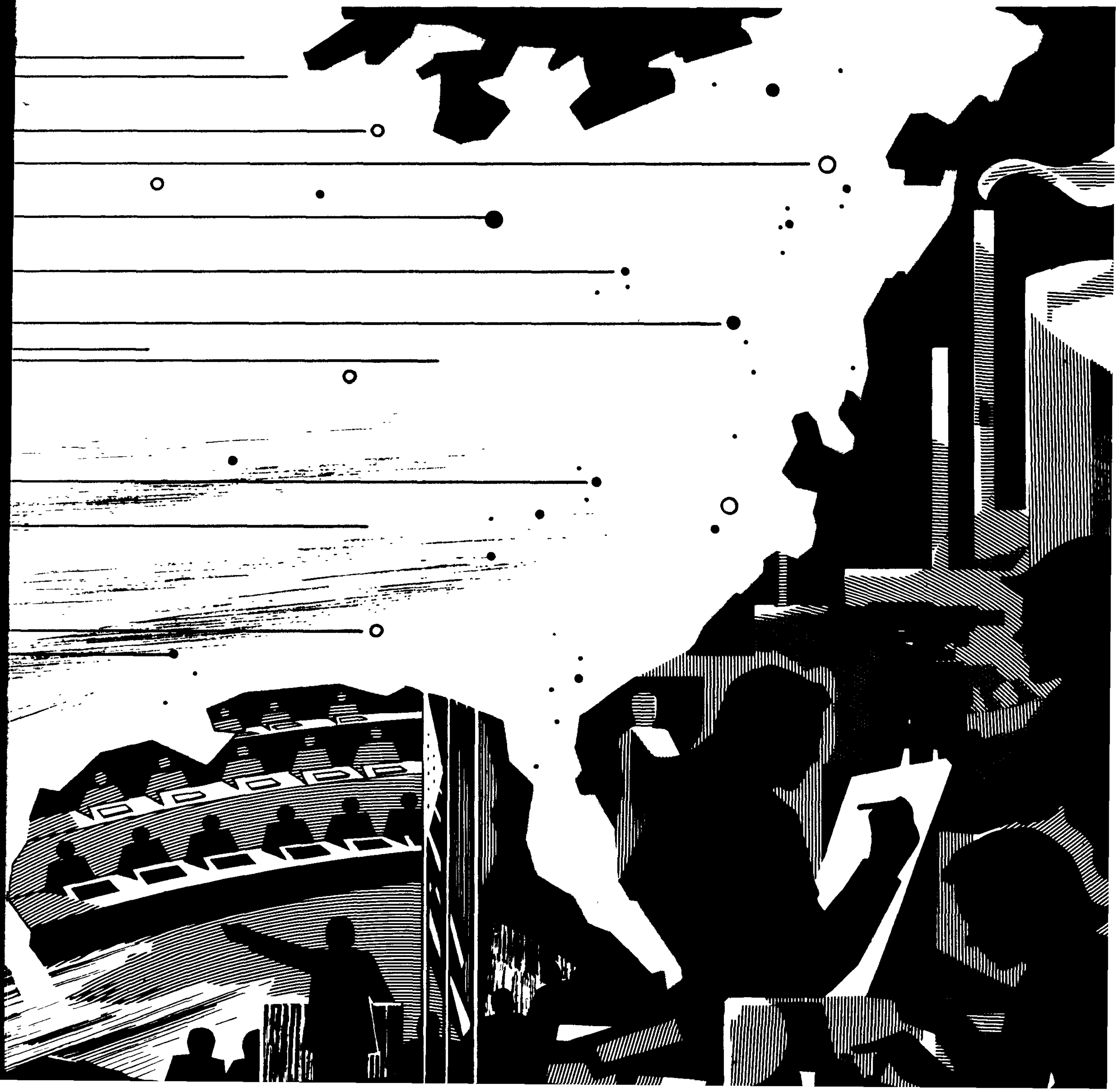
EPA-440/3-77-024

Nonpoint Source Analysis Program of Triangle J Council of Governments

A Case History in 208 Water Quality Management Planning



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NONPOINT SOURCE ANALYSIS PROGRAM OF TRIANGLE J COUNCIL OF GOVERNMENTS

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NOTICE

NONPOINT SOURCE ANALYSIS PROGRAM OF TRIANGLE J COUNCIL OF GOVERNMENTS

PROJECT SUMMARY

The Triangle J Council of Governments (TJCOG) initiated work on its water quality management planning program in May of 1974. The 1,750-square mile (4,530 km^2) planning area is located in the central Piedmont section of North Carolina. A total of 22 local government units participated in the water quality management planning process. Sixty-eight percent of the region's population is contained in a three-city urban core 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 to 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 12-month period. Automatic sampling was conducted under storm event conditions on seven watersheds, each with a predominant land use, to determine pollutant loading rates specific to each land use type. Larger watersheds with many land use types were also sampled. With the data gathered in the sampling and monitoring program and the Storm Water Management Model (SWMM), pollutant loading rates for each of four predominant land use types were determined. To assess in-stream impacts of nonpoint source pollution, loading rates and stream hydrographs for 78 catchments were given as input to the selected receiving stream model – RECEIV II. The models were run under existing and projected development patterns and the modeled parameters included BOD, suspended solids, total nitrogen, and phosphorus.

The results of the model runs were compared to 1983 water quality goals developed by the TJCOG staff 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.

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 for the planning area. These models are now operational and are serving as a continuing planning and evaluation tool for TJCOG. This comprehensive nonpoint source assessment study has produced significant input to TJCOG's areawide program. In addition, the experiences encountered and conclusions reached will aid in guiding other agencies responsible for water quality management planning.

OVERVIEW OF AREA

TJCOG is the state-designated regional planning agency for North Carolina's Region J located in the central Piedmont section. 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 Council member governments in various aspects of planning.

In 1973, the Governor designated TJCOG as the lead agency to undertake water quality management planning in the region. A total of 22 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 smaller water quality planning area are shown in Figure 1. The study zone is within the drainage area of the Neuse and Cape Fear River basins. Two multi-purpose Corps of Engineer reservoirs are proposed for the area: the B. Everett Jordan and the Falls of the Neuse, with surface water areas of 12,490 acres (5,050 ha) and 9,400 acres (3,800 ha) respectively.

Three counties (Orange, Durham, Wake) and portions of two others (Chatham and Johnston) make up the 1,750-square mile (4,530 km^2) 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.

THE NONPOINT SOURCE ASSESSMENT PROGRAM

One of the major focal points in Triangle J's water quality management program was an in-depth study of nonpoint source pollution in the region. This comprehensive effort in pollution source analysis was the first such effort conducted under the provisions of Section 208. It was designed to assess existing and projected water quality and to analyze the source, magnitude, and extent of pollution specific to the 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 modified to serve as water quality planning and evaluation tools for the region. The major objectives of the assessment program were as follows:

- Conduct sampling of streams under storm event conditions and utilize data to develop estimates of nonpoint source pollution loads for selected, representative urban and nonurban watersheds.

- Monitor specific stream reaches continuously in order to evaluate 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 locally collected data) the computer models for nonpoint source runoff and receiving stream response for the area.

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

Water Quality Sampling and Monitoring Program

An extensive sampling program was conducted over a 12-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 using six continuous 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 pro-

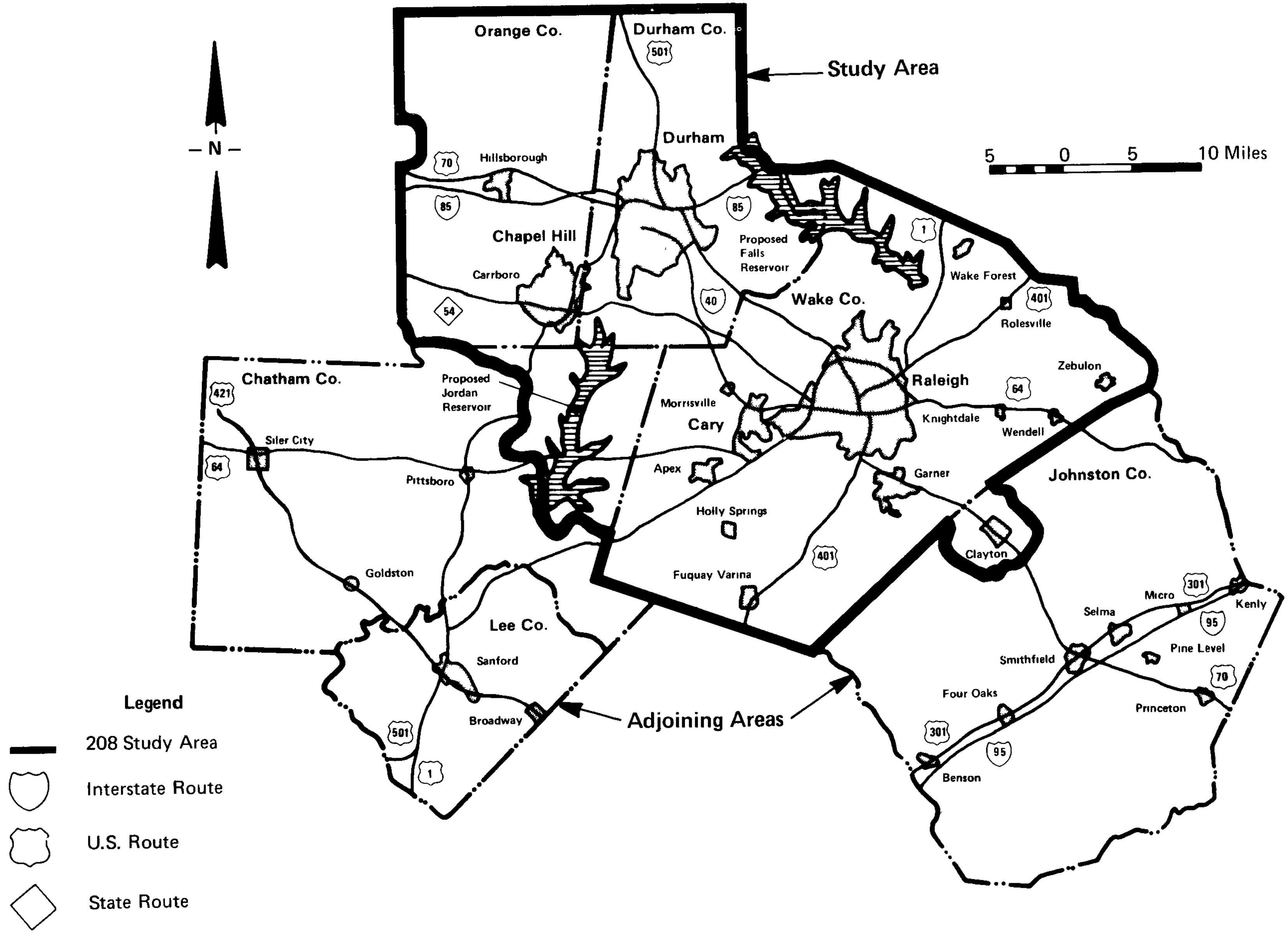

Figure 1. Triangle J Region and 208 Study Area.

vided for dissolved oxygen, temperature, pH, specific conductivity, and stream flow.

It was of particular interest in Triangle J's assessment program to establish relationships between land use, pollutant loading rates, and resultant stormwater runoff characteristics. Samples were taken in watersheds with a predominant land use by 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. Generation of this input data was critical to the application and calibration of computer models which were used in predicting pollutant loading rates and receiving stream water quality.

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 as follows: 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 (50 to 20,000 ha) for predominant land use stations and from 36,000 to 730,000 acres (14,500 to 300,000 ha) 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 location of the station, between five and eleven storm events were sampled over the 12-month period. Locations of the sampling and monitoring stations and the rainfall gauging stations are shown in Figure 2.

Related Nonpoint Source Studies

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

NONPOINT SOURCE ASSESSMENT RESULTS

Determination of Loading Rates by Land Use Type

Triangle J utilized the 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 that four primary land use categories most accurately reflected nonpoint source pollution potential. These categories are as follows:

- 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 and forest areas with associated rural development.

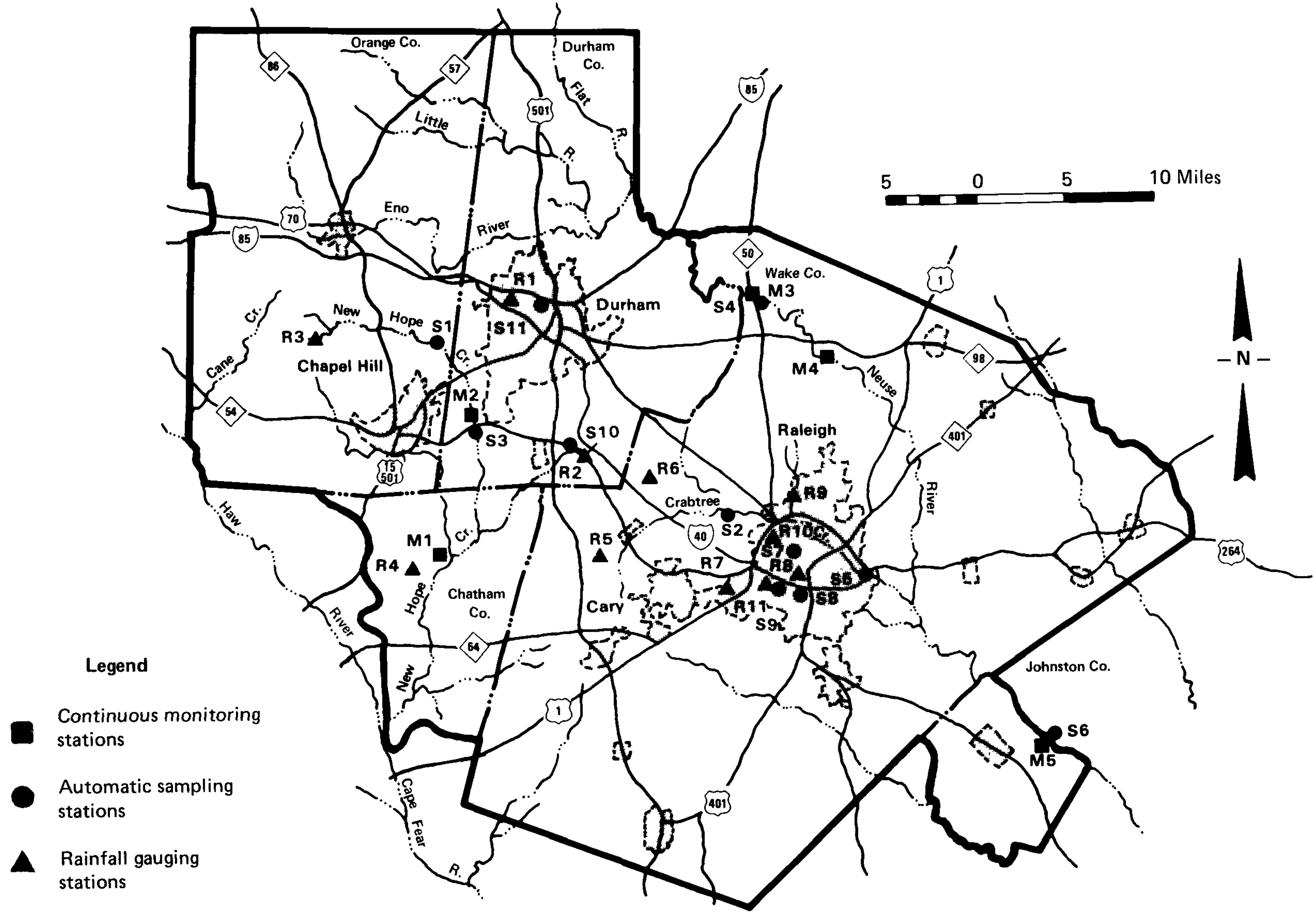

Figure 2. Locations of monitoring, sampling, and rainfall gauging stations.

These land use categories and their respective pollutant loading rates are shown in Table 1. SWMM provided watershed (catchment) hydrographs and pollutographs (BOD, suspended solids, nitrogen, and phosphorus loadings over time) which were given as input to the selected receiving stream model, RECEIV II. Seven major receiving streams were modeled by RECEIV II. With SWMM and RECEIV II, the data collected during the sampling and monitoring effort could be utilized for catchments throughout the planning area, since the models were calibrated for each of the predominant land use types.

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 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 developed relates 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 extent of impervious surface areas, 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 78 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 3 shows the catchments modeled and the location of the nodes for the SWMM runs.

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 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.

SWMM relates only to the characteristics of stormwater runoff from various land uses and its associated pollutant potential. To predict the impact of stormwater runoff on receiving streams, RECEIV II was utilized. SWMM was an input to RECEIV II. Data from the sampling and monitoring program were used to test and calibrate the outputs of RECEIV II.

To assess the relative significance of each parameter on water quality, outputs of RECEIV II were compared with the 1983

Table 1. — Pollutant loading rates based on SWMM model predictions

Land use	Pollutant loading rates (lbs/acre/day) ≈ (kg/ha/day)			
	BOD_5	Suspended Solids	Total Nitrogen	Total Phosphorus
Urban (CBD)	0.42	11.6	.027	.008
Commercial	0.29	21.5	.026	.010
Residential	0.17	18.5	.016	.004
Rural	0.12	15.0	.008	.003

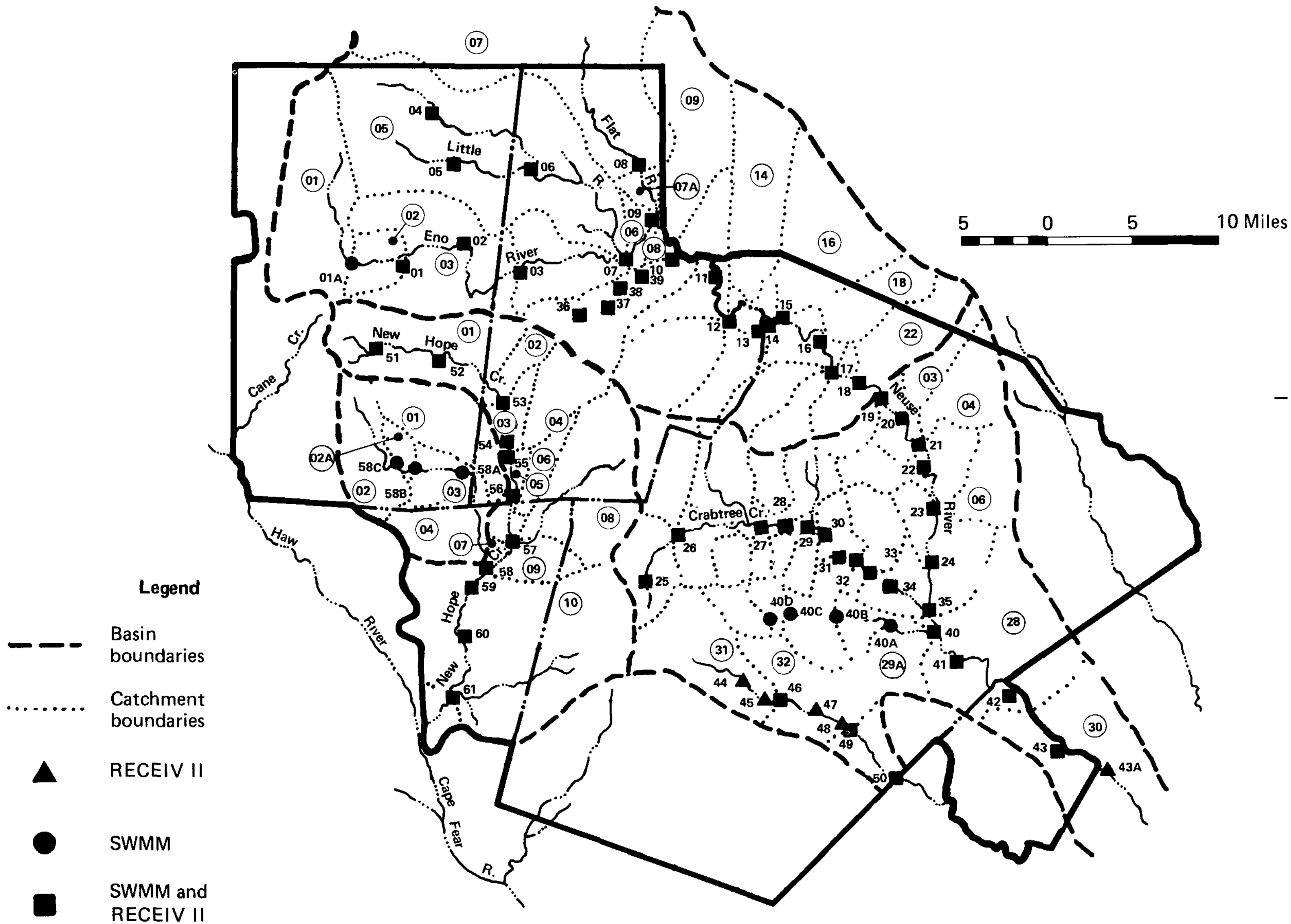

Figure 3. Area modeled with SWMM and RECEIV II.

Table 2. — SWMM-generated loads for the approximately one year design storm under existing and future development patterns (total load in lbs/kg)

Catchment	BOD (lbs/kg x 10^3)		Suspended Solids (lbs/kg x 10^3)		Total Nitrogen (lbs/kg x 10^3)		Catchment Node	Total Phosphorus (lbs/kg x 10^3)	
	Existing	Future	Existing	Future	Existing	Future		Existing	Future
Neuse River							Neuse River		
24	22/9.7	32/14.5	2300/1040	3300/1500	.70/.31	1.0/.45	24	.56/.25	.80/.36
31	12/5.4	15/6.8	740/340	940/430	.52/.23	.68/.31	31	.36/.16	.48/.23
40	35/15.8	43/19.5	2400/1090	2900/1310	.011/.004	.015/.006	40	.88/.40	1.1/.47
New Hope River							New Hope River		
53	26/11.8	29/13.1	1800/820	1900/860	.89/.40	.97/.44	53	.64/.29	.72/.33
57	27/12.2	34/15.4	2100/950	3400/1540	.85/.38	1.1/.47	57	.68/.31	.86/.39

Note: See Figure 3 for locations of the catchments.

water quality goals shown in Table 3. By comparing SWMM and RECEIV II output with these goals, the magnitude of nonpoint source loadings was assessed. It was concluded that several 1983 goals would not be met under existing land uses because of the upstream oxygen demand and phosphorus loadings.

With these broad conclusions and with specific catchment data, TJCOG developed a control program which reflected the need to reduce suspended solids from all 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 analysis of the existing institutional capabilities.

A relationship was observed between increases in suspended solids and phosphorus. Lead was projected as a potential problem. No temperature, nitrate, mercury, or dissolved solids problems were projected.

Future land development conditions were modeled. Some differences were seen in the relative contributions of individual catchments. Overall differences in pollutant concentrations between existing and future conditions did not appear startling except for a few catchments. Increases in average sediment concentrations ranged from 10 to 50 percent.

The results of other aspects of Triangle J's nonpoint source assessment program provided additional information on water quality problems. For example, the analysis of benthic material indicates that its resuspension during storm events is insignificant compared to the loading from stormwater runoff. Nonpoint source phosphorus loadings to the proposed reservoirs are predicted to effect early eutrophication. Stormwater runoff was projected to contribute approximately 65 percent of the calculated annual phosphorus load.

Identification and Applicability of Best Management Practices (BMP's) for the Region

A wide range of best management practices was identified through a literature survey and in conjunction with technical advisory committee input. An annotated list of management practices was prepared by TJCOG and each practice was assessed on the basis of effectiveness in reducing nonpoint source loads which had been documented as problems by

Table 3. — Triangle J 1983 water quality goals

Parameter	Planning goal
Dissolved Oxygen	5.0 mg/l
Suspended Solids	80 mg/l
Total Phosphorus 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	Always less than 84°F with no change 5°F above natural conditions
pH	6.0 to 9.0
Nitrate-Nitrogen as N	10 mg/l
Dissolved Solids	250 mg/l
Mercury	0.002 mg/l
Lead	0.05 mg/l

the sampling and modeling effort. 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 4 lists the BMP's which were considered applicable in the study area.

The applicable practices were incorporated in the nonpoint source control strategy as a major element of the water quality management plan. Of the available 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 developing the detailed list of BMP's, a series of eight workshops was conducted throughout the region. These workshops were co-sponsored by local governments, civic environmental groups, citizens, and special interest groups such as realtors, agri-business representatives, Soil and Water Conservation District representatives, and others. At each workshop, Triangle J staff presented 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. Input from the workshops was used as supporting information for developing the nonpoint source control strategy in the draft Water Quality Management Plan.

The detailed list of BMP's and the workshop recommendations were reviewed with regard to the magnitude of identified nonpoint source problems and the potential 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 institutional and legislative authorities and strengthening those authorities where possible, rather than attempting to control all potential sources.

Table 4. — Best management practices developed for nonpoint source pollution control

Source control	Surface transport control
Land use planning	Street and channel design
Minimization of stripped areas	Grass-lined waterways and outlets
Buffer zones along streams and channels	Channel stabilization and stream bank protection
Porous pavement	
Street sweeping	**Collection**
Grade stabilization	
Seeding and mulching	Detention basins (short term storage)
Terraces and diversion ditches	
Lattice blocks	**Treatment**
Cover crops	
Contour plowing and tillage practices	Gravity settling
	Filtration

NONPOINT SOURCE PROGRAM AND IMPLEMENTATION STRATEGY

Focus of Nonpoint Source Control Program

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

Even with extensive sampling, monitoring, and modeling, some nonpoint source problems cannot be adequately documented. Pesticides, for example, were not modeled because of the large number of different chemicals used and the cost effectiveness of pursuing sampling and analysis for this parameter.

Immediate controls were recommended for implementation if they were practical and inexpensive. Improved water quality can be expected by instituting better street sweeping, passage of ordinances, and the employment of construction site inspectors.

Major Actions and Implementation

Before the draft Water Quality Management Plan was published, all levels of government and other agencies who would be affected by the nonpoint source control program were given the opportunity to review the proposed program. Since publication of the 1977 draft Water Quality Management Plan, some of the proposed actions have already been implemented.

A prime element in TJCOG's nonpoint source program is the control of suspended solids. As a result of the water quality management study, local governments have indicated they will consider adoption of sedimentation and erosion control ordinances. Annual program costs range from less than $1,000 for a small town to over $65,000 for a countywide program.

Steps are being taken, in conjunction with the U.S. Department of Agriculture Soil Conservation Service and appropriate state agencies, to encourage all active farms in the area to develop voluntary conservation management plans to reduce soil loss to four tons per acre per year (43,500 kg/ha/yr). Related actions include securing county financial support and increasing the staff to help prepare plans for soil conservation with area farmers.

TJCOG's sedimentation and erosion control program includes erosion control during all phases of construction. Better land management of construction sites is necessary to reduce suspended solids runoff and associated pollutants, such as phosphorus and lead.

Local governments are currently providing funds and services to Triangle J who in turn will provide technical assistance to homeowners, county inspectors, etc. TJCOG will advise on all aspects of water quality management, especially operation and maintenance of individual septic systems.

Some elements in Triangle J's nonpoint source management program would not and could not have been proposed without extensive monitoring and modeling. This effort provided one way of characterizing and assessing general water quality conditions. Because of this work, local government and industry mostly supported the early implementation of the plan. These models are now functioning as an ongoing planning tool.

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