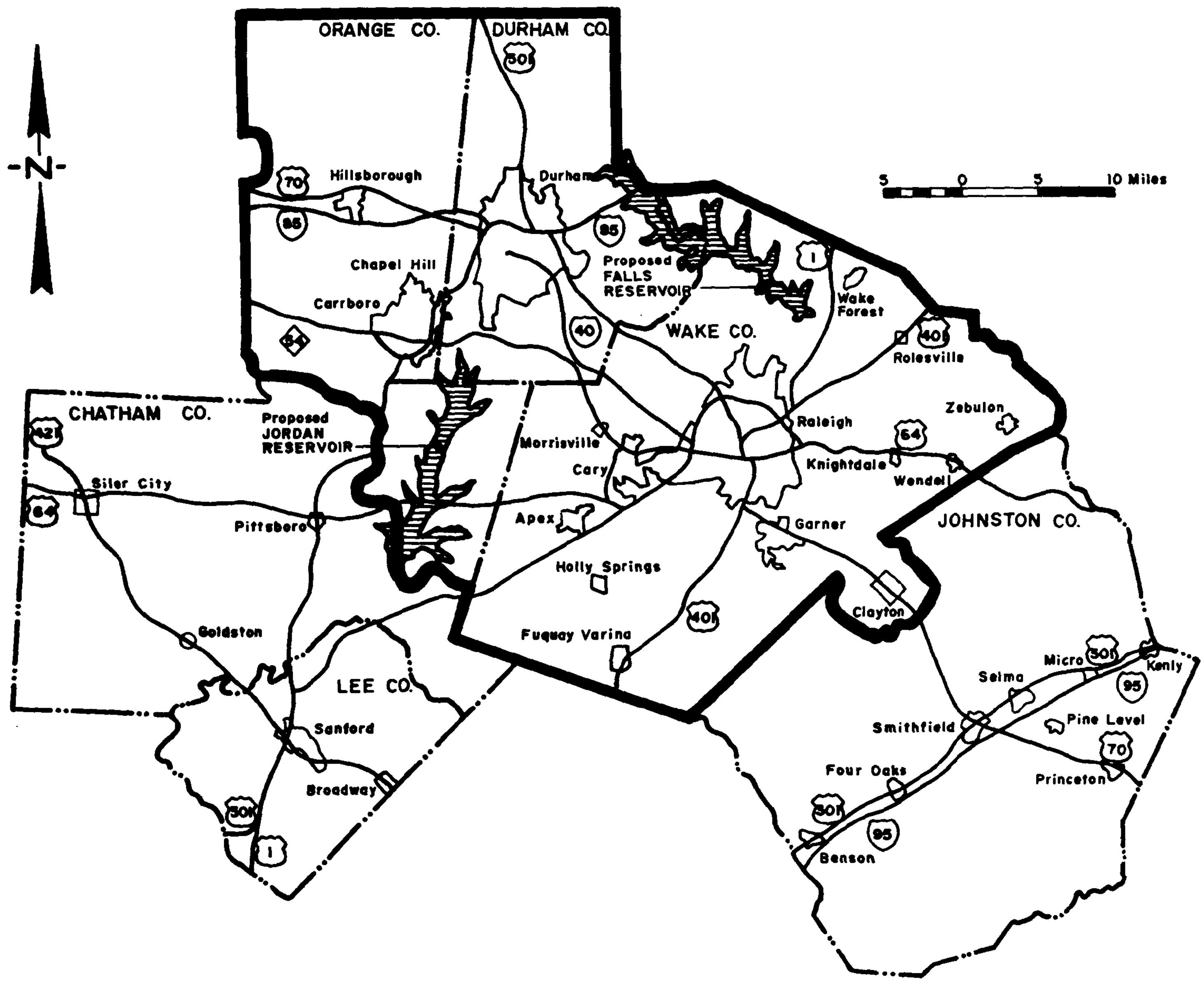


Figure IV-1. Triangle J Region and 208 Study Area

- Conduct sampling of streams under storm event conditions and analyze samples to develop field estimates of nonpoint source pollution loads for selected representative urban and non-urban watersheds.

- Monitor specific stream reaches continuously to permit evaluation of the impact of pollutant loads on water quality.

- Select appropriate computer models to predict nonpoint source runoff and its impact on the major receiving streams in the planning area.

- Collect watershed data, including land use, soil type, and slope and stream channel data for use in the selected computer models.

- Calibrate and verify with collected data, computer models for nonpoint source runoff and receiving stream response for the area.

- Assess the probable impact of pollutant loads on water quality in proposed reservoirs in the region.

Water Quality Sampling and Monitoring Program

An extensive sampling program was conducted over a twelve-month period to determine the nature and extent of nonpoint source pollution specific to the planning area. The water quality data for receiving streams was obtained by the use of six continuous water quality monitoring stations. These stations were established on major streams and located at critical low-flow dissolved oxygen sag points, and at points considered critical under stormwater flow conditions. Continuous readings were provided for dissolved oxygen, temperature, pH, specific conductivity, and stream flow.

It was of particular interest in Triangle J's nonpoint source assessment program to establish relationships between land use, pollutant loading rates, and resultant stormwater runoff characteristics. Sampling, therefore, was conducted in watersheds with a predominant land use by utilizing automatic sampling units. Samples were analyzed for BOD_5, COD, suspended solids, total Kjeldahl nitrogen, nitrate nitrogen, total phosphorus, total organic carbon, and in some instances, heavy metals. Data gathered in this effort were basic to the application and calibration of computer models to predict pollutant loading rates and receiving stream water quality in the planning area.

Eleven sites were selected for the automatic sampling program based on predominant land use typical to the study area and other criteria. Density, type of development, and degree of activity (primarily related to traffic) in the watershed were considered in the selection process. Analysis of maps and data generated from LANDSAT satellite imagery, supplemented with aerial photography, provided ground information necessary for determining appropriate locations for the automatic sampling units. The seven land use types sampled were: low activity rural, high activity rural, low activity residential, high activity residential, low activity commercial, high activity commercial, and urban (central business district).

In addition to these seven watersheds with predominant land use types, four total-load stations were established to determine runoff effects of larger drainage areas with multiple land use types. Drainage areas ranged from 120 to

49,000 acres for predominant land use stations and from 36,000 to 730,000 acres for total-load stations. When a storm event occurred, the samplers were automatically activated and samples were taken at prescribed intervals throughout the storm event. Depending on the particular station, between five and eleven storm events were sampled over the 12-month period. The locations of the sampling and monitoring stations, and rainfall gauging stations are shown in Figure IV-2.

Related Nonpoint Source Studies

Concurrent with the water quality sampling and monitoring program, several other potential nonpoint source pollution problems were studied. A study was made of runoff from a parking lot to determine the potential impact of large impervious surfaces on water quality in nearby streams. Also, a study was undertaken to determine the possible impact of storm flows resuspending sludge deposits below wastewater treatment facilities and causing increased oxygen demand in the stream. Because of the significance of the two proposed Corps of Engineers multi-purpose reservoirs, analyses of nutrient loadings (particularly phosphorus) from point and nonpoint sources were also conducted to assess the potential for eutrophication.

NONPOINT SOURCE ASSESSMENT: RESULTS

Determination of Loading Rates by Land Use Type

Triangle J utilized the EPA Storm Water Management Model (SWMM), modified for specific application in the study area, as a means of estimating runoff quantity and quality. Through a series of sensitivity analyses, model calibration tests, and verification checks on model runs using collected data, pollutant loading rates for land use types were established. It was concluded that nonpoint source pollution potential was closely related to density of development. On the basis of data collected in the field during the sampling program, and the loading rates generated by SWMM, it was determined the four primary land use categories listed below more accurately reflected nonpoint source pollution potential:

- Urban - predominantly Central Business District (CBD).
- Commercial - predominantly high and medium density commercial and industrial development other than CBD.
- Residential - predominantly single and multi-family residential areas.
- Rural - predominantly agricultural, forested, and associated rural development.

These land use categories and their respective pollutant loading rates are shown in Table IV-1. SWMM provided watershed (catchment) hydrographs and pollutographs (BOD, suspended solids, nitrogen, and phosphorus loadings over time) which were input to the selected receiving stream model, RECEIV II.

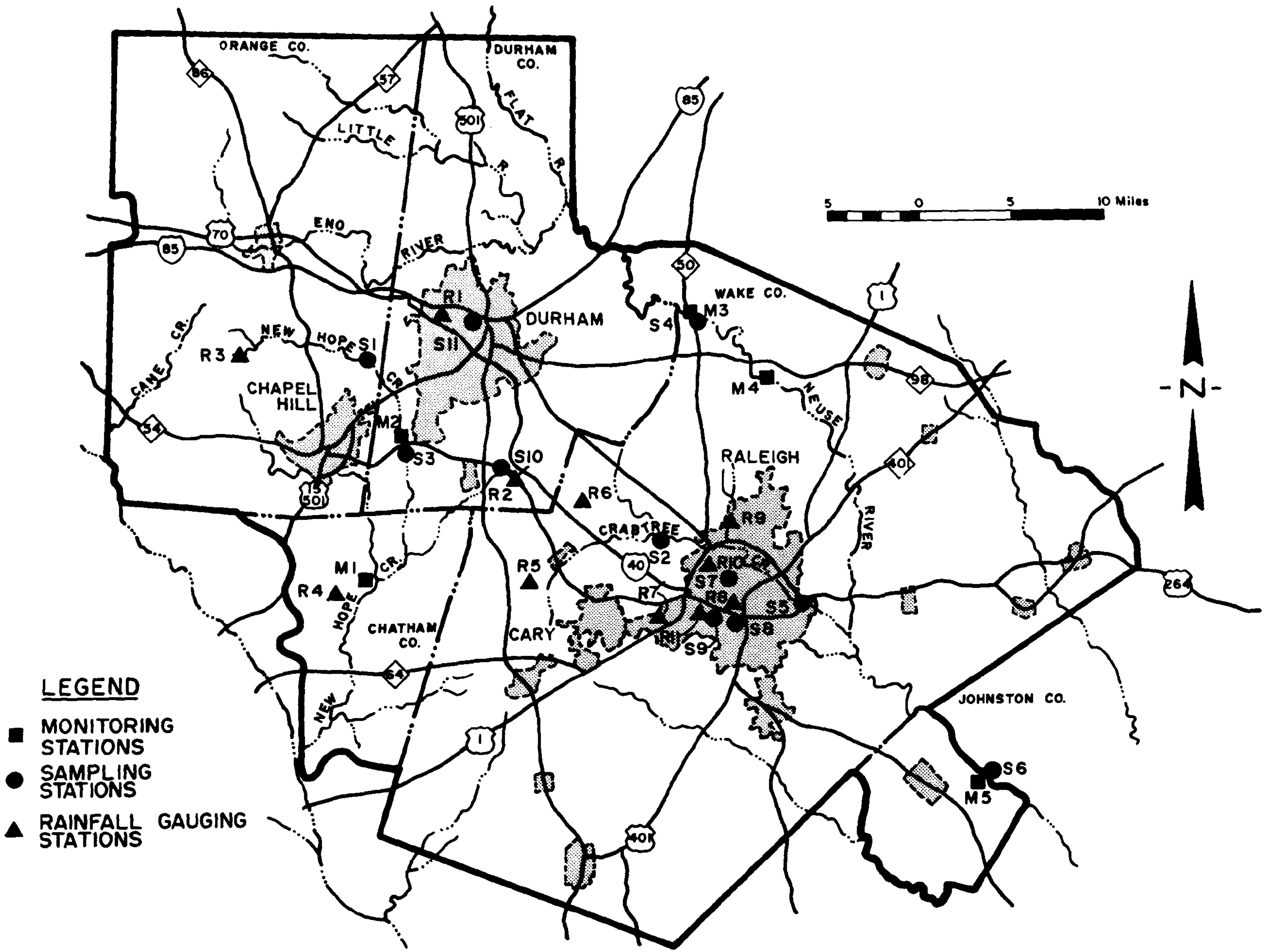


Figure IV-2. Locations of monitoring, sampling, and rainfall gauging stations

Seven major receiving streams in the planning area were modeled using RECEIV II. By using SWMM and RECEIV II, the data collected during the sampling and monitoring effort could be utilized in catchments throughout the planning area, since the models were calibrated for each of the predominant land use types.

Table IV-1.—*Pollutant loading rates developed by Triangle J for use in the Storm Water Management Model*

Land Use	Pollutant Loading Rates - lbs/acre/day			
	BOD_L	Suspended Solids	Nitrate ($x 10^{-3}$)	Phosphorus ($x 10^{-3}$)
Urban (CBD)	0.42	11.6	27.3	8.3
Commercial	0.29	21.5	26.0	9.8
Residential	0.17	18.5	15.6	4.3
Rural	0.12	15.0	8.3	3.0

Source: Triangle J Pollution Source Analysis.

Based on SWMM predictions it was determined that no single land use was responsible for generating the highest pollutant loading rates for all constituents studied. In Table IV-1 for example, it can be seen that urban land use generated the highest BOD loading rate but the lowest suspended solids loading rate. The data presented in this Table relate to the build-up of pollutants on the land and the wash-off potential to a receiving stream under a particular storm event. Other factors such as the degree of impervious surface, total area of a particular land use, hydrological characteristics of the catchment, and contribution of upstream catchments were also considered in assessing the wash-off rates and impacts of pollutants on receiving streams.

Use of Models to Predict Receiving Stream Impacts

To predict water quality throughout the study area, the region was subdivided into a number of individual catchments, each of which drained to a node point on a receiving stream. SWMM was then used to generate runoff data and pollutant loadings from these catchments. Input data on land use type and total area, loading rates for the land use, soils, topography, and various other physical characteristics were developed for each of seventy-eight catchments. For the selected design storm having a recurrence rate of about one year, runoff hydrographs, pollutographs, and average pollutant concentrations were calculated as input to the receiving stream nodes. Figure IV-3 presents the catchments modeled and the location of the nodes for the SWMM runs.

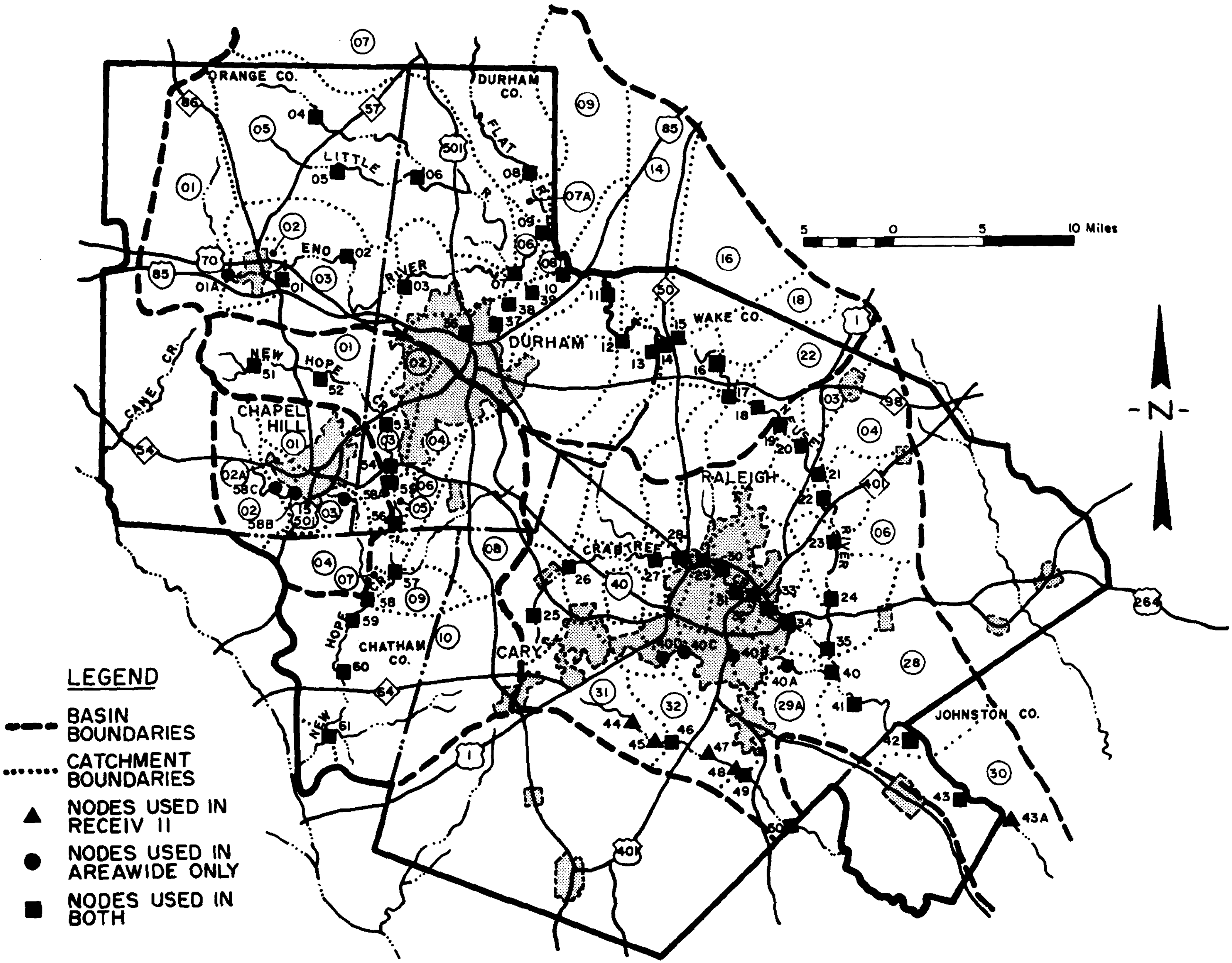


Figure IV-3. Area modeled with SWMM and RECEIV II

SWMM was run with input data for existing and future land use patterns to determine differences in loading rates and pollutant concentrations under alternative growth patterns. Table IV-2 shows output data for selected nodes on the Neuse and New Hope river systems for existing and future conditions. In almost all cases, loading rates and pollutant concentrations increased between existing and future land use conditions.

The results of the SWMM predictions related only to the characteristics of stormwater runoff from various land uses and its associated pollutant potential. To predict the impact of stormwater runoff on the water quality in receiving streams, RECEIV II was utilized. Stormwater hydrographs and pollutographs generated by SWMM were input to RECEIV II, as were pollutant contributions from point sources and various physical characteristics of the stream segments being modeled. Data from the sampling and monitoring program were used to test and calibrate the outputs of RECEIV II.

Comparison of Predicted Water Quality with Water Quality Goals

To assess the relative significance of the modeled parameters on water quality, outputs of RECEIV II were compared with preliminary 1983 water quality goals. These water quality goals were developed through extensive literature review by TJCOG staff to facilitate evaluation of water quality in the study area on the basis of existing and future conditions. With comments from State and federal agencies, university representatives, and technical groups, criteria for various constituents were established. The criteria were not viewed as rigid standards, but as preliminary water quality goals to work toward in improving the water quality in the study area. These goals are presented in Table IV-3.

By comparing the SWMM and RECEIV II modeling results and the predicted receiving stream water quality with the 1983 water quality goals, the relative magnitude of nonpoint source pollution impact on stream quality could be assessed. Because models were used, the impact of stormwater runoff from existing and future development patterns could also be assessed.

As a result of the impact of stormwater runoff, it was concluded that several 1983 water quality goals were not being met under existing land use conditions. Dissolved oxygen problems were found, but the degree of the problem was related to antecedent conditions caused by upstream point source discharges. In all cases, suspended solids were in excess of the 80 mg/l goal and exceeded 1,800 mg/l in some instances. The goal for phosphorus varies by receiving stream type and was generally not met in receiving streams above reservoirs or in reservoir systems. A relationship was observed between increases in phosphorus concentrations and increases in suspended solids levels. Lead concentrations were found to be a problem in the urban areas. With regard to the 1983 goals for temperature, nitrate nitrogen, mercury, and dissolved solids, no significant water quality problems were observed.

When future development and land use conditions were modeled, similar impacts were found. Differences were seen in the relative contributions of individual catchments because of the change in land use and associated runoff loading rates. However, the relative impact of nonpoint source contributions was seen to increase. The increased significance of nonpoint source contributions was primarily the result of general decreases in point source contribu-

Table IV-2.—*SWMM generated pollutant loads for the design storm under existing and future development patterns for selected nodes (Total load in pounds).*

NODE	BOD (x 10^4) Existing	BOD (x 10^4) Future	Suspended Solids (x 10^6) Existing	Suspended Solids (x 10^6) Future	Tot. Kjeldahl Nitrogen (x 10^2) Existing	Tot. Kjeldahl Nitrogen (x 10^2) Future	Tot. Phosphorous (x 10^2) Existing	Tot. Phosphorous (x 10^2) Future
Neuse River								
24	2.2	3.2	2.3	3.3	7.0	0.1	5.6	8.0
31	1.2	1.5	0.74	0.94	5.2	6.8	3.6	4.8
40	3.5	4.3	2.4	2.9	0.11	0.15	8.8	0.11
New Hope River								
53	2.6	2.9	1.8	1.9	8.9	9.7	6.4	7.2
57	2.7	3.4	2.1	3.4	8.5	0.11	6.8	8.6

Note: See Figure IV-3 for the locations of the nodes.

Source: Triangle J SWMM data sheets.

Table IV-3.—*Triangle J preliminary 1983 water quality goals*

Constituent	Planning Area Goal
Dissolved Oxygen	= 5.0 mg/l
Suspended Solids	≦ 80.0 mg/l
Total Phosphates as P	≦ 1.0 mg/l in free flowing streams ≦ 0.5 mg/l in streams above reservoirs ≦ 0.1 mg/l in reservoirs
Temperature	$\Delta T < 5^{o}F$, but always $< 84^{o}F$
pH	6.0 to 9.0
Nitrate-Nitrogen	≦ 10.0 mg/l
Dissolved Solids	≦ 250.00 mg/l
Mercury	≦ 0.002 mg/l
Lead	≦ 0.05 mg/l

Source: Section II, Triangle J Draft Water Quality Managment Plan.

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tions through the facilities planning process. Overall differences in pollutant concentrations between existing and future conditions throughout the region did not appear overwhelmingly significant, but in several catchments very significant increases were noted. Increases in average pollutant concentrations in certain problem catchments ranged from ten to fifty percent from existing to future conditions.

Results of Related Studies

The results of other elements of Triangle J's nonpoint source assessment program provided additional information to characterize potential water quality problems in the region. The study on the impacts of benthic resuspension during storm events, concluded that the effect of this resuspension on water quality was insignificant when compared to that of stormwater runoff. Nonpoint source phosphorus loadings to the proposed reservoirs in the region were predicted to be high and would thus increase eutrophic conditions in the reservoirs. The most significant source of phosphorus to the proposed reservoirs was determined to be from stormwater runoff which contributes approximately 65 percent of the total annual load.

The sampling and modeling efforts were found to be very useful as predictive models of pollutant loads and receiving stream water quality. Specifically, the models enabled the determination of the relative impact of nonpoint source pollution in the major receiving streams throughout the planning area. The models have become part of the TJCOG continuing evaluation process and will be used in the future to assess the impacts of proposed projects and land use changes on water quality in the planning area.

Major Nonpoint Source Problems to be Addressed by BMP's

The results of the pollution source analysis established that there were water quality problems relating specifically to nonpoint sources. The analyses related land use in the region to pollutant loading rates and, more importantly, identified water quality problems as they impacted the areas' receiving streams. Through the model output, the magnitude of the nonpoint source water quality was determined for existing and future conditions and was directly related to watersheds in the region. The relative degree of the nonpoint source problems was established by comparing the concentrations of the modeled constituents to the proposed TJCOG 1983 water quality goals.

The major nonpoint source problem identified was that of suspended solids. Additional nonpoint source problems included oxygen demanding materials, high phosphorus concentrations, and lead concentrations from urban runoff. The latter nonpoint source problems were found to be directly related to erosion and sedimentation and the resulting high concentrations of suspended solids. Through the pollution source analysis, it was clear that all man-influenced land uses contributed to the water quality impacts and that the control of either urban or rural uses alone would not enable maintenance of the water quality goals in area streams.

With these broad conclusions, and with the supporting catchment specific data, TJCOG developed a control program which reflected the need to reduce suspended solids from all man-influenced land uses. As a means of developing the program, TJCOG sought input through literature review and technical advisory committee discussions, a series of public workshops, and an analysis of the existing institutional capabilities to control nonpoint sources of pollution.

Identification and Applicability of BMP's for the Region

A wide range of best management practices was identified through the literature survey in conjunction with technical advisory committee input. An annotated list of management practices was prepared by TJCOG which assessed each practice on the basis of the effectiveness in reducing the nonpoint source loads which had been documented as problems through the sampling and modeling effort. To determine applicability, each management practice was analyzed in terms of its utility in reducing stormwater runoff and suspended solids levels, as well as other considerations such as cost and the effectiveness of the control practice. Table IV-4 lists the best management practices which were studied and indicates those which were considered applicable in the study area.

Table IV-4.—*Best management practices developed for nonpoint source pollution control by category*

Source Techniques

*Land use planning
*Minimization of stripped areas
*Buffer zones along streams and channels
*Porous pavement
*Street sweeping
Enforced solid waste controls
*Grade stabilization
*Seeding and mulching
*Terraces and diversion ditches
Seepage beds and tile fields
Aeration of lawns
Dutch drains
*Lattice blocks
*Cover crops
*Contour plowing and tillage practices
Crop rotation

Surface Transport Techniques

*Street and channel design
Protection of culvert inlets and outlets
*Grass lined waterways and outlets
*Channel stablization and stream bank protection

Collection Techniques

Roof top detention
*Detention basins (short term storage)
Retention basins (long term impoundment)

Treatment Techniques

Screening
*Gravity settling
Aeration
Chemical coagulation and flocculation
*Filtration
Chlorination

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*indicates those BMP's considered specifically applicable in the planning area.

Source: Supplementary Data Report F, Triangle J Draft 208 Plan.

These management practices were incorporated in the nonpoint source control strategy developed as a major element of the water quality management plan. For those available best management techniques, source controls and surface transport controls were assessed to be more effective and less costly than collection and treatment techniques. The modeling results indicated that the severity of nonpoint source problems did not warrant the expense of collecting and treating stormwater runoff.

In conjunction with the development of the detailed list of best management practices, a series of eight workshops was conducted throughout the region. These workshops were co-sponsored by local govenments, civic environmental groups, citizens, and special interest groups such as realtors, agribusiness representatives, soil and water conservation districts, and others. At each workshop, Triangle J staff presented the findings of the pollution source analysis with particular emphasis on how water quality problems affected the interests of those attending the particular workshop. Workshop participants were asked to draw on their own perception of water quality problems and suggest solutions to these problems. After suggestions were tallied, the group was asked to rate the effectiveness of each suggested control measure taking into account the feasibility of implementation. Although many suggestions were broad in scope, the control measures identified during these workshops were closely allied with and supported those which were developed by the staff and technical committees. The results of the workshop were compiled and incorporated as supporting information for the development of the nonpoint source control strategy in the draft Water Quality Management Plan.

The detailed best management practices list and the workshop recommendations were reviewed with regard to the magnitude of the identified nonpoint source problems and the potentials for implementing control programs. Existing and potential management systems were analyzed by TJCOG with particular emphasis on the institutional ability and legal authority to implement control mechanisms. Although the nonpoint source assessment concluded that the control of sediment was of primary importance, other nonpoint sources of pollution were identified and actions to abate these problems were also developed. The TJCOG nonpoint source control program focuses on correcting problems through existing mechanisms and strengthening those mechanisms were possible, rather than attempting to control all potential sources.

NONPOINT SOURCE PROGRAM AND IMPLEMENTATION STRATEGY

Focus of Nonpoint Source Control Program

Through the process of developing management practices applicable to the planning area, TJCOG involved groups and agencies which would have an impact on implementing the proposed nonpoint source program. In presenting the conclusions of the pollution source analysis and focusing on identified problems which were documented and supported by the modeling efforts, these groups gained an awareness of the complexities of nonpoint source problems. Further, TJCOG established the need to take immediate corrective actions on significant problems as a first step in the nonpoint source control program.

Even with the extensive sampling and monitoring program and modeling efforts, some potential nonpoint source problems could not be adequately documented by source or impact. Pesticides, for example, were not sampled for or modeled because of the sheer number of different chemicals being used in the area, variability of application rates and methods, and the lack of specific analysis techniques to identify these constituents. In some urban areas where limited street cleaning practices were in effect, the effectiveness or the resultant impacts of utilizing this BMP on stream quality could not be determined quantitatively. Conversely, suspended solids loads and associated pollutants were quantitatively determined through the pollution source analysis. The TJCOG nonpoint source control strategy, therefore, focused on specific implementation measures to reduce sedimentation and erosion; however, the control program did address other aspects of nonpoint source problems.

Proposed actions were developed for point source discharges, nonpoint source controls, management agencies, and continuing planning agency. These recommendations were presented to the technical advisory committees, special interest groups, and the 208 Steering Committee. The Steering Committee is composed of elected officials and State representatives who would be primarily responsible for implementing the nonpoint source program and other plan recommendations. Through discussion with these groups, actions to control nonpoint sources of pollution were developed which included a strengthening of existing control methods (sedimentation and erosion control ordinances) and the development of new methods (urban stormwater management legislation).

Major Actions and Implementation

Prior to publishing the TJCOG Draft Water Quality Managment Plan, each local government and other agencies who would be affected by the nonpoint source control program were given the opportunity to review the proposed program elements. In this manner, initial commitments to proceed with the various elements was gained. The Draft Water Quality Management Plan, published in December, 1976, is currently going through the final review process and, while some of the proposed actions are already being implemented, plan adoption and submission to the Governor is anticipated by May, 1977.

A prime element of the TJCOG nonpoint source program is the control of suspended solids. Enabling legislation exists in the State for local sedimentation and erosion control programs but local programs are voluntary. As a result of the water quality management program, the eleven local governments which do not have local programs have indicated they will adopt erosion control ordinances by July 1, 1977. Annual program costs range from less than $1,000 for a small town participating in a county-wide program, to over $65,000 to initiate and administer a full county-wide program. Additionally, the nonpoint source management plan calls for amendments to the State legislation which would give municipalities the authority to exercise erosion control in their extra-territorial jurisdictions.

Rural sources of sedimentation were determined to be significant contributors of suspended solids. Agrucultural activities, however, are not regulated by the State's erosion control legislation. Steps are being taken, in conjunction with the Soil Conservation Service and appropriate State agencies to encourage all active farms in the area to be brought under Conservation Management Plans with the goal of reducing soil loss to an average of four tons per acre per year. Actions include county governmental financial support to increase staffing of county Soil and Water Conservation Districts to prepare soil conservation plans for area farmers, and encouraging increased federal allocations for Soil Conservation Service efforts.

While the sedimentation control program is concerned with reducing erosion during construction, continuing management of stormwater runoff is necessary to maintain reduced suspended solids levels and associated pollutants such as phosphorus and lead. At the present time, no State program exists for stormwater management, the nonpoint source control program of TJCOG has initiated support for proposed legislation for a Comprehensive Stormwater Management Act. This legislation would focus on controlling the quantity and quality of runoff from a site after development is completed through state-local responsibility, similar to that of the existing state-wide sedimentation and erosion control legislation. In conjunction with local governments, TJCOG has proposed specific elements for such an act which include authorization for local governments to require stormwater management plans, establishing maximum runoff rates, preparation of a model ordinance with minimum standards, and fixing responsibilities and penalties for violations. Such state-wide legislation is being encouraged to the enacted by July 1, 1978.

As the assessment of pollutant loading rates from individual land uses concluded that no single land use or type of development contributed the greatest pollution potential, specific recommendations with regard to development regulations could not be supported. A variety of development regulations are in effect in the planning area. Some of the provisions, for example strict curb and gutter requirements, may not be compatible with water quality objectives. As an element of the continuing water quality management planning program and TJCOG's Regional Development Plan, these regulations will be reviewed for their potential impact on stormwater runoff.

In addition to the above actions, which have received initial support from those agencies involved, several elements of Triangle J's nonpoint source program focus on the continuing planning agency. As the continuing planning agency, Triangle J will provide technical assistance primarily to local governments on all aspects of water quality planning and management. Triangle J will monitor the implementation of the Water Quality Management Plan, including annual plan updates and continuing monitoring and evaluation of the effectiveness, costs, and benefits derived from the nonpoint source control program.

Some of the elements of Triangle J's nonpoint source management program could have been proposed in the absence of the extensive sampling, monitoring, and modeling program. This comprehensive program functioned as a demonstration effort as well as provided a means of characterizing and assessing existing and projected water quality conditions specific to the planning area. In this manner, the program enabled the development of a detailed nonpoint source data base and area-specific documentation for identified problems. Because of the extensiveness of the assessment program, govenmental and technical support of the results and the nonpoint source management plan were significantly enhanced. Additionally, the models are now operational and are functioning as a continuing planning and evaluation tool. The experiences gained and conclusions drawn as a result of the sampling, monitoring, and modeling effort have provided significant input to the TJCOG water quality management planning program and will provide useful guidance to other areas and agencies undertaking water quality management planning.