ROANOKE RIVER CORRIDOR STUDY

PHASE II

August 1990

ROANOKE RIVER CORRIDOR STUDY, PHASE II

AUGUST, 1990

This report is a joint effort of policy, technical and citizens committees, consisting of representatives from Montgomery, Roanoke, Franklin and Bedford Counties, Roanoke City, Salem, Vinton, Smith Mountain Lake Policy Advisory Board, Fifth Planning District Commission, New River Valley Planning District Commission, West Piedmont Planning District Commission, Central Virginia Planning District Commission, and twenty-two local interest groups. It was funded by a 205j grant from the Virginia Water Control Board with matching funds from the above PDCs.

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EXECUTIVE SUMMARY

Introduction

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The study area for both phases includes the Roanoke River Corridor from its headwaters in Roanoke and Montgomery Counties, through the Roanoke Valley to Hardy Ford Bridge in Bedford County. This includes primarily land parcels within 750 feet of the river floodplain. It is acknowledged that non-point source pollution often originates outside this narrow band of land along the corridor. Although it was outside the scope of this study to examine entire watersheds, an attempt was made to roughly estimate the proportion of the overall problem that originates outside the corridor study area. It is expected that a third phase can be conducted in the future that takes this analysis a step further and examines pollution contributions from entire watersheds.

Three committees were utilized for both phases of the river study. Technical Advisory Committee (TAC) representatives came from each locality, each PDC and the Smith Mountain lake Policy Advisory Board. These entities also appointed members to the Policy Advisory Committee (PAC). The Citizens Advisory Committee (CAC) worked on both technical and policy issues. The 25 CAC members represented a variety of interest groups and brought their first-hand knowledge and perspective of the river to the study.

Major Field Survey Findings

The primary purpose of this study has been to conduct a field survey in search of specific potential non-point source pollution problems along the Roanoke River. Non-point source pollution is defined by the VWCB as "any pollution whose specific point of generation and whose exact point of entry into a watercourse cannot be determined" (Urban BMP Handbook, 1979, p. i).

The following is a summary of the major findings of the Spring 1990 field surveys. As this summary includes some generalizations, the maps found in Appendix II of this report should be consulted for specific results.

1. Failure to follow Best Management Practices was found to be a major source of NPS pollution in Montgomery County. Examples include farms that are cultivated close to the river without a buffer strip and farms where livestock is allowed to graze on the riverbank or in the river. Both practices result in erosion. Such cultivation practices contribute to chemical runoff also.

2. At several places in Montgomery County, farmers have strung fences across the river to allow their livestock to pass from one side of the riverbank to another, yet stay within that farm's overall boundary. These fences catch debris during storms.

3. Poor stormwater management practices result in streambank erosion due to runoff from roads or parking areas. This is more likely to appear in the urban part of the study area than in the rural part, although it is evident throughout the corridor.

4. Illegal dumping of solid waste occurs throughout the study area but was found to be more severe in Montgomery County, which does not provide house-to-house solid waste collection. (Montgomery County does provide green boxes for its citizens.) With some exceptions, roadside litter was associated with access points; perhaps litter is frequently dumped from cars.

5. Some homeowners mow their laws up to the river's edge without leaving a buffer between the lawn and river. At numerous places, field surveyors saw evidence that grass clippings have been dumped down the riverbank.

6. Structures, such as bridges or railroad trestles, that cross the river may cause erosion depending on the way in which they are built. In some places they serve as obstructions to the river flow, causing swirling eddies that erode the riverbank during high flows.

7. Railroad tracks are frequently found adjacent to the river. In some instances, they have resulted in streambank erosion and contamination from coal or other materials falling off trains or from creosote-treated railroad ties, herbicides, etc.

8. Survey crews found numerous reminders of past floods along the Roanoke River. Flood debris is still located on riverbanks in some places throughout the study area. Much natural erosion and scouring of riverbanks can be attributed to past floods (naturally-caused erosion is not shown on the maps herein). In some cases this erosion has weakened the riverbank until even minor subsequent high waters cause increasing erosion at these weakened places.

9. Some land uses, such as industries, allow outside storage of materials close to the riverbank. Although surveyors were unable to visually determine if these materials are hazardous, past experience indicates that at least one industry adjacent to the river stores hazardous materials in drums on a concrete patio by the river. Other industries that store materials on the ground might possibly pollute the groundwater as well as surface water.

10. Public sewer lines are frequently located adjacent to the river. On one occasion, a field surveyor saw fluid leaking from sewage interceptors into the river. This was subsequently reported to the State Water Control Board and the responsible locality. At future follow-up field visits, these interceptors were not found to be leaking. Previous State Water Control Board research indicates that portions of the river are indeed affected by sewage interceptor overflows. The Water Control Board's 1990 305(b) Report gives Glade Creek as an example of an area where extensive bacterial pollution counts have occurred as a result of these overflows.

11. At some locations, the natural riverbank has been replaced by riprap or other materials. A prominent example is that of the riverbank adjacent to an industry in the urban portion of the study area.

Recommendations

Phase I of the Roanoke River Corridor Study (funded in part by the Virginia Environmental Endowment) was completed in June 1990. Phase I and Phase II utilized the same policy, technical, and advisory committees, with Phase II's time frame running three months behind that of Phase I. Although Phases I and II were funded and written separately, the advisory committees saw frequent overlapping needs in both phases. The results of each phase reinforced the needs uncovered by the other phase's research. Consequently, the recommendations included in the Phase I report apply also to the Phase II project (see Recommendation 5). Additional Phase II recommendations are noted below (see Recommendations 1-4).

1. Littering in the study area should be addressed by local governments in their solid waste management plans (required by the Virginia Department of Waste Management by July 1, 1991). Littering may be reduced by mechanisms such as:

    a. increased local government use of uniform disposal cans, such as those provided by the City of Salem to its residents;

    b. increased recycling incentives; and

    c. house-to-house collection of solid waste in rural localities now using greenboxes.

2. Continued monitoring and correction of sewage interceptor overflows should be a priority activity for the Virginia Water Control Board and applicable localities.

3. Local governments should increase enforcement efforts in regard to illegal activities, such as dumping, construction without erosion controls, unauthorized land uses, etc.

4. A non-point source pollution educational program should be undertaken focusing on urban activities that can be easily controlled by the property owner. Examples would include discouraging outside storage of industrial materials, encouraging stabilization of streambank erosion, informing homeowners of the proper disposal of yard wastes, etc. Such educational materials should be designed for the general public, but special effort should be made to specifically contact property owners in the portion of the study area where polluting activities were found during the spring 1990 field survey.

5. The Phase I report recommendations are included herein as a part of the Phase II recommendations. They are as follows:

I. Public Sector

A. Short-Term Recommendations - it is recommended that:

1. Each locality within the Roanoke River Corridor Study Area amend their Comprehensive Plans by adopting the following statements:

GOAL: To establish the Roanoke River Corridor Area, as identified in the Roanoke River Corridor Study, as an area of special environmental concern worthy of coordinated conservation efforts by all governmental jurisdictions lying within the upper Roanoke River basin.

POLICY 1: To participate in the creation of the Roanoke River Conservation District Commission by appointing the Directors of Planning Departments from each jurisdiction within the study area, and seeking the appointment of the Planning District Executive Directors for the purpose of developing a Comprehensive Roanoke River Conservation Overlay Zone that would encompass the entire corridor study area.

POLICY 2: Coordinate all proposed Comprehensive Plan or Zoning Ordinance changes which would affect the Roanoke River Conservation Overlay Zone with the Roanoke River Conservation District Commission for comment prior to their enactment.

POLICY 3: Endorse the need for better coordination and cooperation through a single non-profit conservation organization to help achieve the goals and objectives of the plan for the entire Roanoke River Basin.

2. Recommend that the provisions of the Roanoke River Conservation Overlay Zone include the following elements:

   a. Limitations on the development and use of lands lying within the Corridor Overlay Zone;

   b. Require compliance with Best Management Practices for all uses and development undertaken within the Conservation Overlay Zone in accordance with State Water Control Board and Soil and Water Conservation District handbook guidelines;

   c. Require establishment and/or retention of minimum vegetative buffer areas along the banks of the Roanoke River within the Corridor Area to stabilize the shoreline and increase filtration of nutrients and pollutants prior to their reaching the water;

   d. Require soil and erosion control measures in accordance with local Soil and Erosion Control Ordinances for all land disturbance activities that occur within the Overlay Zone;

   e. Establish performance criteria for land development planned for areas lying within the Overlay Zone; and

   f. Ensure enforcement by the zoning official within each jurisdiction of the provisions of the Overlay Zone with technical assistance from appropriate state and federal agencies and the local Soil and Water Conservation District.

3. Recommend that the Roanoke River Conservation District Commission meet on a monthly or more frequent basis until the Overlay Zone Ordinance is presented to each jurisdiction for review and adoption.

4. Establish as a time frame for preparation of the Roanoke River Conservation Overlay Zone Ordinance, a period of six months from the date of acceptance of the Roanoke River Corridor Study by each jurisdiction.

B. Long-Term Recommendations

1. Request the Parks and Recreation Departments within each jurisdiction covered by the Roanoke River Corridor Study to participate in the development of the Overlay District Ordinance with particular attention to the management of the resulting Roanoke River Greenway that would entail the following elements:

   a. Utilize the locations of areas identified as encompassing sites of conservation importance as identified in the Roanoke River Corridor Study and resulting from the implementation of the Overlay Zoning District, ranking and selecting those sites determined to be most important for preservation;

   b. Include a comprehensive recreation program that indicates public access points, future park sites, linear trail systems, etc.;

   c. Provide guidance and recommendations with respect to land and water conservation alternatives for the protection of those areas identified as worthy of protection;

   d. Promote a conservation easement program that would comply with the Overlay District Zone's conservation objectives and that would be coordinated in conjunction with the Virginia Outdoors Foundation, Division of Natural Heritage (Department of Conservation and Recreation) and the Department of Historic Resources. The easement program would be coordinated through the Roanoke River Conservation District Commission in conjunction with cooperating conservation organizations to acquire easements on land identified as being worthy of conservation;

   e. Establish an educational program for the Upper Roanoke River Basin that would focus on environmental awareness and stewardship issues. An example of which could be the "Adopt A Stream" Program which is part of the Isaac Walton League's SAVE A STREAM project.

2. Develop and Adopt an Erosion and Sediment Control Plan for the river corridor in accordance with the guidelines of the Virginia Soil and Water Conservation Board and in conjunction with participating Soil and Water Conservation Districts and seek its implementation in each jurisdiction within the study area.

3. Develop a Comprehensive Stormwater Management Plan for the Roanoke River Watershed in cooperation with Planning District Commissions, local governments and appropriate state agencies.

4. Initiate a Comprehensive Roanoke River Tributary Study, based on the Fifth Planning District Commission/Virginia Water Control Board's Tinker Creek Model, that would provide guidance to localities for land use policies and decisions encompassing these tributaries.

5. Actively encourage the study of Minimum Instream Flow criteria and standards for major Virginia Waterways by the appropriate state agencies.

6. Encourage the establishment of a mechanism for providing long-term leadership and guidance to the Roanoke River Conservation District Commission on matters relative to the Roanoke River Corridor Overlay District Zone.

II. Private Sector Policy Recommendations

A. Encourage increased coordination and cooperation among private non-profit conservation organizations in order to improve their involvement in preserving areas (sites) identified as being worthy of preservation as a result of the Overlay Zoning District.

B. Increase involvement in environmental education programs for the Roanoke River Basin that focus on environmental awareness (e.g., the Isaac Walton League's "Adopt A Stream" Program which is part of their SAVE A STREAM national project).

C. Cooperate with Parks and Recreation officials and appropriate state agencies in developing and implementing a Comprehensive Conservation Easement Program for the Roanoke River Corridor (and Basin).

D. Establish a program to monitor activities that occur within the river corridor (and basin) area that may have a deleterious impact upon the water quality of the River and Lake.

E. Act as liaison with local government officials, regional advisory committees, state and federal agencies and other conservation organizations regarding issues, policies, programs and proposed legislation relative to environmental protection of the river corridor and basin area.

INTRODUCTION

Statement of Purpose

Urban development's effects on water quality are numerous. Most of these effects relate to two things - (1) development almost always includes an increase in impervious surface that reduces percolation of stormwater and increases runoff, and (2) development often introduces pollutants into the environment, many of which enter the water supply through runoff. In other words, there is both an increase in the volume of runoff and increased pollution in that runoff. Peak discharge rates increase. Increased flows also may cause erosion and loss of vegetation. Stream channels may degrade as they attempt to accommodate increased flows. Floods become more frequent. If combined sewage and stormwater systems are used, floods may result in sewer overflows into receiving waters and even sewer backups in basements.

Of urban development's many hydrologic effects, this report primarily looks at nonpoint source pollution. As this report studies the effects of local urban land development practices on water quality, its focus is on (1) identification of specific nonpoint source pollution problems along the Roanoke River, and (2) a review of structural and nonstructural alternative solutions to these problems.

VWCB's Role in Study

This study was partially funded by a 205j grant from the Virginia Water Control Board (VWCB). The three Planning District Commissions that were involved contributed a 25% match. Much of the background material for this study came from VWCB records and reports. The authors are grateful for the VWCB's technical and financial assistance on this project.

One VWCB's report, the 1983 Water Quality Management Strategy for the Roanoke SMSA led directly to this study. That 1983 VWCB document was a biological study that looked at pollution along the river, identified priority segments, and called for further planning efforts. Of the many findings in that report, the following conclusions had special significance for this study:

> a. "there is a need to locate and identify specific nonpoint source problems, i.e., impervious areas, construction areas, litter, etc., in the priority watersheds that fall into the general land use categories of predominantly urban and

mixed land uses;"... (p. xiii)

b. "watersheds with known agricultural activities continue to demonstrate elevated aerial loads of total suspended solids and total phosphorus;"... (p. xiii)

c. "existing urban areas contribute the majority of nonpoint source runoff and the localities need to review structural solutions, nonstructural solutions and funding mechanisms for implementation in the priority watershed." (p. xiii)

In addition, the VWCB's Best Management Practices Handbooks were instrumental for this report's review of management alternatives.

Roanoke River Corridor Study, Phase I

The Roanoke River Corridor Study, Phase I (June 1990) was partially funded by the Virginia Environmental Endowment with matching funds from the Fifth Planning District Commission, Central Virginia Planning District Commission, New River Valley Planning District Commission, and West Piedmont Planning District Commission. It consists of an extensive database on the Roanoke River and policy recommendations for future management of the river. Where appropriate, the Phase I report served as a separate reference document for this study.

Other Major Resources

EPA's five-year study on runoff contributed many helpful findings to this study. The Nationwide Urban Runoff Program was an exhaustive review of runoff's effects; many of its findings are transferable to the Roanoke River Study. The Virginia Division of Soil and Water Conservation's 1989 Non-point Source Pollution Management Program and Assessment Report were helpful in identifying problem areas and possible local actions. Other resources are noted in the text.

Study Area

The study area includes the Roanoke River Corridor from its headwaters in Roanoke and Montgomery Counties, through the Roanoke Valley to Hardy Ford Bridge in Bedford County. This includes primarily land parcels within 750 feet of the river floodplain. It is acknowledged that non-point source pollution often originates outside this narrow band of land along the corridor. Although it was outside the scope of this study to examine entire watersheds, an attempt was made to roughly estimate the proportion of the overall problem that originates outside the corridor study area. It is expected that a third phase can be conducted in the future that takes this analysis a step further and examines pollution contributions from entire watersheds.

Committee Structures

The Phase I committees were utilized for this Phase II work also. Technical Advisory Committee (TAC) representatives came from each locality, each PDC and the Smith Mountain lake Policy Advisory Board. These entities also appointed members to the Policy Advisory Committee (PAC). The Citizens Advisory Committee (CAC) worked on both technical and policy issues. The 25 CAC members represented a variety of interest groups and brought their first-hand knowledge and perspective of the river to the study. The CAC members came from the following groups:

- Roanoke Valley Bird Club
- Friends of the Roanoke River
- Nature Conservancy
- Sierra Club
- Wildlife Society
- Citizens Environmental Council
- Shawsville Ruritan Club
- Smith Mountain Lake Partnership
- Salem Historical Society
- Montgomery County Forestry & Wildlife Association
- Smith Mountain Lake Assoc.
- Blue Ridge Soil and Water Conservation
- Float Fisherman
- Archaeological Society
- Clean Valley Council
- Virginia Water Project
- Citizens Task Force
- Chamber of Commerce of Salem/ Roanoke County
- League of Women Voters
- Bedford Chamber of Commerce
- Peaks of Otter Soil and Water Conservation
- Roanoke Regional Preservation Office

VIRGINIA WATER CONTROL BOARD DATA ON WATER QUALITY FOR THE ROANOKE RIVER

The Virginia Water Control Board (VWCB) is the primary agency charged with collecting information on water quality of the Roanoke River. The VWCB West Central Regional Office's latest 305(b) report was made available in April of 1990. The following information is a summary of the water quality statistics contained in the 305(b) report. It is included herein as background information for the reader:

North Fork Roanoke River

The North Fork of the Roanoke River is Effluent-Limited. Recent corrective actions in the North Fork area include movement of two discharges to off-stream locations in early 1985 (treated industrial wastewater from Federal Mogul and municipal discharges from Blacksburg-Cedar Run). Cedar Run flows into Wilson Creek, where tests have indicated that bacterial problems still exist. The VWCB 305(b) report calls for more study to ensure that the polluting influence has been corrected. In regard to total phosphorus along the North Fork, tests indicate that VWCB efforts to reduce phosphorus through use of regulating discharges have been successful. In regard to copper concentrations in edible fish samples, the VWCB assumes there is still a heavy metal problem in the North Fork. Recent tests also indicate that nickel is a persistent problem.

South Fork Roanoke River

The South Fork of the Roanoke River is also Effluent-Limited and has been designated as Put and Take Trout waters. Both Shawsville and Elliston-Lafayette wastewater treatment facilities discharge to the South Fork of the River. Monitoring stations near these discharges indicate compliance with water quality standards. The VWCB reports considerable improvement on the South Fork since the last 305(b) report period.

North Fork/South Fork Confluence to Lafayette Monitoring Station

Less than one-half mile below the confluence of the North and South Forks, a water quality station is maintained by the VWCB. Tests at this station indicate that the water quality passes the stringent standards for trout waters. At this Lafayette Gage bacterial levels were found to be half what they were during the last 305(b) reporting period. Fishing and swimming goals under the Clean Water Act are met at the Lafayette station. The VWCB puts importance upon this finding due to the population of Orangefin Madtom and the Roanoke Logperch found in portions of the North Fork, Bradshaw Creek, and

Roanoke River.

Urban River Segments to 14th Street Bridge Monitoring Station

Industrial dischargers above the 14th Street Bridge monitoring station include Roanoke Electric Steel, Koppers Company, Salem Stone, and the Norfolk Southern Railroad. In addition, this segment of the river passes through large portions of developed urban land which possibly contribute to non-point source pollution along the river. This portion of the river is classified as Water Quality Limited with a phosphorus limitation imposed. Two public water intakes for the City of Salem are found within the upper part of this segment. At the 14th Street Bridge in Roanoke, approximately 21% of the VWCB samples exceeded fecal coliform bacteria standards. Although this percentage is a decrease from previous sampling records, this segment of the river still does not meet the Clean Water Act fishable/swimmable goals. The VWCB's 305(b) report states that the fair to poor water quality at this monitoring station is typical of urban areas.

Peters Creek, Ore Branch, Lick Run, Glade Creek, Tinker Creek and Back Creek Tributaries

Although data on Peters Creek is limited, the VWCB report indicates that a biological station above the Roanoke Electric Steel discharge showed good water quality in the upper portion of the tributary. However, in 1986, the aquatic living conditions were found to be below the optimum at a point downstream from the Roanoke Electric Steel discharge.

Lick Run and Glade Creek are streams that flow into Tinker Creek. Both streams, along with Ore Branch, show extensive bacterial pollution. The largest counts are found in Glade Creek, which is reported to be effected by sewage interceptor overflows. Clean Water Act fishable/swimmable goals are not met in these tributaries.

Discharges to Tinker Creek include cooling water from Eli Lilly, along with urban runoff and sewer overflows. At Route 24, Tinker Creek shows bacterial standard violation in 33% of the samples in 1987 through 1989. This is a decrease from the 60% of standard violations in samples from 1983 through 1985. However, this portion of Tinker Creek has not met the Clean Water Act fishable/swimmable goals for at least six years according to the VWCB.

Back Creek, a heavily forested watershed, is Effluent-Limited. Shell Oil Company discharges to the stream. Coliform bacterial counts occasionally exceed state standards, possibly due to animal waste pollution.

Hardy Ford Bridge

The monitoring station at Hardy Ford Bridge is approximately seven miles downstream from the Roanoke metropolitan area. The Roanoke Regional Sewage Treatment Plant and Norfolk Southern Railroad are the major dischargers for this portion of the river. Samples indicate high concentrations of lead and zinc. The VWCB states in the 305(b) report that research should be conducted to determine the source of these metals. Their report gives as a possible explanation the likelihood that metal bearing sediments drop out of the water column where the river encounters the reservoir waters (which are moving much more slowly than the river). Fecal coliform bacterial levels at this station continue to exceed state standards.

NON-POINT SOURCE POLLUTION

Definition & General Contents

Non-point source (NPS) pollution is defined by the VWCB as "any pollution whose specific point of generation and whose exact point of entry into a water course cannot be defined" (Urban BMP Handbook, 1979, p i). This pollution can enter surface water by means of runoff after rainfall, or it can seep or percolate into the ground. As runoff moves over the land to the water channel, it takes with it numerous contaminants, such as the following common pollutants:

Pollutant	Source	Effect on Water Quality
1. Sediment	a) excessive soil erosion	a) decreases flow capacity in drainageways
	b) construction	b) takes up storage volume in reservoirs
		c) covers the bottom of waterways, which kills oxygen-producing plants and ruins spawning grounds
		d) carries along other damaging pollutants
2. Nutrients (such as phosphorus & nitrogen)	a) fertilizer washoff	a) causes excessive algae growth (which depletes dissolved oxygen needed by fish)
	b) decomposed leaves or other organic materials	
3. Pathogenic Micro-organisms (such as fecal coliforms)	a) animal droppings	a) causes health hazard until purification can be accomplished

Pollutant	Source	Effect on Water Quality
4. Toxic Substances (such as heavy metals, pesticides, other chemicals)	a) motor vehicles b) pesticide use c) industrial sources	a) causes fish kills (in high concentrations) b) enters the food chain (to cause long-term problems higher up the chain)
5. Oxygen-demanding Substances	a) organic materials that consume oxygen as they decompose (i.e., fallen leaves, grass clippings, septic tank overflows, and animal droppings)	a) causes oxygen depletion (odor, discoloration) b) causes imbalance in aquatic population
6. Petroleum Substances (such as gas, oil, and grease)	a) motor vehicles	a) coats aquatic organisms and their habitats (cuts off their oxygen supply) b) exerts an oxygen demand
7. Chlorides	a) roadway de-icing chemicals	a) causes intolerable living conditions for aquatic life

Source: VWCB, Urban BMP Handbook, 1979, pp. I-1 and I-2.

The majority of pollutants in runoff will enter the receiving waters during the "first flush". The first flush is the first portion of a storm, such as the first 3/10 inch to 1 inch of rainfall during a storm.

NATIONAL STATISTICS ON URBAN RUNOFF CHARACTERISTICS

NURP Studies

In 1978, the U.S. Environmental Protection Agency established the Nationwide Urban Runoff Program (NURP), a five-year program to examine the quality characteristics of runoff, its relation to water quality problems, and the control of pollutant loads from runoff. The 1983 NURP Final Report (Volume I, p. 2-6) explains that the NURP "was intended to be a support function which would provide information and methodologies for water quality planning efforts." The NURP accomplished this by making a detailed examination of runoff in 28 urban locations throughout the United States. A stated program objective is transferability, therefore eliminating the need for duplicative data collection efforts in localities that choose to utilize the information.

The 28 locations involved in the study are as follows:

1. Ann Arbor, Michigan
2. Austin, Texas
3. Baltimore, Maryland
4. Bellevue (Seattle Area)
5. Champaign-Urbana, Illinois
6. Coyote Creek (San Francisco Area)
7. Denver, Colorado
8. Durham, New Hampshire
9. Fresno, California
10. Irondequoit Bay (Rochester Area)
11. Kansas City
12. Knoxville, Tennessee
13. Lake Ellyn (Chicago Area)
14. Lake George
15. Lake Quinsigamond (Boston Area)
16. Lansing, Michigan
17. Little Rock, Arkansas
18. Long Island (Nassau and Suffolk Counties)
19. Milwaukee, Wisconsin
20. Myrtle Beach, South Carolina
21. Rapid City, South Dakota
22. Salt Lake City, Utah
23. SEMCOG (Detroit Area)
24. Springfield-Eugene, Oregon
25. Tampa, Florida
26. Upper Mystic (Boston Area)
27. WASHCOG (Washington, D.C. Metropolitan Area)
28. Winston-Salem, North Carolina

Because water quality problems vary from one region to another, NURP adopted this 3 point definition of a water quality problem:

- impairment or denial of beneficial uses;
- water quality criterion violation; and
- local public perception.

The NURP results are summarized below.

Standard Pollutants

The NURP database represents the results of testing done for 2,300 separate storm events at 81 in 28 different cities. Comparisons of results on runoff quality (as opposed to volume) for different land uses are shown in Table 1. This table reveals that there is a significant difference between the runoff quality for the open/nonurban category and the urban category (defined here by EPA as residential, mixed and commercial). However, EPA cautions planners against attempts to use these data to distinguish significantly different quality effects within the three urban categories. Although the NURP data cannot be used to predict a specific runoff quality from a residential site versus a commercial site, it can be used to predict runoff quality from an average urban site (this includes residential, mixed and commercial. The commercial category includes industrial parks, but not typical heavy industries). It also can be used to show that there is a significant difference between the quality of runoff from urban uses and nonurban uses.

Although it is unclear exactly how the quality of runoff will vary by urban land use, NURP includes data on how urban runoff volumes vary by land use. Table 2 shows annual urban runoff loads, based on annual rainfall, site mean pollutant concentrations, and the runoff coefficient. NURP assigned different runoff coefficients to different land use categories on the basis of sample data. Because runoff relates to the degree of imperviousness on-site, commercial uses have a higher runoff coefficient. (As noted above, the commercial category includes industrial parks but not heavy industrial uses). This table shows the far greater load (quality times quantity) that comes from commercial uses.

Table 3 shows the water quality characteristics of urban runoff. EPA notes that although there would be exceptions to any generalization, these data "are recommended for planning level purposes as the best description of the characteristics or urban runoff" (p. 6-43).

Priority Pollutants

The NURP also analyzed 121 urban runoff samples for the existence of 129 priority pollutants. Tests revealed the presence of 63 organic pollutants and 14 inorganic pollutants. These results are summarized in Table 4. This table shows some toxic metals to be present in over 90% of the samples. Organic priority pollutants were found less frequently. Nutrient loads and oxygen-demanding substances were present in smaller amounts. Total suspended solids were fairly high. Table 5 compares these sample results with the EPA water quality criteria and drinking water standards. Numerous times, the samples exceeded national standards. Whether or not an actual criteria violation occurred depends on the degree to which the runoff was diluted when it flowed into the receiving waters.

Table 1

Median EMCs For All By Land Use Category

Pollutant	Residential Median	Residential CV	Mixed Median	Mixed CV	Commercial Median	Commercial CV	Open/Nonurban Median	Open/Nonurban CV
BOD (mg/l)	10.0	0.41	7.8	0.52	9.3	0.31	-	-
COD (mg/l)	73	0.55	65	0.58	57	0.39	40	0.78
TSS (mg/l)	101	0.96	67	1.14	69	0.85	70	2.92
Total Lead (ug/l)	144	0.75	114	1.35	104	0.68	30	1.52
Total Copper (ug/l)	33	0.99	27	1.32	29	0.81	-	-
Total Zinc (ug/l)	135	0.84	154	0.78	226	1.07	195	0.66
Total Kjeldahl Nitrogen (ug/l)	1900	0.73	1288	0.50	1179	0.43	965	1.00
NO_2-N+NO_3-N (ug/l)	736	0.83	558	0.67	572	0.48	543	0.91
Total P (ug/l)	383	0.69	263	0.75	201	0.67	121	1.66
Soluble P (ug/l)	143	0.46	56	0.75	80	0.71	26	2.11

NOTE: EMC = (Storm) Event Mean Concentration (a water quality statistic based on total constituent mass discharge divided by total runoff volume).

CV = Coefficient of Variable (quantifies the variability of site characteristics within each land use category).

SOURCE: EPA, Results of the Nationwide Urban Runoff Program, Volume I, Final Report, Dec. 1983, p. 6-31.

Table 2

Annual Urban Runoff Loads KG/HA/YEAR

Constituent	Site Mean Concentration mg/l	Residential	Commercial	All Urban
Assumed Rv		0.3	0.8	0.35
TSS	180	550	1460	640
BOD	12	36	98	43
COD	82	250	666	292
Total P	0.42	1.3	3.4	1.5
Sol. P	0.15	0.5	1.2	0.5
TKN	1.90	5.8	15.4	6.6
NO_{2+3}-N	0.86	2.6	7.0	3.6
Tot. Cu	0.043	0.13	0.35	0.15
Tot. Pb	0.182	0.55	1.48	0.65
Tot. Zn	0.202	0.62	1.64	0.72

NOTES:

1. Assumes 40 inches/year rainfall as a long-term average.
2. Rv - mean runoff coefficient (the ratio of runoff volume to rainfall volume).
3. TSS - Total Suspended Solids
   BOD - Biochemical Oxygen Demand
   COD - Chemical Oxygen Demand
   Tot. P - Total Phosphorus (as P)
   Sol. P - Soluble Phosphorous (as P)
   TKN - Total Kjeldahl Nitrogen (as N)
   NO_{2+3}-N - Nitrite + Nitrate (as N)

   Tot. Cu - Total Copper
   Tot. Pb - Total Lead
   Tot. Zn - Total Zinc

Source: EPA, Results of the Nationwide Urban Runoff Program, Volume I, Final Report, December 1983, p. 6-64.

Table 3

Water Quality Characteristics of Urban Runoff

Constituent	Event to Event Variability in EMC's (Coef Var)	Site Median EMC	
		For Median Urban Site	For 90th Percentile Urban Site
TSS (mg/l)	1-2	100	300
BOD (mg/l)	0.5-1.0	9	15
COD (mg/l)	0.5-1.0	65	140
Tot. P (mg/l)	0.5-1.0	0.33	0.70
Sol. P (mg/l)	0.5-1.0	0.12	0.21
TKN (mg/l)	0.5-1.0	1.50	3.30
NO_{2+3}-N (mg/l)	0.5-1.0	0.68	1.75
Tot. Cu (ug/l)	0.5-1.0	34	93
Tot. Pb (ug/l)	0.5-1.0	144	350
Tot. Zn (ug/l)	0.5-1.0	160	500

Source: EPA, Results of the Nationwide Urban Runoff Program, Volume I, Final Report, December 1983, p. 6-43.

Table 4

Most Frequently Detected Priority Pollutants In NURP Urban Runoff Samples

Priority Pollutants Detected in 75 Percent or More of the NURP Samples

Inorganics	Organics
Lead (94%)	None
Zinc (94%)	
Copper (91%)	

Priority Pollutants Detected in 50 Percent to 74 Percent of the NURP Samples

Inorganics	Organics
Chrominum (58%)	None
Arsenic (52%)	

Priority Pollutants Detected in 20 Percent to 49 Percent of the NURP Samples

Inorganics	Organics
Cadmium (48%)	Bis (2-ethylhexyl) phthalate (22%)
Nickel (43%)	a-Hexachlorocyclohexane (20%)
Cyanides (23%)	

Priority Pollutants Detected in 10 Percent to 19 Percent of the NURP Samples

Inorganics	Organics
Antimony (13%)	a-Endosulfan (19%)
Beryllium (12%)	Pentachlorophenol (19%)
Selenium (11%)	Chlordane (17%)
	y-Hexachlorocyclohexane (Lindane) (15%)
	Pyrene (15%)
	Phenol (14%)

Priority Pollutants Detected in 10 Percent to 19 Percent of the NURP Samples (Cont'd)

Phenanthrene (12%)
Dichloromethane (methylene chloride) (11%)
4-Nitrophenol (10%)
Chrysene (10%)
Fluoranthene (16%)

NOTE: Based on 121 sample results received as of September 30, 1983, adjusted for quality control review. Does not include special metals samples.

Source: EPA, Results of the Nationwide Urban Runoff Program, Volume I, Final Report, December 1983, p. 6-51.

Table 5

Summary of Water Quality Criteria Exceedance for Pollutants Detected in At Least 10 Percent of NURP Samples: Percentage of Samples in which Pollutant Concentration Exceed Criteria[1]

POLLUTANT	Frequency of Detection (%)	Detections/ Samples[2]	Criteria Exceedances[3] None	FA	FC	OL	HH	HC[4]	DW
Pesticides									
a-Hexachlorocyclohexane	20	21/106						8.18.20	
y-Hexachlorocyclohexane (Lindane)	15	15/100			8			0.10.15	
Chlordane	17	7/42		2	17			17.17.17	
a-Endosulfan	19	9/49			10				
Metals and Inorganics									
Antimony	13	14/106	X						
Arsenic	52	45/87						52.52.52	1
Beryllium	12	11/94			6*			12.12.12	
Cadmium[5]	48	44/91		8	48		1		1
Chromium[5+6]	58	47/81			1*				1
Copper[5]	91	79/87		47	82				
Cyanides	23	16/71		3	22		4		
Lead[5]	94	75/80		23	94		73		73
Nickel[5]	43	39/91			5		21		
Selenium	11	10/88			5		10		10
Zinc[5]	94	88/94		14	77				

POLLUTANT	Frequency of Detection (%)	Detections/ Samples[2]	Criteria Exceedances[3] None	FA	FC	OL	HH	HC[4]	DW
Halogenated Aliphatics									
Methane, dichloro-	11	3/28						0.0.11	
Phenols and Cresols									
Phenol	14	13/91	X						
Phenol, pentachloro-	19	21/111		1*	11*	1			
Phenol, 4-nitro-	10	11/107	X						
PHTHALATE ESTERS									
Phthalate, bis(2-ethylhexyl)	22	15/69			22*				
POLYCYCLIC AROMATIC HYDROCARBONS									
Chrysene	10	11/109						10.10.10	
Fluoranthene	16	17/109	X						
Phenanthrene	12	13/110						12.12.12	
Pyrene	15	16/110						15.15.15	

NOTE:

* Indicates FTA or FTC value substituted where FA or FC criterion not available (see below).

1 Based on 121 sample results received as of September 30, 1983, adjusted for quality control review.

2 Number of times detected/number of acceptable samples.

NOTE: (Con'd)

3 FA = Freshwater ambient 24-hour instantaneous maximum criterion ("acute" criterion).
FC = Freshwater ambient 24-hour average criterion ("chronic" criterion).
FTA = Lowest reported freshwater acute toxic concentration. (Used only when FA is not available.)
FTC = Lowest reported freshwater chronic toxic concentration. (Used only when FC is not available.)
OL = Taste and odor (organoleptic) criterion.
HH = Non-Carcinogenic human health criterion for ingestion of contaminated water and organisms.
HC = Protection of human health from carcinogenic effects for ingestion of contaminated water and organisms.
DW = Primary drinking water criterion.

4 Entries in this column indicate exceedances of the human carcinogen value at the $10^{©5}$, $10^{©6}$, and $10^{©7}$ risk level, respectively. The numbers are cumulative, i.e., all $10^{©5}$ exceedances are included in the $10^{©6}$ exceedances, and all $10^{©6}$ exceedances are included in $10^{©7}$ exceedances.

5 Where hardness dependent, hardness of 100 mg/l $CaCO_3$ equivalent assumed.

6 Different criteria are written for the trivalent and hexavalent forms of chromium. For purposes of this analysis, all chromiums assumed to be in the less toxic trivalent form.

SOURCE: EPA, Results of the Nationwide Urban Runoff Program, Volume I, Final Report, Dec. 1983, p. 6-53.

NATIONAL FINDINGS ON EFFECT OF RUNOFF ON RECEIVING WATERS

Receiving Waters

The NURP studies described above also analyzed the effect of runoff on receiving waters. Although it is easier to generalize about the characteristics of urban runoff, the effect of this runoff is more likely to vary on a site specific basis. EPA cautions that this portion of the NURP report should be viewed as "representative estimates."

Control of the heavy metals (especially copper, lead, and zinc, discussed in previous sections) in runoff is particularly important for the protection of aquatic life. Criteria for these metals are frequently exceeded in-stream following storms. However, the NURP studies found that when exposures were intermittent and of short duration, the effect on aquatic life was not as great as might be expected. However, toxicity is influenced by regional variations in surface water hardness, thereby affecting the influence of heavy metals on aquatic life. In the south and southeast U.S. (and to a lesser extent, the northeast), heavy metals can significantly threaten aquatic life. Of the three metals noted, copper is considered to be a greater threat to aquatic life.

The NURP studies found that the organic priority pollutants in urban runoff are far less of a problem for in-stream aquatic life than are the heavy metals. Limited NURP data is available on the effect of erosion and scour. At one site northeast of Washington, D.C., such factors appeared to reduce the number of fish species, specifically the most environmentally sensitive species. At one Washington State site, sedimentation and streambed scour were found to be more harmful than pollutants, causing significant habitat changes. In Denver and Milwaukee, heavy metal concentrations were found in river sediments. Extensive fecal coliform counts were found in many of the NURP projects. EPA stated that further study is needed on sedimentation and coliforms nationwide.

Several NURP studies looked at the effect of urban runoff on lakes. They found that runoff will generally increase lake eutrophication and limit recreational use of the lake. Many of the lakes had problems with high fecal coliform counts. It was determined that most of this problem was due to sewage overflow entering the storm drainage system during major storm events.

Two NURP projects looked at how sole source aquifers are affected by the use of recharge basins for urban runoff. Both found that the percolation system is effective in keeping pollutants from reaching the groundwater. Both had a depth-to-groundwater of at least 20 feet. EPA cautions that these findings may not be transferable to areas with high water tables. Because pollutants accumulate in the soil over time, further study is needed on the total ability of the soil to filter pollutants over many years (both NURP had been in use for over 20 years).

Management Practices Evaluation

The NURP studies included limited research on the effectiveness of some management practices. Recognizing that similar tests elsewhere might vary, the NURP results lend a practical perspective to the Best Management Practices (BMPs) discussed elsewhere in this report.

EPA found that adequately designed detention basins and recharge devices were very effective, especially for removal of particulates. Street sweeping was not found to be an effective means of controlling urban runoff quality, in most cases. However, one of the NURP found that street sweeping provided some benefit in reducing runoff pollution when done just prior to that locality's rainy season. Results on grass swales were mixed. Two with swales saw no improvement in runoff quality, while a third site experienced 50 percent reduction in heavy metals and 25 percent reduction in ammonia, COD, and nitrate. EPA reports that design factors, especially infiltration enhancement, would greatly influence the effectiveness of grass swales. The use of wetlands to control urban runoff quality was only briefly studied in the NURP projects. Results were inconclusive, but EPA terms the technique as "promising".

EXISTING DEVELOPMENT PATTERNS ALONG THE ROANOKE RIVER

Volumes One and Two of Phase I of the Roanoke River Corridor Study examine the land use, aesthetic, and environmental factors related to the Roanoke River. The following information on existing development patterns is summarized from the Phase I report, which was funded in part by the Virginia Environmental Endowment.

Existing Land Use

The majority of tax parcels in the Montgomery County portion of the study area are used for agricultural or forestry purposes. Montgomery County is the only part of the study area that utilizes officially designated Agricultural/Forestal Districts. These districts, as designated under the Virginia Agricultural and Forestal Districts Act, provide for the voluntary creation of special districts in order to "protect agricultural and forestal lands as valued natural and ecological resources" and to "encourage development and improvement of ...[these] lands for the production of food and other agricultural and forestal products". The largest extent of Agricultural/Forestal District land in the study area is located along Montgomery County's Upper North Fork. This is also the part of the study area containing the greatest acreage in active agricultural production.

Agricultural activities along the North Fork include a small dairy operation, some limited cropland, and grassland farming for cattle grazing or for hay. Due to the rocky terrain, most farming takes place along the bottom land near the river where the flat terrain results in less erosion. Somewhat less farming activity occurs along Montgomery County's South Fork of the River. There are approximately 80 acres in active cropland there, as well as a small sod operation and a small dairy operation.

Other land uses along the North and South Forks of the Roanoke River in Montgomery County include small communities such as Ironto, Ellett, Alleghany Springs, and Piedmont, etc. The Blacksburg Country Club and its residential component are an example of newer developments in Montgomery County. The greatest variety of land uses within the Montgomery County portion of the corridor occur along the lower South Fork in the vicinity of Elliston, Lafayette and Shawsville. There, residential, commercial, industrial and public/semi-public uses compete with agriculture for available land along the river.

In western Roanoke County, the land use map is dominated by vacant land, residential land, and some agricultural uses. Near Glenvar, vegetables and small fruits are grown, and several nurseries and greenhouses are nearby. Hay and pastureland are also found along the river in the western part of the Roanoke Valley. A few more intensive land uses are found near Exit 39 (from Interstate 81) and near the Salem City Line. The railroad, which is considered to be industrial land use, parallels the river through much of the study area.

In Salem, large blocks of commercial, industrial, and residential uses are located along the river, especially on the northern side of the river. The land south of the river in Salem is often residential, with some agricultural land.

Moving into Roanoke City, a large mixture of land uses can be found along the Roanoke River. These include residences, intensive land uses such as industrial , and a number of public parks which use the river as a focal point.

Along the corridor, the river is most accessible for public use in Salem and Roanoke City. Moving eastward out of Roanoke City, the river becomes less accessible due to terrain. From Tinker Creek (the boundary of Roanoke City and Vinton) eastward, the primary land use adjacent to the river is the railroad.

Both north and south of the river in Bedford County, Franklin County and East Roanoke County, the land use map is dominated by agricultural, forestry, residential, and vacant land use categories. In regard to agricultural practices in these counties, most of the Bedford land is woodland, with only about 110 acres cleared and devoted to any agricultural activities (primarily pastureland and/or land for hay). There are no major dairy or beef cattle operations in this area. In Franklin County, the cultivated areas of agricultural land are used for hayland and grassland. The steep slopes in the eastern portion of the study area inhibit active farming there.

Related Land Use Considerations

Throughout the corridor area, flat terrain is often associated with both development and floodplain land. A land use survey found that a wide variety of land uses are often located within the floodplain, especially in the more urbanized portion of the study area. A prominent example of this is the railroad, an industrial use, which is quite frequently found adjacent to the river. Other industries are located within the floodplain, as are both commercial and residential uses. It is assumed that most of these uses were in place prior to current local floodplain regulations. In the outlying portions of the study area, steep bluffs have precluded intensive development at many points.

Several of the communities within the study area have utilized the river as a focal point for recreational land. Examples include the Green Hill Park in Roanoke County, and Roanoke City's series of parks, such as Wasena and Smith Park. Bike routes are found within the corridor area in Roanoke County and Montgomery County, Salem and Roanoke City. Two private recreational in Montgomery County are owned by the Nature Conservancy (Falls Ridge Preserve and the Ironto Shale Barrens). Access to these two private recreational is limited due to their valuable and rare resources. Recreational use of the river elsewhere includes canoeing and trout fishing (as some parts of the river are natural trout waters and some are stocked trout waters).

Development near the river is often dependent upon the availability of public water and sewer services. These are available at scattered within Montgomery County, with services becoming increasingly available in western Roanoke County. In both Roanoke City and Salem, almost all parcels have access to public water and sewer services, as do a portion of the land parcels near the river in Vinton. Eastward toward Hardy Ford Bridge, only limited water and sewer services are available within the corridor.

Each locality within the study area differs somewhat in its zoning and comprehensive plan guidelines. While localities might use similar category names, regulations pertaining to these districts may differ. An example is the minimum lot size in agriculture or forestry zones. These range from 15,000 square feet in Roanoke County to 8 acres in Salem. Phase I of this study included a detailed analysis of the zoning regulations and maps for the study area localities. Quite typically, it indicated that more intensive zoning categories are found in the more urbanized sections of the corridor. Two striking features of the future land use maps found in each locality's Comprehensive Plan are the variety of coding systems used by the localities and the variety of uses suggested for future development in the corridor.

NON-POINT SOURCE POLLUTION SURVEY OF THE ROANOKE RIVER

The primary purpose of this study has been to conduct a field survey in search of specific potential non-point source pollution problems along the Roanoke River. As noted earlier, non-point source pollution is defined by the VWCB as "any pollution whose specific point of generation and whose exact point of entry into a watercourse cannot be determined" (Urban BMP Handbook, 1979, p. i). As is obvious from this definition, non-point source (NPS) pollution is difficult to locate.

The Technical Advisory Committee for the study was primarily responsible for approving the field procedures used to conduct the survey. The Citizens Advisory Committee also participated in suggesting problem areas. The PDC staffs compiled the field procedure by consulting with acknowledged experts at the Virginia Water Control Board and the Soil Conservation Service. A staff member took photos of examples of non-point source pollution, and the Technical Committee met to determine how these non-point source problems would be quantified in the survey. Appendix I of this report details the NPS field survey procedures followed by the field crews.

The field surveys were conducted in the spring of 1990 by professional planners. It is acknowledged that some NPS problems might have been overlooked in the survey due to lack of visibility at some locations, although surveyors were as thorough as possible. Some sources of non-point pollution were found to be transitory. For example, the Clean Valley Council held a valleywide clean-up activity during the survey period. Therefore, some litter concentrations that were noted earlier in the survey period may no longer exist. While future surveys may not indicate that these problems continue to exist in the exact locations found in the spring of 1990, it is expected that future surveys would find the same types of problems in the same general areas.

As can be seen from the maps found in Appendix II of this report, erosion is frequently found along the riverbanks. The field survey crews attempted to distinguish between natural erosion and man-aided erosion. The survey did not note instances of purely natural erosion, these being primarily areas of the riverbank that have been scoured by high waters or rapid flows of past floods. Man-aided erosion is quite different from natural erosion and is easily distinguished during the field surveys. The erosion noted on the accompanying maps is man-aided erosion.

The field survey results indicate potential, but not proven, sources of pollution. They should be considered as a database from which localities can work toward resolving these problems. Major conclusions and suggested alternatives for dealing with NPS pollution are noted in later chapters of this report.

WATERSHED-WIDE NPS POLLUTION

The Nationwide Urban Runoff Program (NURP) data discussed in an earlier chapter of this report provides national statistics on the contents of watershed-wide runoff. It is assumed that these statistics would apply to the Roanoke River in a similar manner. Although the Roanoke River Corridor Study does not examine entire watersheds, the study's advisory committees are aware of the potential effect the entire watershed would have on the river. By limiting this study to a narrow ribbon along the river, the study group is able to examine only part of the problem. This chapter is an acknowledgement of that fact, as well as an attempt to estimate the proportion of the overall NPS problem that originates outside the corridor. It is the group's intention to eventually expand its research to include entire watersheds.

In March 1990, Camp Dresser and McKee (CDM) prepared, for the Fifth PDC, an update of their 1985 stormwater management study for the Roanoke Valley. The original study, completed in May 1985, is entitled Feasibility Study for a Roanoke Valley Comprehensive Stormwater Management Program. The 1990 Addendum to that study extensively addresses stormwater runoff quality and provides a methodology for determining NPS pollutant loads for specific watersheds. That determination would be made by examining each watershed's land use and soil characteristics to derive a rate for the watershed, shown in pounds per acre per year. CDM recommends that calculations be based on the loading factor data found in the Northern Virginia PDC's 1979 Guidebook for Screening Urban Nonpoint Pollution Management Strategies, prepared for the Metropolitan Washington COG. Jurisdictions in the Roanoke Valley are currently considering participation in a regional stormwater management plan which, if funded, would include NPS pollution load calculations such as those described above. Until that time, exact data on pollutant loads are not available for the River's watersheds.

Table 6 details the number of separate watersheds that drain into the Roanoke River from its headwaters to Hardy Ford Bridge at Smith Mountain Lake. Watersheds are further delineated by low, medium and high levels of urbanization.

Storm sewers are one indication of the potential runoff from watersheds. In 1985, Camp Dresser and McKee (CDM) investigated the availability of data on storm sewer locations in the Roanoke Valley. They found that storm sewer plans and profiles are available for the larger subdivisions in Salem and Vinton and for urban developments in Roanoke County after 1979. A more extensive storm sewer database is available for Roanoke City. For example, Table 7 contains information CDM compiled on storm sewers with diameters greater than or equal to 42 inches in

Roanoke City's watersheds. (CDM found that most storm sewers in Roanoke County, Vinton and Salem have diameters of less than 42 inches.)

While conducting the NPS field survey, the Roanoke River Corridor Study field survey team noted the location of pipes designed to discharge into the river (not including pipes that discharge below the surface of the river). These pipes have been installed in two ways -- (1) pipes that discharge water in a way that does not cause an erosion problem as the discharge flows into the river from the pipe. Examples include pipes that extend over the riverbank a sufficient distance and pipes that discharge onto grass swales or riprap. The other pipe category is (2) pipes that cause erosion problems as they discharge runoff into the river. Both types of pipes are shown on the maps found in Appendix II of this report. These maps refer only to erosion at the river end of the pipe and make no assumptions about the content of runoff that enters the pipe from other points. These pipes might come from storm sewers or licensed point dischargers. Some pipes might be blocked upstream and therefore no longer able to discharge into the river. The study group is unable to research this further at this time, although such data will be helpful in future watershed studies. See the following chapter for major conclusions derived from the survey.

Table 6
Roanoke River Tributary Watersheds by Locality & Urbanization

	Total Number of Watersheds that Drain into Study Area	Watersheds that Drain into Study Area by Amount of Urbanization		
		Low	Medium	High
Roanoke County	36	22	8	6
Salem	14	5	6	3
Roanoke City	12	4	2	6
Vinton	3	2	1	0
Montgomery County	56	56	0	0
Bedford County	5	5	0	0
Franklin County	1	1	0	0
Botetourt County	3	3	0	0

NOTE: Approximately half the above watersheds cross one or more jurisdictional boundaries.

SOURCE: Camp Dresser and McKee, Feasibility Study for a Roanoke Valley Comprehensive Stormwater Management Program, prepared for the Fifth PDC, March 1985, p. 2-3; West Piedmont PDC; Bedford County Planning Department; Montgomery County Planning Department.

Table 7
Roanoke City Storm Sewers > 42 inches in diameter

Roanoke City Watershed	Drainage Area in Roanoke City (sq. mi.)	Total Drainage Area (sq. mi.)	Storm Sewer Length in Miles
Peters Creek	4.50	9.00	0.51
Roanoke City Drainage	4.58	4.58	1.59
Lick Run	10.22	10.40	4.62
Carvin Creek	1.33	28.80	0.80
Tinker Creek	5.60	37.60	2.78
Glade Creek	2.43	32.40	0.30
Mudlick Creek	3.16	9.30	0.28
Murray Run	2.34	2.90	0.55
Ore Branch	4.10	4.10	0.89
			12.32

SOURCE: Camp Dresser and McKee, Feasibility Study for a Roanoke Valley Comprehensive Stormwater Management Program, prepared for the Fifth PDC, March 1985, p. 6-13.

MAJOR FIELD SURVEY FINDINGS

The following is a summary of the major findings of the field surveys. As this summary includes some generalizations, the accompanying maps found in Appendix II of this report should be consulted for specific results.

1. Failure to follow Best Management Practices was found to be a major source of NPS pollution in Montgomery County. Examples include farms that are cultivated close to the river without a buffer strip and farms where livestock is allowed to graze on the riverbank or in the river. Both practices result in erosion. Such cultivation practices contribute to chemical runoff also.

2. At several places in Montgomery County, farmers have strung fences across the river to allow their livestock to pass from one side of the riverbank to another, yet stay within that farm's overall boundary. These fences catch debris during storms.

3. Poor stormwater management practices result in streambank erosion due to runoff from roads or parking areas. This is more likely to appear in the urban part of the study area than in the rural part, although it is evident throughout the corridor.

4. Illegal dumping of solid waste occurs throughout the study area but was found to be more severe in Montgomery County, which does not provide house-to-house solid waste collection. (Montgomery County does provide green boxes for its citizens.) With some exceptions, roadside litter was associated with access points; perhaps litter is frequently dumped from cars.

5. Some homeowners mow their laws up to the river's edge without leaving a buffer between the lawn and river. At numerous places, field surveyors saw evidence that grass clippings have been dumped down the riverbank.

6. Structures, such as bridges or railroad trestles, that cross the river may cause erosion depending on the way in which they are built. In some places they serve as obstructions to the river flow, causing swirling eddies that erode the riverbank during high flows.

7. Railroad tracks are frequently found adjacent to the river. In some instances, they have resulted in streambank erosion and contamination from coal or other materials falling off trains or from creosote-treated railroad ties, herbicides, etc.

8. Survey crews found numerous reminders of past floods along the Roanoke River. Flood debris is still located on riverbanks in some places throughout the study area. Much natural erosion and scouring of riverbanks can be attributed to past floods (naturally-caused erosion is not shown on the maps herein). In some cases this erosion has weakened the riverbank until even minor subsequent high waters cause increasing erosion at these weakened places.

9. Some land uses, such as industries, allow outside storage of materials close to the riverbank. Although surveyors were unable to visually determine if these materials are hazardous, past experience indicates that at least one industry adjacent to the river stores hazardous materials in drums on a concrete patio by the river. Other industries that store materials on the ground might possibly pollute the groundwater as well as surface water.

10. Public sewer lines are frequently located adjacent to the river. On one occasion, a field surveyor saw fluid leaking from sewage interceptors into the river. This was subsequently reported to the State Water Control Board and the responsible locality. At future follow-up field visits, these interceptors were not found to be leaking. Previous State Water Control Board research indicates that portions of the river are indeed affected by sewage interceptor overflows. The Water Control Board's 1990 305(b) Report gives Glade Creek as an example of an area where extensive bacterial pollution counts have occurred as a result of these overflows.

11. At some locations, the natural riverbank has been replaced by riprap or other materials. A prominent example is that of the riverbank adjacent to an industry in the urban portion of the study area.

ALTERNATIVES FOR STRUCTURAL AND NONSTRUCTURAL SOLUTIONS

Extensive research has been conducted in the past on structural and nonstructural methods for dealing with NPS pollution. The primary methods that have been previously identified are noted below.

BMPs

The Virginia Water Control Board (VWCB), with assistance from numerous other agencies, developed Best Management Practices Handbooks in the late 1970s. This was part of the State 208 water quality planning effort that grew out of the Federal Water Pollution Control Act Amendments of 1972. That federal law set water quality goals to be met by 1983. The Best Management Practices (BMPs) are aimed at controlling the nonpoint source part of the pollution problem. The VWCB defines a BMP as:

> a practice, or combination of practices, that is determined by a State (or designated areawide planning agency) to be the most effective practicable means of preventing or reducing the amount of pollution generated by nonpoint sources to a level compatible with water quality goals. (VWCB, Urban Best Management Practices Handbook, 1979, p i)

BMP Handbooks were prepared for Agriculture, Forestry, Mining, Urban, Hydrologic Modifications, and Sources Affecting Groundwater. BMPs are voluntary measures that can be undertaken on individual sites or throughout a locality. The Virginia Division of Soil & Water Conservation takes a major role in the BMP implementation process.

For the purpose of this study, the agricultural and urban BMPs are most applicable (although other BMPs may need to be consulted for some cases). They include, as listed in the Urban BMP Handbook:

POLLUTION SOURCE CONTROLS
- Street Cleaning
- Solid Waste Collection and Disposal
- Vegetative Control
- Fertilizer Application Control
- Pesticide Use Control
- Reduction of Traffic-Generated Pollutants
- Highway De-icing Compound Control
- Non-point Source Pollution Control on Construction Sites

RUNOFF CONTROLS

- Urban Impoundments
- Parking Lot Storage
- Rooftop Detention
- Rooftop Runoff Disposal
- Cistern Storage
- Infiltration Pits and Trenches
- Concrete Grid and Modular Pavement
- Porous Asphalt Pavement
- Grassed Waterways, Filter Strips, and Seepage Areas

COLLECTION AND TREATMENT

- Sewer System Control
- Conveyance System Storage
- Conventional Flow Regulators
- Fluidic Flow Regulators
- Treatment

The Agricultural BMP Handbook lists the following alternatives:

EROSION AND SEDIMENT CONTROL

- Access Road
- Chiseling and Subsoiling
- Conservation Cropping System
  - Grasses and Legumes in Rotation
- Conservation Tillage
- Contour Farming
- Contouring Orchard and Other Fruit Areas
- Cover and Green Manure Crops
- Critical Area Planting
  - Agricultural Lands
  - With Ground Covers, Vines, Shrubs and Trees
  - With Bermudagrass
  - Dunes
  - Tidal Banks
  - Supplemental Guides for Critical Area Planting -- Installing Jute and Excelsior Matting
- Crop Residue Use
- Debris Basin
- Diversion
- Fencing
- Field Windbreak
- Filter Strips
- Grade Stabilization Structure
- Irrigation Water Management
- Minimum Tillage
- Mulching
- Pasture and Hayland Management
- Pasture and Hayland Planting

- Planned Grazing Systems
- Pond
- Pond Sealing or Lining
- Row Arrangement
- Streambank Protection
- Stripcropping
  - Contour
  - Field
- Subsurface Drain
- Terrace
- Water Supply Dispersal
  - With a Pipeline
  - By Spring Development
  - With a Trough or Tank
  - With a Well
- Waterway or Outlet
  - Grassed
  - Lined
- Sediment and Water Control Basin

ANIMAL WASTE AND FERTILIZER CONTROL

- Waste Management System
- Waste Application Site Selection
- Timing and Methods of Application of Animal Wastes
- Waste Storage Pond
- Waste Storage Structure
- Waste Treatment Lagoon
- Salt, Mineral and Feed Supplement site Locations
- Shade Areas
- Planned Travelways
- Transportation of Wastes
- Controlled Feed and Water Access
- Elimination of Excess Runoff Water
- Piles, Open Stack Storage and Composting
- Waste Utilization and Disposal
- Land Absorption Areas
- Disposal of Dead Animals and Poultry
- Soil Testing and Plant Analysis
- Proper Fertilizer Application
- Slow Release Fertilizers

PESTICIDES AND OTHER TOXIC SUBSTANCES CONTROL

- Alternative Pest Control Methods
- Applicator Certification
- Determination of Optimum Pest Control Practices
- Prevention of Overtreatment
- Prevention of Water Source Contamination
- Proper Application of Pesticides
- Cleaning Pesticide Application Equipment

Disposal of Unused Pesticides
Disposal of Pesticide Containers
Proper Storage of Pesticides

E&S Controls

The Urban BMP Handbook also references the erosion and sediment controls in the Virginia Erosion and Sediment Control Handbook. The VWCB considered those erosion and sediment (E&S) controls to be part of the collection of urban controls. However, the following E&S controls from the 1980 Virginia E&S Control Handbook (Virginia Soil and Water Conservation Commission) are not considered to be merely voluntary. Title 21, Chapter 1, Article 6.1 of the Code of Virginia requires that appropriate measures be taken to control erosion and sedimentation that occurs with specific land disturbing activities. Most privately-sponsored construction projects which disturb greater than 10,000 square feet of land are subject to these regulations. Developers choose from the following conservation practices in preparing their E&S Control Plan for local approval:

ROAD STABILIZATION
- Temporary Gravel Construction Entrance
- Construction Road Stabilization

SEDIMENT BARRIERS
- Straw Bale Barriers
- Silt Fence
- Brush Barrier
- Storm Drain Inlet Protection

DIKES AND DIVERSIONS
- Temporary Diversion Dike
- Temporary Fill Diversion
- Temporary Right-of-Way Diversion
- Diversion

SEDIMENT TRAPS AND BASINS
- Temporary Sediment Trap
- Temporary Sediment Basin

FLUMES
- Temporary Slope Drain
- Paved Flume

WATERWAYS AND OUTLET PROTECTION
- Stormwater Conveyance Channels
- Outlet Protection
- Riprap
- Check Dams
- Waterway Drop Structure
- Level Spreader

STREAM PROTECTION
- Vegetative Streambank Stabilization
- Structural Streambank Stabilization
- Temporary Stream Crossing

MISCELLANEOUS STRUCTURAL PRACTICES
- Subsurface Drain

SITE PREPARATION (FOR VEGETATIVE ESTABLISHMENT)
- Surface Roughening
- Topsoiling

GRASS ESTABLISHMENT
- Temporary Seeding
- Permanent Seeding
- Sodding
- Bermudagrass Sprigging

MULCHES
- Mulching

OTHER VEGETATION
- Trees, Shrubs, Vines and Ground Covers

MISCELLANEOUS VEGETATIVE PRACTICES
- Tree Preservation and Protection
- Dust Control

RECOMMENDATIONS

Phase I of the Roanoke River Corridor Study (funded in part by the Virginia Environmental Endowment) was completed in June 1990. Phase I and Phase II utilized the same policy, technical, and advisory committees, with Phase II's time frame running three months behind that of Phase I. Although Phases I and II were funded and written separately, the advisory committees saw frequent overlapping needs in both phases. The results of each phase reinforced the needs uncovered by the other phase's research. Consequently, the recommendations included in the Phase I report apply also to the Phase II project (see Recommendation 5). Additional Phase II recommendations are noted below (see Recommendations 1-4).

1. Littering in the study area should be addressed by local governments in their solid waste management plans (required by the Virginia Department of Waste Management by July 1, 1991). Littering may be reduced by mechanisms such as:

   a. increased local government use of uniform disposal cans, such as those provided by the City of Salem to its residents;

   b. increased recycling incentives; and

   c. house-to-house collection of solid waste in rural localities now using greenboxes.

2. Continued monitoring and correction of sewage interceptor overflows should be a priority activity for the Virginia Water Control Board and applicable localities.

3. Local governments should increase enforcement efforts in regard to illegal activities, such as dumping, construction without erosion controls, unauthorized land uses, etc.

4. A non-point source pollution educational program should be undertaken focusing on urban activities that can be easily controlled by the property owner. Examples would include discouraging outside storage of industrial materials, encouraging stabilization of streambank erosion, informing homeowners of the proper disposal of yard wastes, etc. Such educational materials should be designed for the general public, but special effort should be made to specifically contact property owners in the portion of the study area where polluting activities were found during the spring 1990 field survey.

5. The Phase I report recommendations are included herein as a part of the Phase II recommendations. They are as follows:

I. Public Sector

A. Short-Term Recommendations - it is recommended that:

1. Each locality within the Roanoke River Corridor Study Area amend their Comprehensive Plans by adopting the following statements:

GOAL: To establish the Roanoke River Corridor Area, as identified in the Roanoke River Corridor Study, as an area of special environmental concern worthy of coordinated conservation efforts by all governmental jurisdictions lying within the upper Roanoke River basin.

POLICY 1: To participate in the creation of the Roanoke River Conservation District Commission by appointing the Directors of Planning Departments from each jurisdiction within the study area, and seeking the appointment of the Planning District Executive Directors for the purpose of developing a Comprehensive Roanoke River Conservation Overlay Zone that would encompass the entire corridor study area.

POLICY 2: Coordinate all proposed Comprehensive Plan or Zoning Ordinance changes which would affect the Roanoke River Conservation Overlay Zone with the Roanoke River Conservation District Commission for comment prior to their enactment.

POLICY 3: Endorse the need for better coordination and cooperation through a single non-profit conservation organization to help achieve the goals and objectives of the plan for the entire Roanoke River Basin.

2. Recommend that the provisions of the Roanoke River Conservation Overlay Zone include the following elements:

   a. Limitations on the development and use of lands lying within the Corridor Overlay Zone;

   b. Require compliance with Best Management Practices for all uses and development undertaken within the Conservation Overlay Zone in accordance with State Water Control Board and Soil and Water Conservation District handbook guidelines;

   c. Require establishment and/or retention of minimum vegetative buffer areas along the banks of the Roanoke River within the Corridor Area to stabilize the shoreline and increase filtration of nutrients and pollutants prior to their reaching the water;

   d. Require soil and erosion control measures in accordance with local Soil and Erosion Control Ordinances for all land disturbance activities that occur within the Overlay Zone;

   e. Establish performance criteria for land development planned for areas lying within the Overlay Zone; and

   f. Ensure enforcement by the zoning official within each jurisdiction of the provisions of the Overlay Zone with technical assistance from appropriate state and federal agencies and the local Soil and Water Conservation District.

3. Recommend that the Roanoke River Conservation District Commission meet on a monthly or more frequent basis until the Overlay Zone Ordinance is presented to each jurisdiction for review and adoption.

4. Establish as a time frame for preparation of the Roanoke River Conservation Overlay Zone Ordinance, a period of six months from the date of acceptance of the Roanoke River Corridor Study by each jurisdiction.

B. <u>Long-Term Recommendations</u>

1. Request the Parks and Recreation Departments within each jurisdiction covered by the Roanoke River Corridor Study to participate in the development of the Overlay District Ordinance with particular attention to the

management of the resulting Roanoke River Greenway that would entail the following elements:

a. Utilize the locations of areas identified as encompassing sites of conservation importance as identified in the Roanoke River Corridor Study and resulting from the implementation of the Overlay Zoning District, ranking and selecting those sites determined to be most important for preservation;

b. Include a comprehensive recreation program that indicates public access points, future park sites, linear trail systems, etc.;

c. Provide guidance and recommendations with respect to land and water conservation alternatives for the protection of those areas identified as worthy of protection;

d. Promote a conservation easement program that would comply with the Overlay District Zone's conservation objectives and that would be coordinated in conjunction with the Virginia Outdoors Foundation, Division of Natural Heritage (Department of Conservation and Recreation) and the Department of Historic Resources. The easement program would be coordinated through the Roanoke River Conservation District Commission in conjunction with cooperating conservation organizations to acquire easements on land identified as being worthy of conservation;

e. Establish an educational program for the Upper Roanoke River Basin that would focus on environmental awareness and stewardship issues. An example of which could be the "Adopt A Stream" Program which is part of the Isaac Walton League's SAVE A STREAM project.

2. Develop and Adopt an Erosion and Sediment Control Plan for the river corridor in accordance with the guidelines of the Virginia Soil and Water Conservation Board and in conjunction with participating Soil and Water Conservation Districts and seek its implementation in each jurisdiction within the study area.

3. Develop a Comprehensive Stormwater Management Plan for the Roanoke River Watershed in cooperation with Planning District Commissions, local governments and

appropriate state agencies.

4. Initiate a Comprehensive Roanoke River Tributary Study, based on the Fifth Planning District Commission/Virginia Water Control Board's Tinker Creek Model, that would provide guidance to localities for land use policies and decisions encompassing these tributaries.

5. Actively encourage the study of Minimum Instream Flow criteria and standards for major Virginia Waterways by the appropriate state agencies.

6. Encourage the establishment of a mechanism for providing long-term leadership and guidance to the Roanoke River Conservation District Commission on matters relative to the Roanoke River Corridor Overlay District Zone.

II. Private Sector Policy Recommendations

A. Encourage increased coordination and cooperation among private non-profit conservation organizations in order to improve their involvement in preserving areas (sites) identified as being worthy of preservation as a result of the Overlay Zoning District.

B. Increase involvement in environmental education programs for the Roanoke River Basin that focus on environmental awareness (e.g., the Isaac Walton League's "Adopt A Stream" Program which is part of their SAVE A STREAM national project).

C. Cooperate with Parks and Recreation officials and appropriate state agencies in developing and implementing a Comprehensive Conservation Easement Program for the Roanoke River Corridor (and Basin).

D. Establish a program to monitor activities that occur within the river corridor (and basin) area that may have a deleterious impact upon the water quality of the River and Lake.

E. Act as liaison with local government officials, regional advisory committees, state and federal agencies and other conservation organizations regarding issues, policies, programs and proposed legislation relative to environmental protection of the river corridor and basin area.

APPENDIX I

NPS FIELD SURVEY PROCEDURES

ROANOKE RIVER CORRIDOR STUDY - PHASE II
NPS FIELD SURVEY PROCEDURES

1. Use the attached list as a guide to the types of pollution sources you might find. If you find something that is not on the list, note it under "other, please specify."

2. Use any type of field map you prefer, except for tax maps. You could use topo or aerial maps. The data will be transferred to USGS scale maps for the final report. Field maps will be turned over to the Fifth Planning District Commission for final data transfer. Final maps will show dots for eroded soil, dots for chemical runoff, etc. However, your field notes/maps should contain far more detail in case local planners want to later follow-up instances that are zoning ordinance violations. For example, your field map might show the location of occurrences numbered 1 through 50. Field notes would explain each numbered occurrence. For example: Map Dot 1- Code F (decomposing organic materials) - found under the 419 bridge behind Willow River Apartments. Appears to be debris left from past floods - mainly tree limbs. Map Dot 2 - Code O (pipe outlet with erosion control) - large concrete pipe 5 feet above river with riprap.

3. You will notice from the above example that the TAC decided to inventory all pipe outlets, regardless of where they originated from (i.e., a pipe can carry stormwater from outside the study area). Pipe outlets (items O and P on list) are divided into two categories. Item O includes outlets that have erosion controls (such as riprap, etc.) or outlets that are located so as to not cause erosion as the water flows from the pipe into the river (such as pipes that extend so far out from the bank that the runoff does not touch the bank as it drops into the river). On item P (pipe outlet - no erosion control), we are referring to pipes situated so as to allow erosion to occur when the runoff drops from the pipe to the river. A good example is a pipe outlet 10 feet above the river on a steep bank with no riprap between the outlet and the river. Remember that on items O & P, the erosion control pertains to the outlet end of the pipe. We are not making reference to any erosion controls on the stormwater entering the pipe at the other end outside the scope of this study.

   Remember that all pipe outlets should be noted, both those that cause erosion and those that do not. This is an exception to the procedure used for the other pollution sources, where we only note "problems". This exception will help us estimate the proportion of the overall pollution that comes from outside the watershed.

4. Much of the study area includes railroad tracks, which usually have creosote coatings. The text of the report will discuss this situation and its potential disadvantages. If you see a special problem relating to the railroad (such as hazardous material storage, erosion, etc.), please note it under the correct category in the list and explain it in the field notes.

5. Carry identification during survey. If property is posted for no trespassing, obtain owner permission before entering. An alternative is conducting the field survey by canoe for those parcels.

6. Some survey categories (such as construction activities without erosion controls) may be local ordinance violations. When the report is complete, all localities will receive a copy. If any locality chooses to follow-up on illegal actions, they (not this committee) are the party responsible for doing so. We are a research committee, not an enforcement group.

7. Some categories are difficult to define. If you have questions on how to define some occurrences, the TAC can give guidance at their next meeting. The quantification of erosion and litter was discussed at the February 28, 1990 TAC (sample photos show the level at which these occurrences qualify for inclusion on the map).

CHECKLIST OF POTENTIAL NON-POINT POLLUTION SOURCES

Runoff From:

A. Animal holding/management areas

B. Bridge construction

C. Chemical runoff (pesticides, fertilizer, creosote, etc.)

D. Construction activities without erosion controls

E. Crop production

F. Decomposing organic materials

G. Dysfunctional septic systems

H. Eroded soil

I. Feed lots

J. Forestry activities

K. Highway maintenance runoff

L. Land disposal of sludge, wastewater, etc.

M. Landfills

N. Litter concentrations

O. Pipe outlet with erosion control

P. Pipe outlet - no erosion controls

Q. Mining activities

R. Motor vehicle runoff

S. Removal of riparian vegetation

T. Sewer system infiltration or overflow

U. Storage container/tank leaks or spills

V. Streambank modification/destabilization

W. Undetermined surface runoff

X. Other, please specify

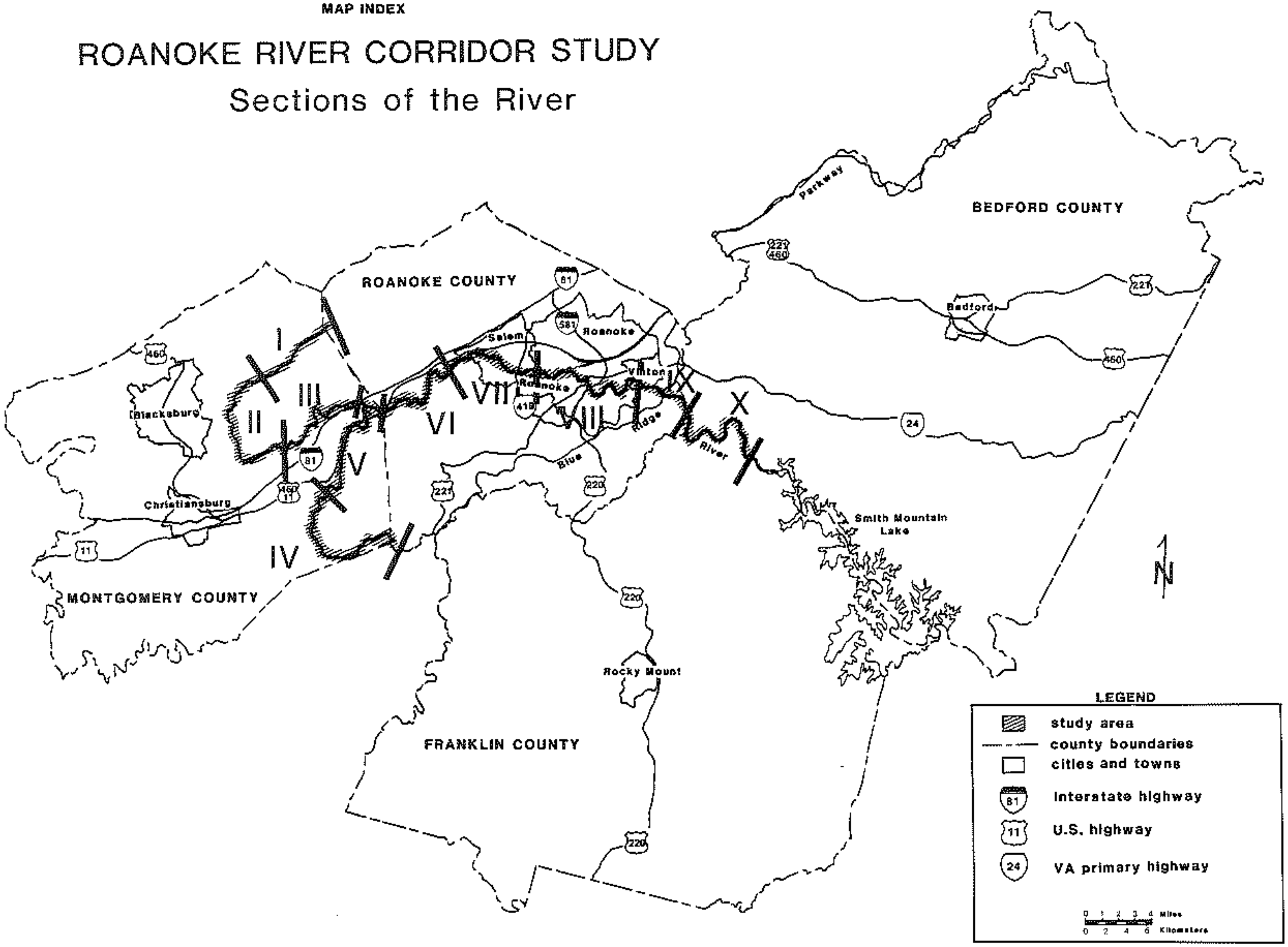
APPENDIX II

NPS FIELD SURVEY MAPS

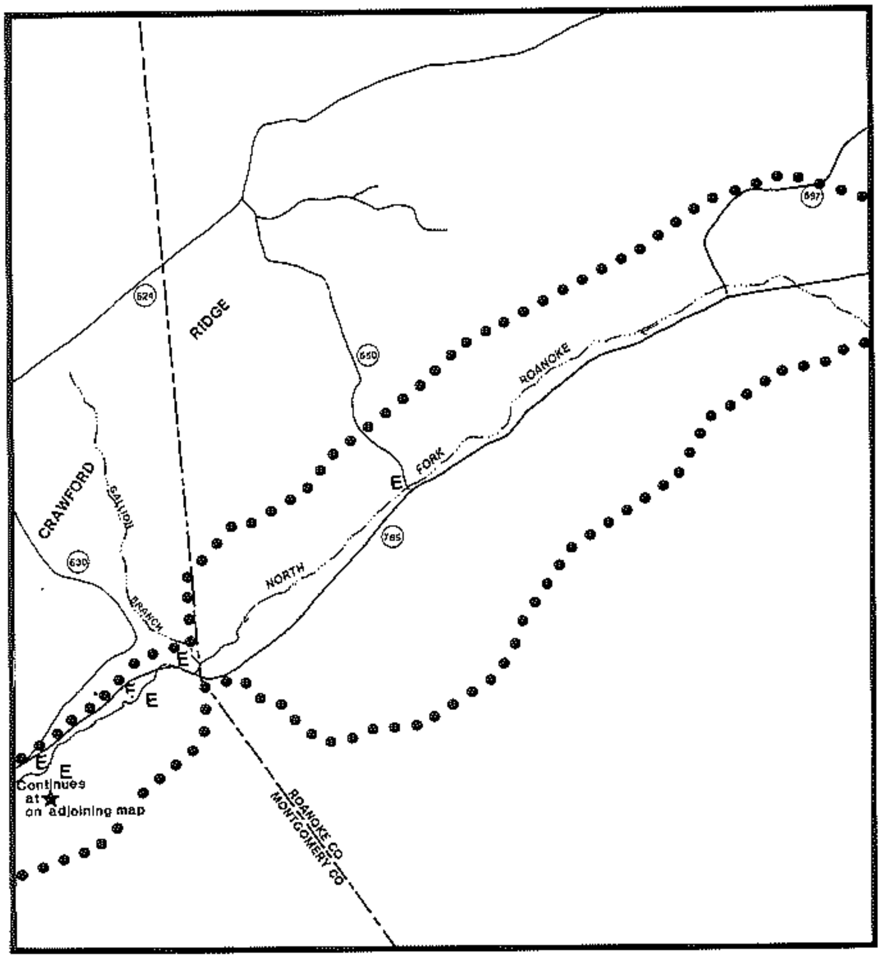
MAP INDEX

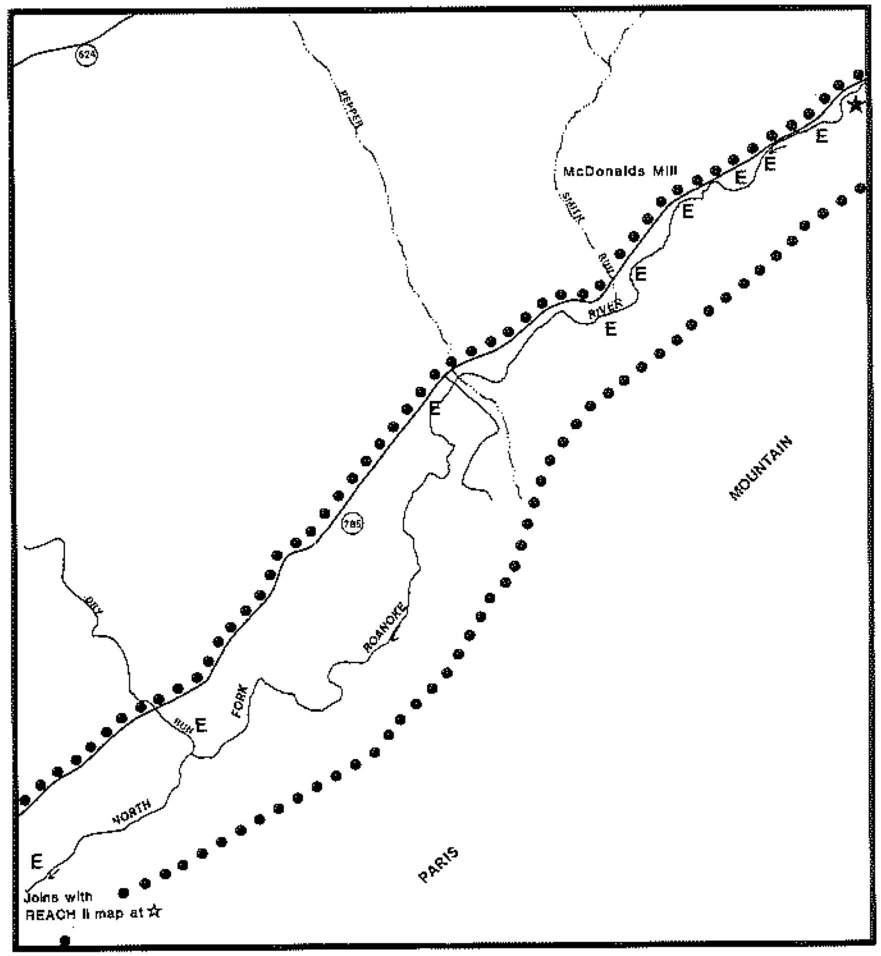
ROANOKE RIVER CORRIDOR STUDY

Sections of the River



PREPARED BY: Fifth Planning District Commission (Field Survey-1990)





REACH I (Roanoke & Montgomery Counties)
ROANOKE RIVER CORRIDOR STUDY

0 ½ 1 MILE

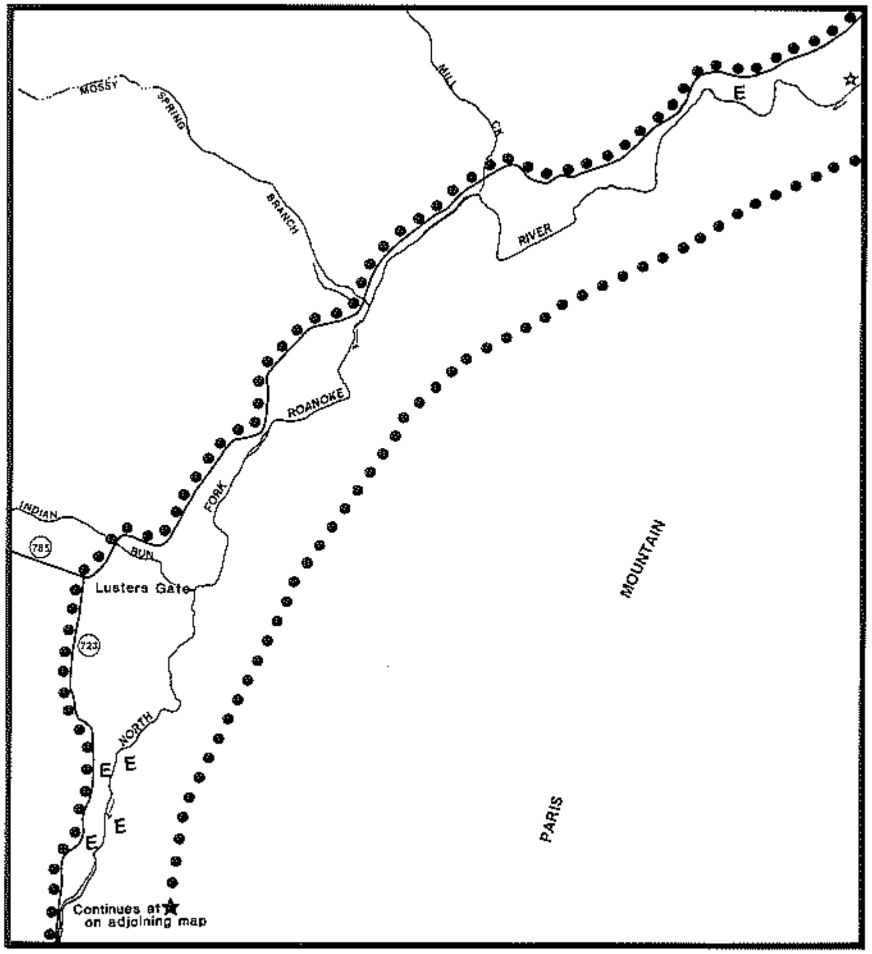
N

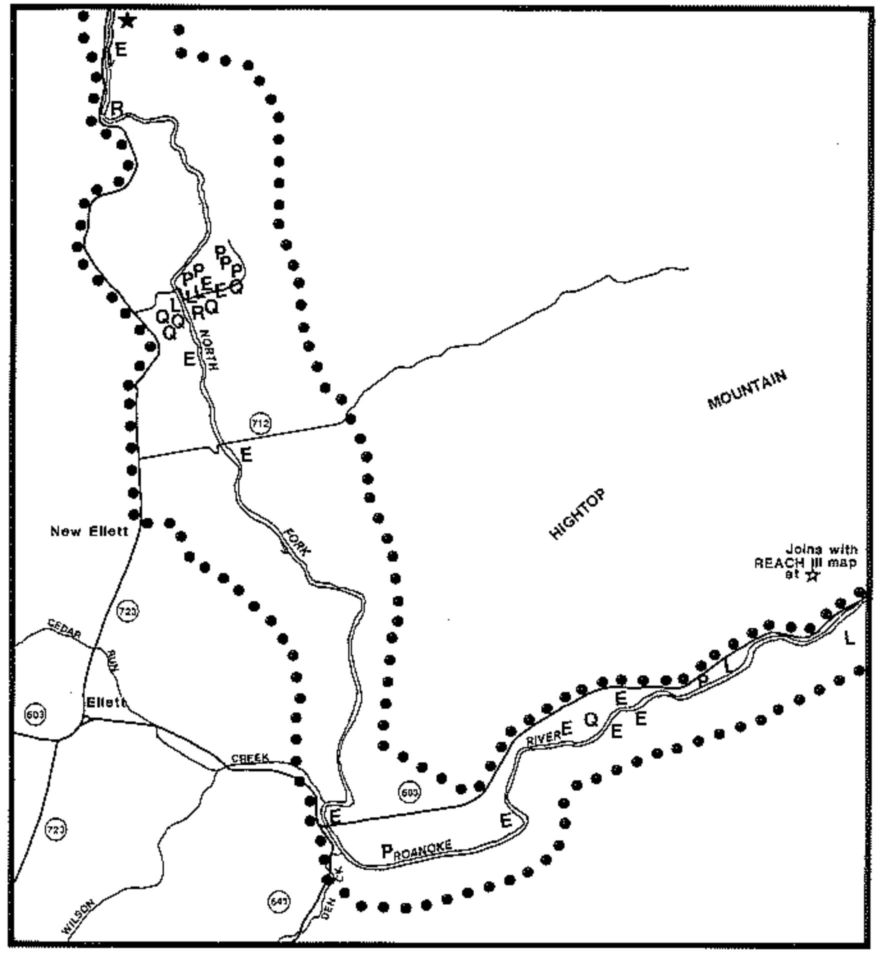
● ● STUDY AREA BOUNDARY

LEGEND:

- D - Decomposing Organic Materials
- E - Erosion
- L - Litter Concentration
- R - Removal of Streambank Vegetation
- S - Sewage Interceptor Overflows

- P - Pipe Outlet With Erosion Controls
- Q - Pipe Outlet Without Erosion Controls





REACH II (Montgomery County)
ROANOKE RIVER CORRIDOR STUDY

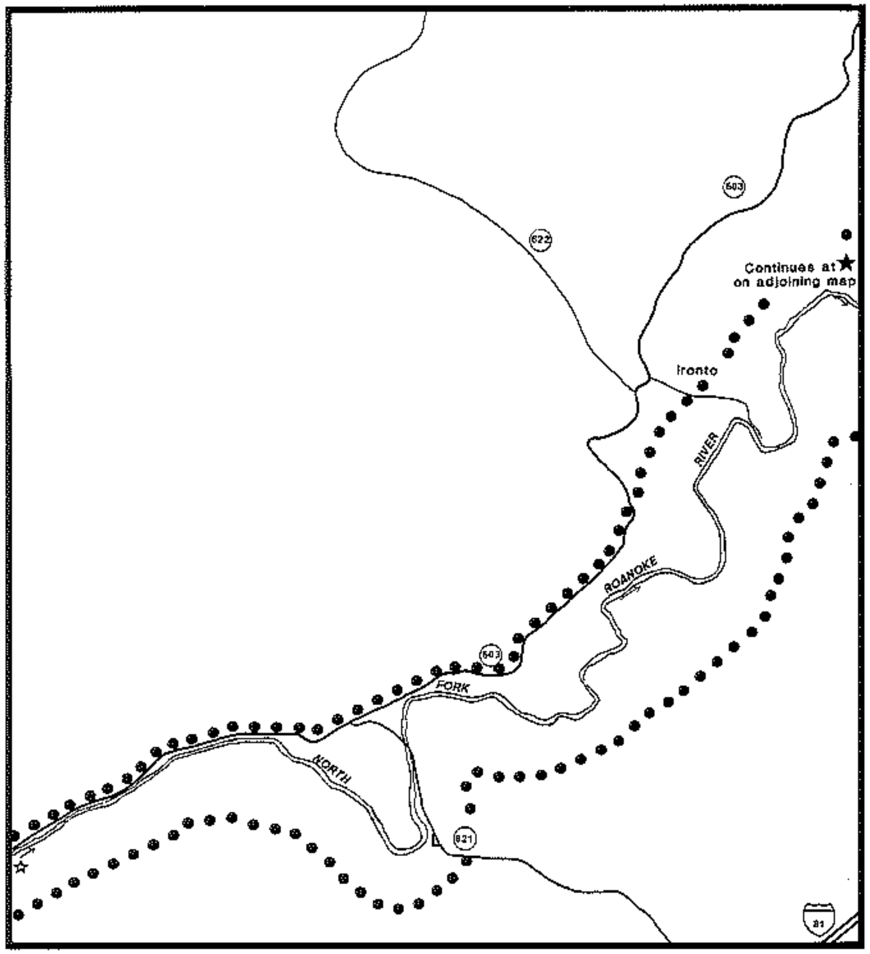
0 ½ 1 MILE

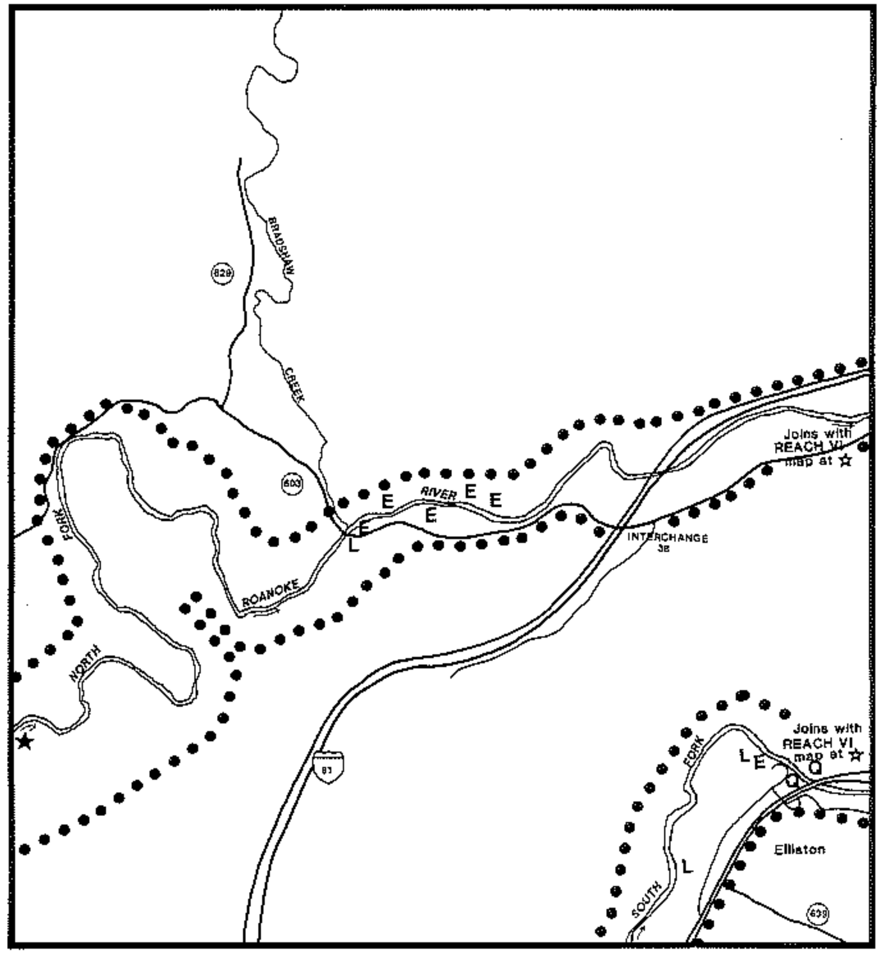
N

● ● STUDY AREA BOUNDARY

LEGEND:
D - Decomposing Organic Materials
E - Erosion
L - Litter Concentration
R - Removal of Streambank Vegetation
S - Sewage Interceptor Overflows

P - Pipe Outlet With Erosion Controls
Q - Pipe Outlet Without Erosion Controls





LEGEND:
D - Decomposing Organic Materials
E - Erosion
L - Litter Concentration
R - Removal of Streambank Vegetation
S - Sewage Interceptor Overflows

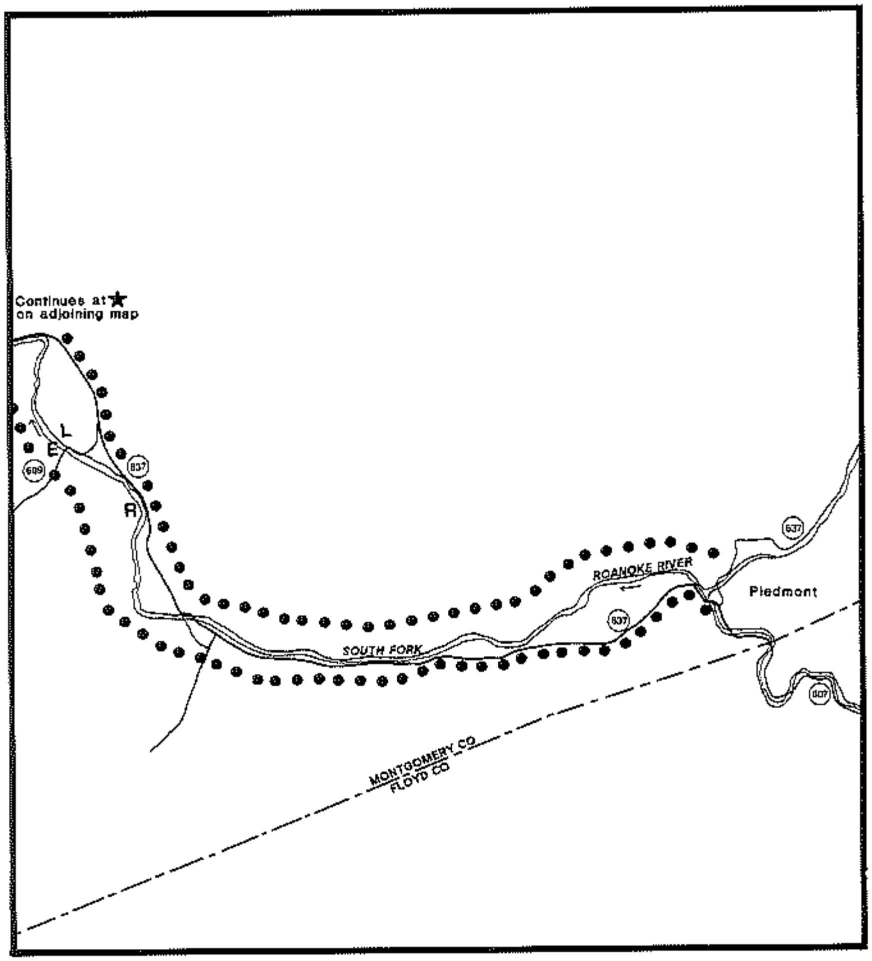
P - Pipe Outlet With Erosion Controls
Q - Pipe Outlet Without Erosion Controls

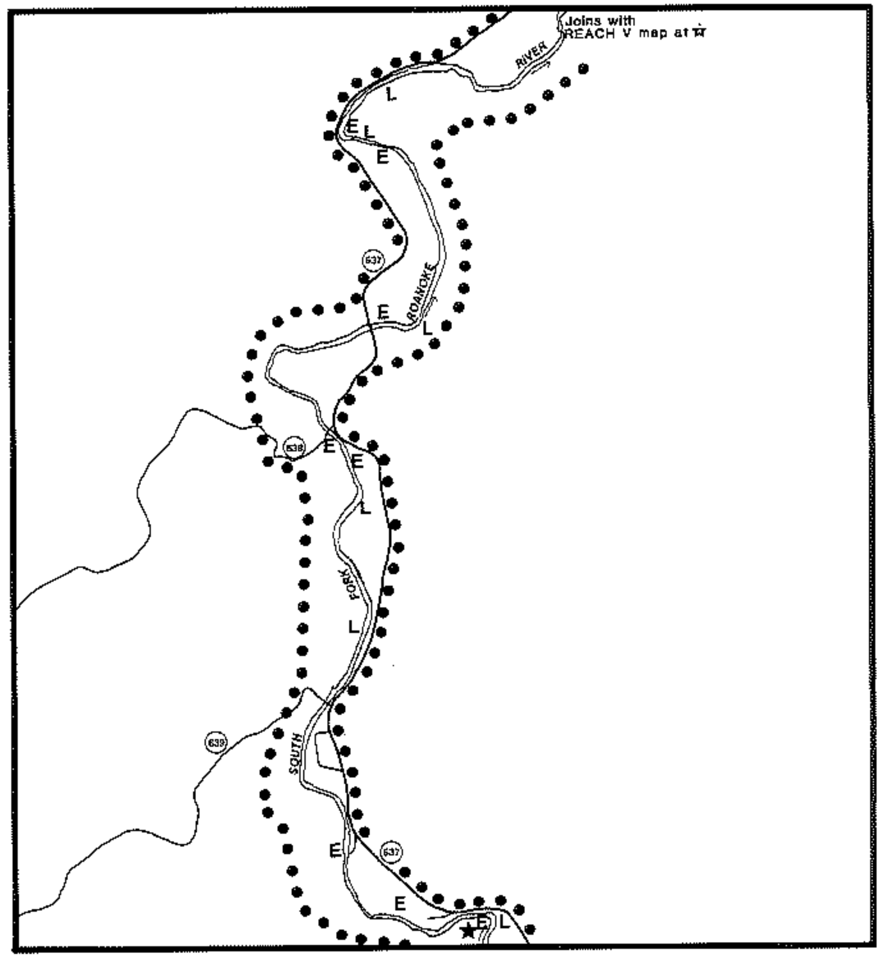
REACH III (Montgomery County)
ROANOKE RIVER CORRIDOR STUDY

0 ½ 1 MILE

N

● ● STUDY AREA BOUNDARY





REACH IV (Montgomery County)
ROANOKE RIVER CORRIDOR STUDY

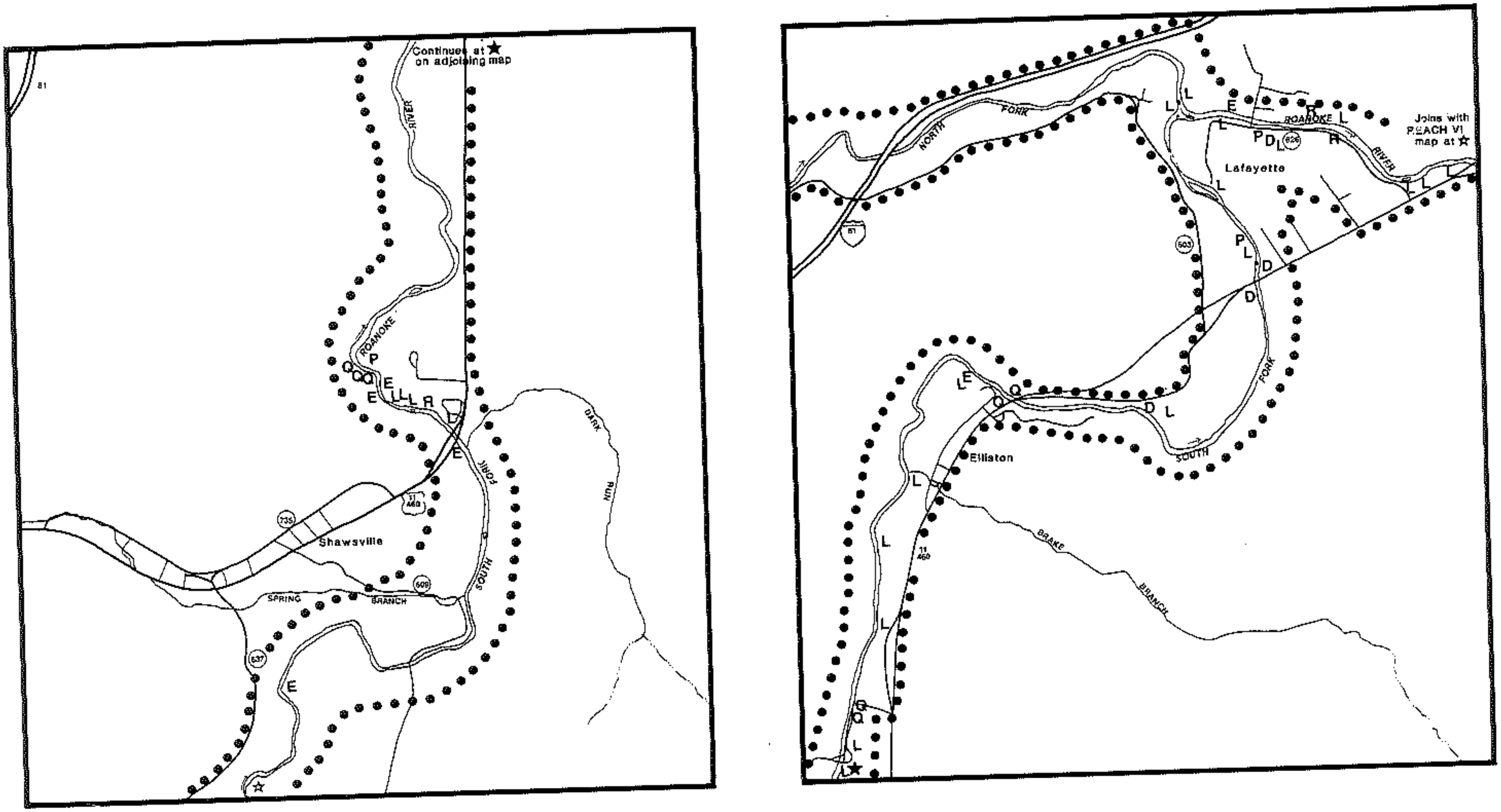
0 ½ 1MILE

N

● ● STUDY AREA BOUNDARY

LEGEND:
D - Decomposing Organic Materials
E - Erosion
L - Litter Concentration
R - Removal of Streambank Vegetation
S - Sewage Interceptor Overflows

P - Pipe Outlet With Erosion Controls
Q - Pipe Outlet Without Erosion Controls



REACH V (Montgomery County)
ROANOKE RIVER CORRIDOR STUDY

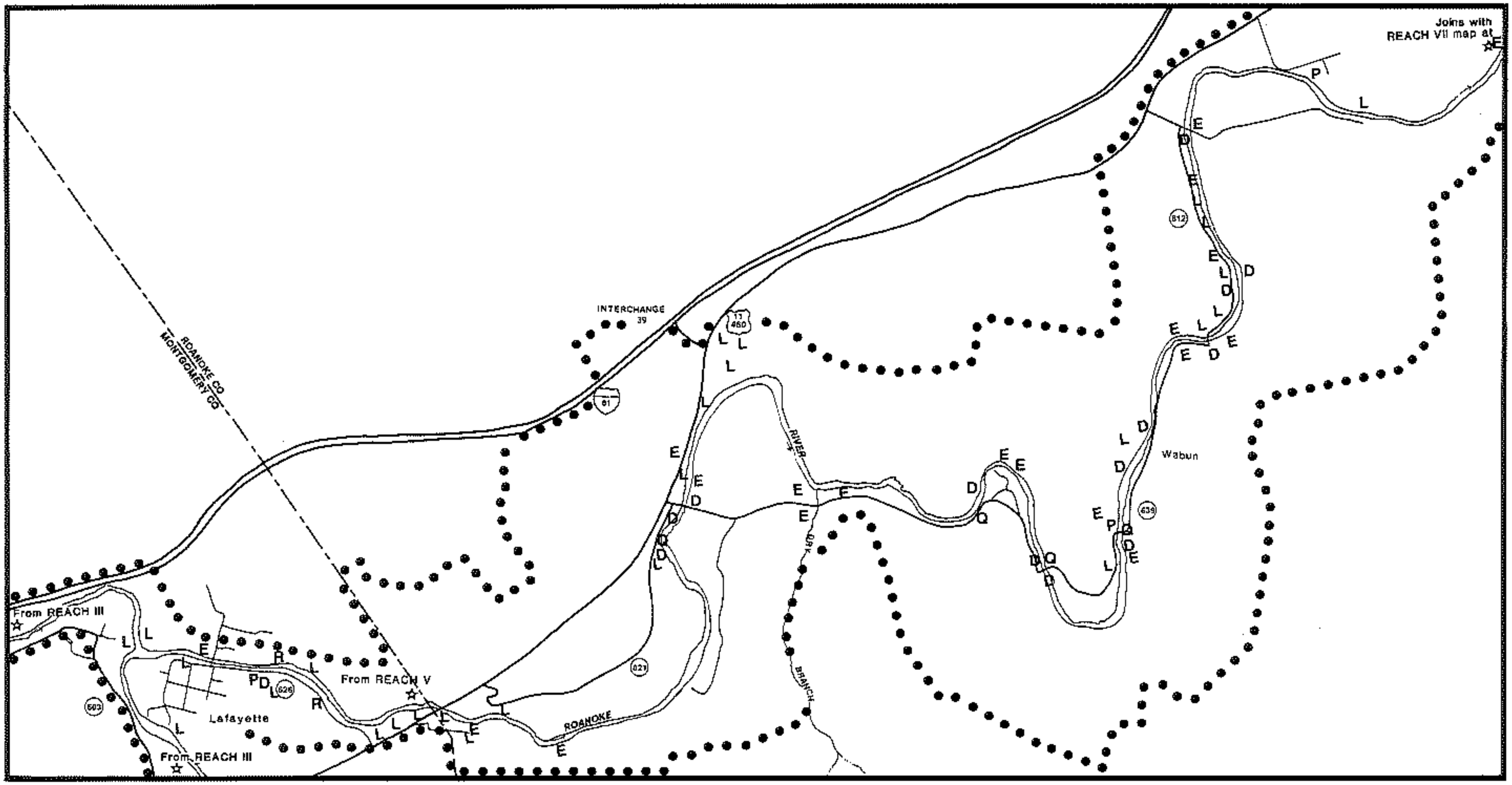
0 ½ 1 MILE

N

● ● STUDY AREA BOUNDARY

LEGEND:
D - Decomposing Organic Materials
E - Erosion
L - Litter Concentration
R - Removal of Streambank Vegetation
S - Sewage Interceptor Overflows

P - Pipe Outlet With Erosion Controls
Q - Pipe Outlet Without Erosion Controls



REACH VI (Roanoke & Montgomery Counties)
ROANOKE RIVER CORRIDOR STUDY

0 ½ 1 MILE

N

● ● STUDY AREA BOUNDARY

LEGEND:
D - Decomposing Organic Materials
E - Erosion
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R - Removal of Streambank Vegetation
S - Sewage Interceptor Overflows

P - Pipe Outlet With Erosion Controls
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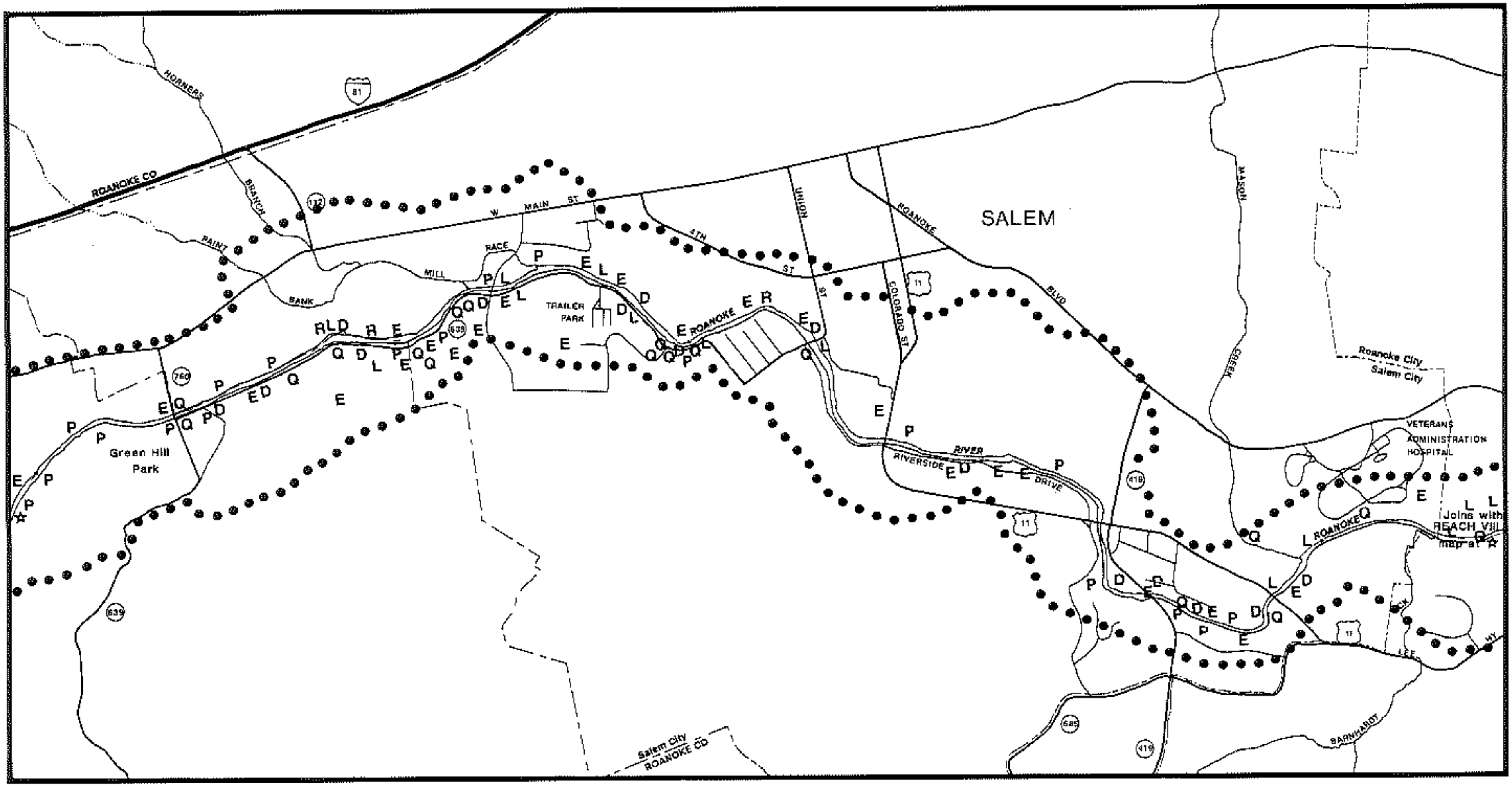

REACH VII (Roanoke County, Salem & Roanoke Cities)
ROANOKE RIVER CORRIDOR STUDY

0 ½ 1 MILE

N

● ● STUDY AREA BOUNDARY

LEGEND:
D - Decomposing Organic Materials
E - Erosion
L - Litter Concentration
R - Removal of Streambank Vegetation
S - Sewage Interceptor Overflows

P - Pipe Outlet With Erosion Controls
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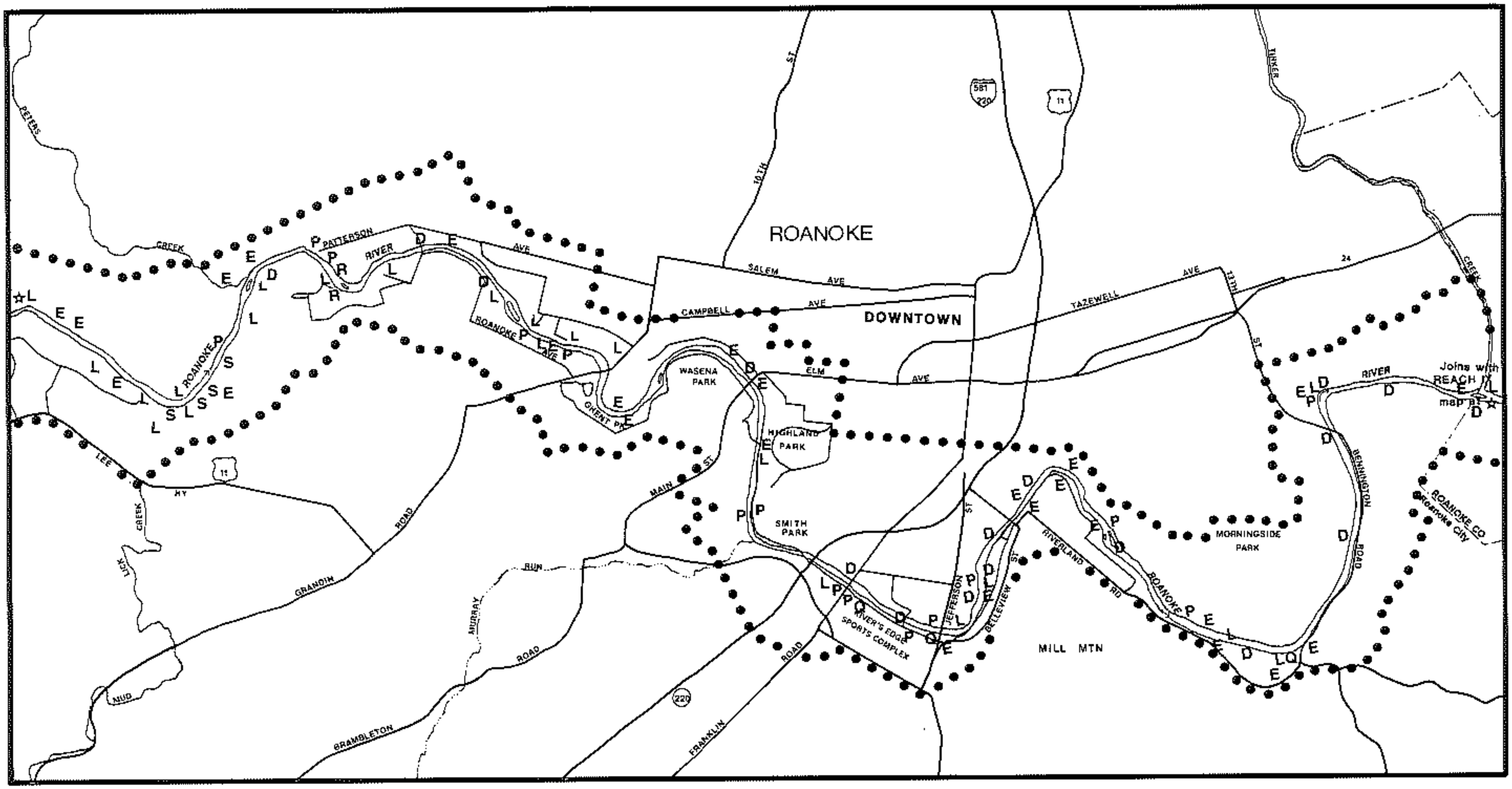
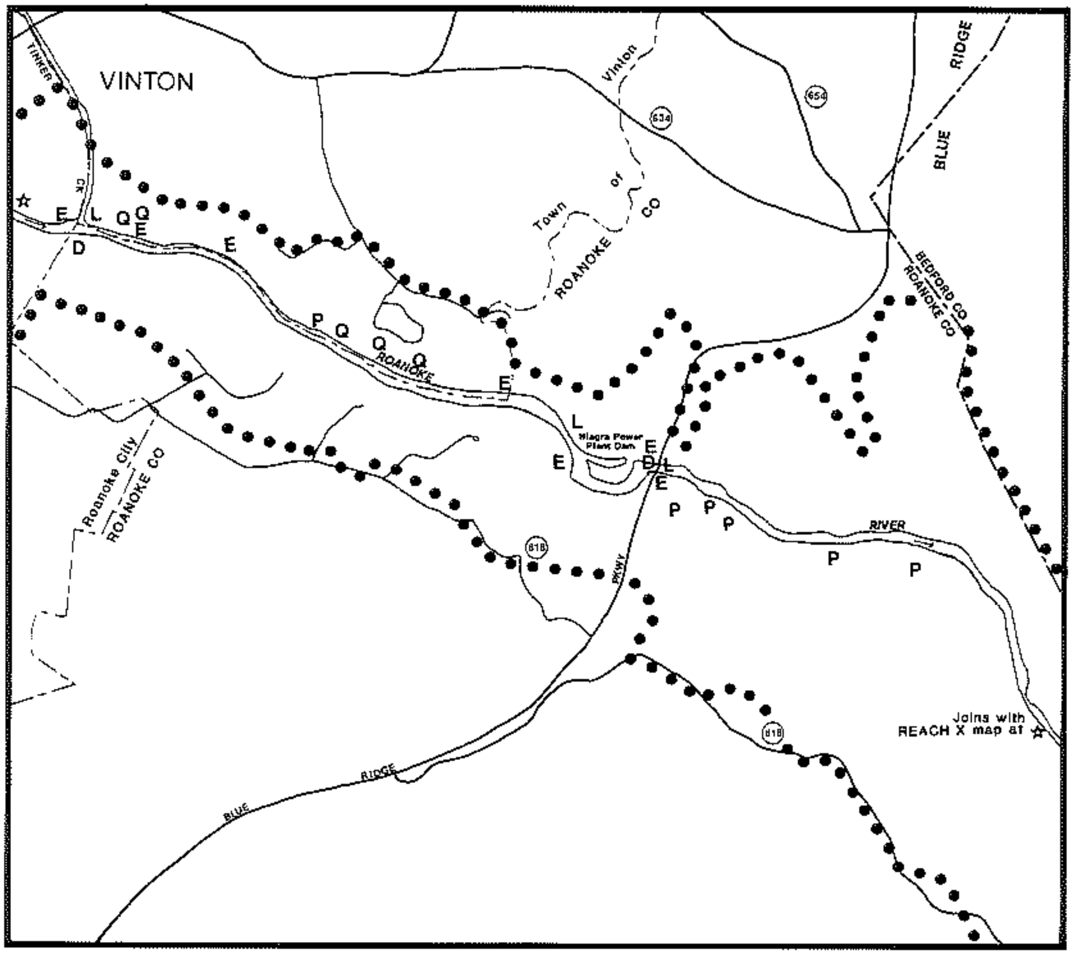


REACH VIII (Roanoke County, Roanoke City)
ROANOKE RIVER CORRIDOR STUDY

LEGEND:
D - Decomposing Organic Materials
E - Erosion
L - Litter Concentration
R - Removal of Streambank Vegetation
S - Sewage Interceptor Overflows

P - Pipe Outlet With Erosion Controls
Q - Pipe Outlet Without Erosion Controls



REACH IX (Roanoke & Bedford Counties)
ROANOKE RIVER CORRIDOR STUDY

0 ½ 1 MILE

N

● ● STUDY AREA BOUNDARY

LEGEND:
D - Decomposing Organic Materials
E - Erosion
L - Litter Concentration
R - Removal of Streambank Vegetation
S - Sewage Interceptor Overflows
P - Pipe Outlet With Erosion Controls
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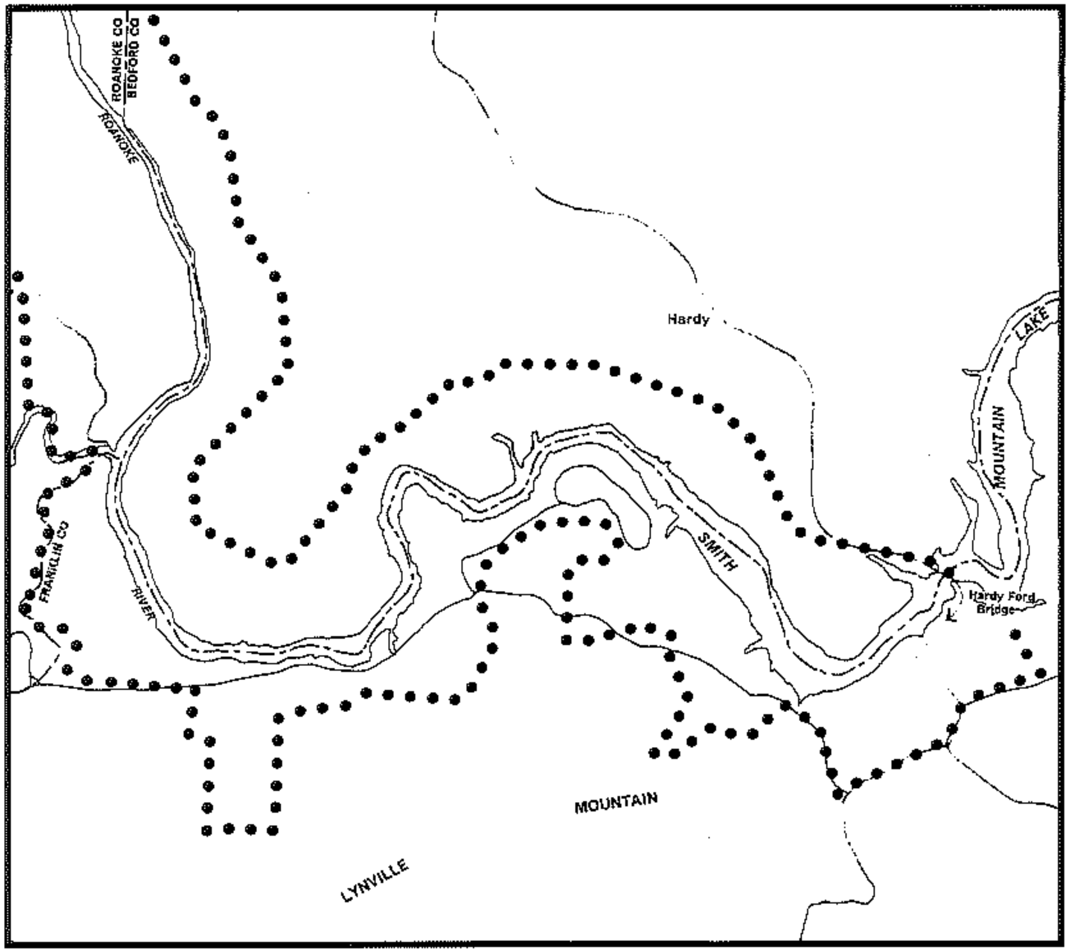

REACH X (Roanoke, Bedford & Franklin Counties)
ROANOKE RIVER CORRIDOR STUDY

0 ½ 1 MILE

N

● ● STUDY AREA BOUNDARY

LEGEND:
D - Decomposing Organic Materials
E - Erosion
L - Litter Concentration
R - Removal of Streambank Vegetation
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