DRAFT
ENVIRONMENTAL IMPACT STATEMENT

UPGRADING and EXPANSION of the FALLING CREEK WASTEWATER TREATMENT FACILITY

Chesterfield County, Virginia

Prepared By

U. S. ENVIRONMENTAL PROTECTION AGENCY
REGION III
PHILADELPHIA, PA.

AUGUST 1975

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
6TH AND WALNUT STREETS
PHILADELPHIA, PENNSYLVANIA 19106

September 2, 1975

SUBJECT: Upgrading and Expansion of the Falling Creek Wastewater Treatment Facilities, Chesterfield County, Virginia (C-51-484-01)

In accordance with the National Environmental Policy Act of 1969 (P.L. 91-190), submitted herewith for your information and consideration is a Draft Environmental Impact Statement for the proposed upgrading and expansion of the Falling Creek Wastewater Treatment Facility.

The proposed project consists of increasing the capacity of the existing 6 MGD plant to 12 MGD and upgrading the degree of treatment from 90 percent BOD removal to 95 percent BOD removal. The expanded service area will encompass the drainage basin of Falling Creek and its tributaries as well as the upper Swift Creek Watershed.

We would appreciate receiving your comments within forty-five (45) calendar days from the date of this transmittal. In addition, a public hearing will be held Thursday, October 9, 1975, 7:30 p.m. at the Chesterfield County Court House. Those submitting comments or who wish to testify at the public hearing should contact Mr. George Pence, Chief, Environmental Impact Branch, at the above address.

Daniel J. Snyder, III
Regional Administrator

Enclosure

DRAFT
ENVIRONMENTAL IMPACT STATEMENT

UPGRADING AND EXPANSION OF THE FALLING CREEK WASTEWATER TREATMENT FACILITY CHESTERFIELD COUNTY, VIRGINIA

Prepared By
U. S. ENVIRONMENTAL PROTECTION AGENCY
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PHILADELPHIA, PENNSYLVANIA 19106

Approved By:

Regional Administrator

July 28, 1975
Date

EPA-3-VA-CHESTERFIELD-XX-WWTP-75

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LIST OF ABBREVIATIONS

AADT	Annual Average Daily Traffic
APCB	Air Pollution Control Board
AQCR	Air Quality Control Region
AQMA	Air Quality Maintenance Area
ARWA	Appomattox River Water Authority
AWT	Advanced Wastewater Treatment
CFR	Code of Federal Regulations
COE	Corps of Engineers
DOT	Department of Transportation
DSPCA	Division of State Planning and Community Affairs
EIS	Environmental Impact Statement
ELP	Emissions Limitation Plan
EPA	Environmental Protection Agency
FWPCA	Federal Water Pollution Control Act

LIST OF ABBREVIATIONS (Cont'd.)

GPCD	Gallons Per Capita Daily
HUD	Department of Housing and Urban Development
MGD	Million Gallons Per Day
NAAQS	National Ambient Air Quality Standards
NEDS	National Emission Data System
PCD	Planned Community Development
RRPDC	Richmond Regional Planning District Commission
STP	Sewage Treatment Plant
SWCB	State Water Control Board
UMA	Urban Metropolitan Area
VALC	Virginia Advisory Legislative Council
VMT	Vehicle-Miles of Travel
VPI-SU	Virginia Polytechnic Institute and State University

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SUMMARY

Upgrading and Expansion of the Falling Creek STP
Chesterfield County, Virginia
(X) Draft
( ) Final

U.S. Environmental Protection Agency
Region III
Philadelphia, Pennsylvania
(X) Administrative Action
( ) Legislative Action

This Draft Environmental Impact Statement concerns the proposed expansion of the 6 million gallon per day Falling Creek Wastewater Treatment Facility to 12 MGD and upgrading to provide advanced wastewater treatment. Federal financial assistance under P.L. 92-500 has been requested by Chesterfield County. The plant expansion, in conjunction with a locally-funded interceptor and collector system, is designed to gradually eliminate existing septic tanks and place future growth on public sewers as much as possible. The goal of the County Sewerage Program is to alleviate potentially detrimental health effects due to malfunctioning on-lot systems and to protect local groundwater and surface water supplies in the Service Area. The Environmental Impact Statement focuses on two issues.

1. The appropriate sewage treatment plant expansion capacity, and
2. The direct and indirect effects of the applicant's proposed action on water quality and water supply, particularly concerning the Swift Creek Reservoir.

The Service Area of the proposed action lies southwest of Richmond in Central Virginia. Air quality is generally good, especially in the western section. However, heavy growth in the eastern section around Richmond has caused several problems concerning the hydrocarbon-nitrogen dioxide-photochemical oxidant interreactions. Chesterfield County has been included in the Richmond Metropolitan Area Air Quality Maintenance Area, which is designated for particulates.

Improperly functioning septic tank systems have led to local degradation of private water supplies and general groundwater quality. This contamination combined with the increased development-related pollutants, has resulted in eutrophic conditions within the two County Reservoirs - Falling Creek and Swift Creek Reservors.

The differences in population growth projections and other determinants of wastewater flow estimates prompts an analysis which postulates a high and a low estimate of wastewater flows over time. A cost comparison among five selected plant expansion options (6 MGD; 4 MGD followed by 2 MGD; 3 MGD followed by 3 MGD; 2 MGD followed by 4 MGD; and three increments of 2 MGD) for both the high and low growth estimates reveals that on a cost basis alone almost all options can be considered equivalent. The other factors which therefore determine the proper plant expansion size are: environmental effects, the wastewater treatment planning process, engineering aspects, and the consequences and probabilities of "overdesigning" and "underdesigning" the plant.

The water quality of Swift Creek Reservoir is discussed. Appropriate models and assumptions are presented which quantify expected conditions in the Service Area. At present the Reservoir is eutrophic and undergoing in-lake treatment. In addition to appropriate State and County construction standards, it is hoped that a Swift Creek Watershed Management Program is adopted to protect this sensitive area from future development.

Minor short-term adverse impacts of the applicant's proposed action are anticipated during the construction of the facilities and associated County-financed trunk and collector lines. Examples are increased siltation of streams, disruption of wildlife habitat, decreased ambient air quality, and inconvenience to local residents. These impacts should be minimized through the enforcement of State and local management practices.

Potential long-term adverse impacts of the applicant's proposed action affecting surface water and groundwater quality, sensitive areas (wetlands, floodplains and aquifer recharge areas), agricultural lands, air quality, biology, and the community's social and economic environment are discussed. Adherence to sedimentation and erosion control standards and other County policies will be essential to mitigate these impacts.

Various alternatives for sludge and effluent disposal, treatment processes and site location are evaluated. Decentralized alternatives to centralized sewage treatment are discussed. An environmental and economic analysis of septic tank systems as a viable long-term decentralized alternative is made, based on recent research and operational developments. It has been concluded that septic tanks are not a suitable substitute for centralized service in most of the Service Area.

EPA has decided that the Falling Creek STP should be expanded to 9 MGD at this time.

INTRODUCTION

This Draft Environmental Impact Statement (EIS) has been prepared in accordance with the National Environmental Policy Act (PL 91-190), the Guidelines of the Council on Environmental Quality (40 CFR, Part 1500) and the EPA Environmental Review Regulations (40 CFR, Part 6).

The proposed expansion and upgrading of the Falling Creek Wastewater Treatment Facility from 6 MGD to 12 MGD is a major component of Chesterfield County's Sewerage Improvement Program, Phase I. Other Phase I facilities for which EPA has already made Federal Grants are the Proctors Creek treatment plant and associated trunk sewers, the Kingsland Creek trunk sewer, and the Oldtown Creek trunk sewer. The remaining part of the Program is being funded without Federal assistance and consists primarily of interceptor sewers in the Falling Creek Service Area.

This EIS analyses the proposed expansion and upgrading of the Falling Creek STP and several alternatives and their effects on the natural and social environment in the Service Area. After describing the existing natural and man-made environments in Chapter II, Chapter III evaluates the potential direct and indirect impacts of the proposed action. Because of the direct relationship between the STP expansion and the Service Area, the scope of Chapter III includes both the treatment plant and the locally-funded interceptors. Chapter IV reviews the various alternatives which have been considered. For example, although the original proposal included an incinerator for sludge handling and volume reduction, it now appears, as a result of the analysis in Chapter IV, that the expanded plant will utilize anaerobic digestion and disposal by landfill.

This EIS focuses on two major issues: the appropriate treatment capacity that EPA should sponsor under the Federal Water Pollution Control Act Amendments, and the effects on water quality and public water supplies which may result from providing sewer service in the Falling Creek Service Area. Accordingly, a large part of the material is devoted to these issues: the reader's attention is invited to Sections II.A.5., III.B., III.C.1. and IV.D for discussion and analysis of each. Chapter V attempts to bring together information presented in other sections of the EIS so that cogent findings on the key issues can be made.

EPA Region III has received excellent assistance from a number of people throughout this study. Among these are the staffs of Chesterfield County's Engineering, Health, and Planning Departments; the County's environmental and engineering consultants: EcolSciences, Inc., R. Stuart Royer & Associates, and J. K. Timmons & Associates; the Richmond Regional Planning District Commission; State Water Control Board; Sea Pines, Inc; Carolyn Baker; and Ray Ballard, and Tom Cole of the Old Dominion Chapter of the Sierra Club. Each contributed valuable information and insight concerning the proposed project and Service Area. Principal EPA staff members involved in the preparation of this report are Lawrence Teller, project coordinator, Leland Maxwell, land use planner, Robert Pickett, environmental scientist, Raymond Cyphers, air quality specialist, and Margie Hanish, secretary.

This Draft EIS is being distributed to solicit comments from all interested parties. A Final EIS will be prepared and distributed after EPA has held a public hearing and has had an opportunity to consider all comments received.

I. BACKGROUND

A. LOCATION

Chesterfield County is located in east-central Virginia, immediately southwest of Richmond. Figure I-1 shows the relationship of the County to the State and to EPA, Region III. With a land area of 441.6 square miles (1143.7km^2), the County had an estimated population of 116,548 in January, 1975. The population growth rate is the second highest in Virginia.

B. DESCRIPTION AND CONTEXT OF APPLICANT'S PROPOSED ACTION

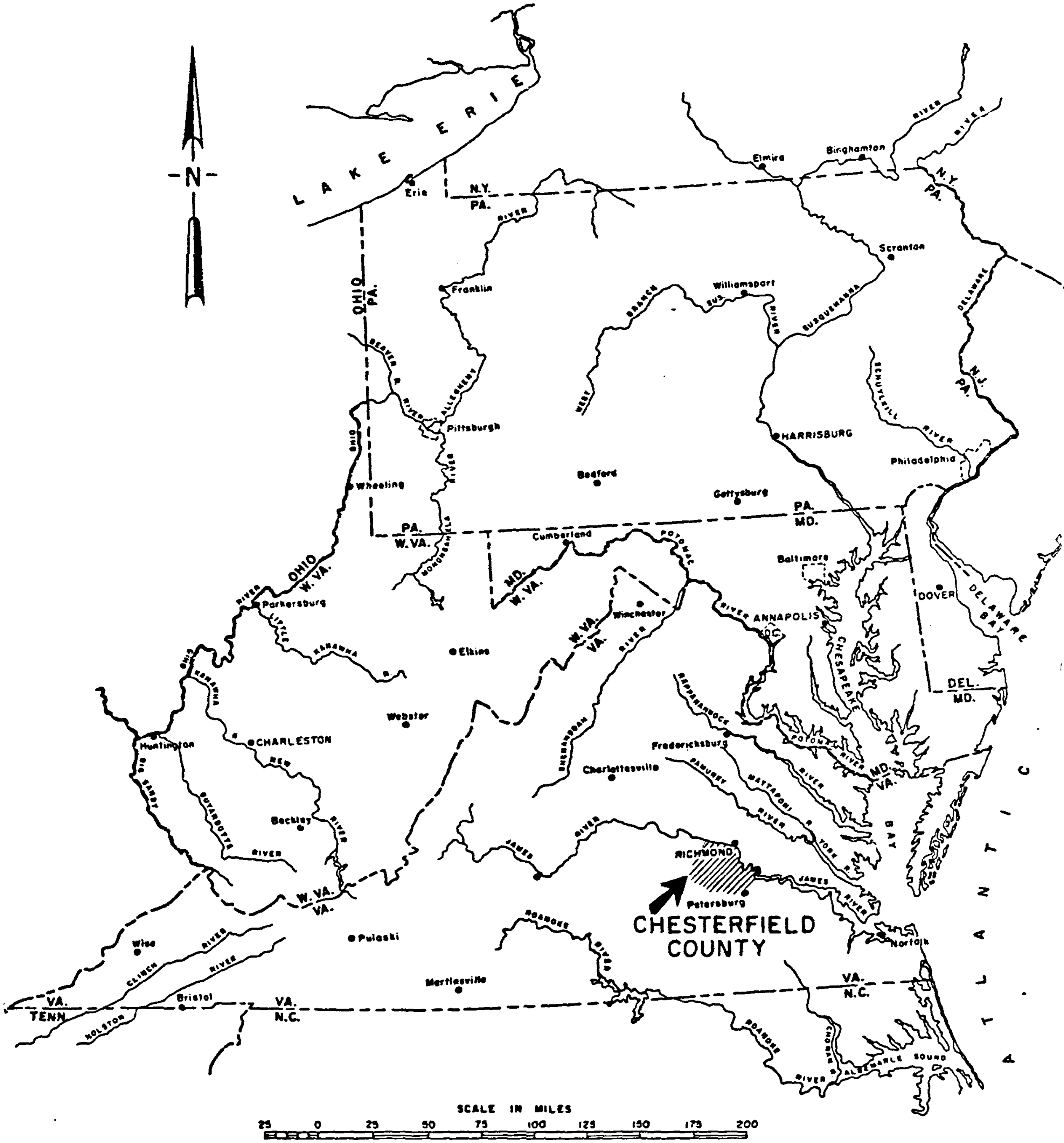
Chesterfield County began a sewerage improvement program in 1962 with the installation of the first sanitary sewers. A County bond referendum in 1973 raised $18 million to pay for most of this Phase I sewerage improvement program. This program has three major goals:

1. to provide public sewarage service to all present and future County residents, in accordance with approved growth plans;
2. to effectively and efficiently treat wastes generated within the County; and
3. to comply with the effluent discharge regulations of the State Water Control Board to maintain and/or enhance receiving water quality.

The three phases identified to accomplish these goals were originally scheduled as follows: Phase I, 1972-1977; Phase II, 1977-1987; and Phase III, 1987-2000. At the end of Phase III, three centralized wastewater treatment plants are to be operating, serving most or all of the County's residents.

This Environmental Impact Statement focuses on the Falling Creek Wastewater Treatment Facility, shown in Map 1. It is, at present, a 6 Million Gallons per Day (MGD) activated sludge plant serving the northern section of the County. Chesterfield County has applied for an EPA Construction Grant for the upgrading and expansion of the plant to 12 MGD. The network of Phase Itrunk and collector sewers that serves the plant has been completely financed by the County Bond referendum, and is shown in Map 3.

Other existing wastewater treatment facilities in the Service Area of the Falling Creek STP are many on-lot septic tanks and one small STP. The presence of soils unsuitable for septic tanks has caused a number of malfunction or need repair, contributing to the present need for the County sewerage improvement program. Upgrading and expansion of the Falling Creek STP is expected to relieve existing problems and to prevent similar problems from occurring in the future.



LOCATION OF CHESTERFIELD COUNTY IN EPA Region III

FIGURE 1-1

II. ENVIRONMENTAL SETTING

A. NATURAL

1. Climate

Chesterfield County is in a region of generally temperate climate. Yearly temperatures average 60°F, with monthly averages ranging from the mid-thirties in January to the mid-seventies in July.

Precipitation is evenly distributed in the County, averaging 40 inches annually: January is the driest month, with an average of 3 inches of rain, and July is the wettest month, averaging 5 to 6 inches. Seasonal figures show monthly minimums of 1 to 2 inches and maximums of 4 to 12 inches.

Prevailing winds in Chesterfield County are generally from the south, with a mean annual velocity of 8 to 10 miles per hour. However, winds exceeding 80 miles per hour accompanying hurricanes or intense thunderstorms have occurred.

2. Air Quality

The nature of the subject of air quality necessitates that no smaller geographical area than the entire County be discussed in most of this section. In general the ambient air quality in Chesterfield County with respect to sulfur oxides, suspended particulates and carbon monoxide is satisfactory. Nitrogen dioxide, although data is very sparse, appears to pose no problem. Photochemical oxidant (e.g., ozone) and hydrocarbon levels are high and will be subject to control measures.

a. Sulfur Oxides and Suspended Particulates

Table A-1 (Tables identified with a letter are in the indicated Appendix section.) displays monitoring results for sulfur oxides and suspended particulates at the Bensley Fire Department. Comparing the data with the National Ambient Air Quality Standards (NAAQS), it is seen that the primary and secondary standards for sulfur oxides and suspended particulates are not exceeded.

Another way to look at particulates and SO_x is to examine total emissions from point and area sources, as opposed to a sampling of ambient air quality. National Emission Data System (NEDS) information, in conjunction with that from the Virginia Air Pollution Control Board (APCB), indicate that total emissions in the County for both particulates and SO_x are far less than allowed by the State Implementation Plan, as shown in Table A-2.

b. Carbon Monoxide

Carbon monoxide levels have not been directly measured, but estimated by an analysis of the impact of traffic conditions on localized concentrations. Annual average daily traffic (AADT) data for nineteen segments of seven major highways in the County were analyzed. The most heavily traveled segment for each of the seven highways is tabulated in Table A-3. Deriving peak hour traffic from AADT and using vehicular emission factors, Milligan's equations estimate the peak CO concentration. With a high CO estimate of 8.25 ppm, the NAAQS of 35.0 ppm is not exceeded.

c. Ozone and Nitrogen Dioxide

Table A-4 shows that ozone concentrations for the sampling period consistently exceeded the primary ambient standard. Since this is the only data currently available, definitive conclusions as to the severity of the problem must await further sampling. It should be noted however, that the AQCR which contains Chesterfield County (State Capital Intrastate AQCR) has declared oxidants and particulates as the principal air pollution problems. Although there are too few daily NO_2 values to calculate an annual mean, the sampling period revealed only one daily value (0.060 ppm) in excess of the annual mean value (0.05 ppm).

d. Hydrocarbons

Although measurements of ambient hydrocarbon levels are not available, an analysis of hydrocarbon emissions based on vehicle-miles of travel (VMT) for the County has been made, as shown in Table A-5.

Hydrocarbon emissions data are important because of the relationship between hydrocarbons and oxidants. This relationship, as estimated in Figure A-1, indicates that as hydrocarbon levels change, oxidant levels change in the same direction. Figure A-1 shows the percentage reduction in hydrocarbon emissions necessary to attain National Ambient Air Quality Standards for photochemical oxidants, for any given level of such oxidants. For Chesterfield, with the applicable oxidant reading of 0.149 ppm, the required reduction would be 46 percent or 7,091 tons per year. This would give an allowable emission level of 8,325 tons per year (15,416 minus 7,091) for hydrocarbons in Chesterfield County. It is obvious that this level would be very difficult to attain. Even with the 79 percent reduction in mobile source emissions anticipated from implementation of the Federal Motor Vehicle Emission Control Program by 1977, the total emissions would considerably exceed the standard, due largely to the stationary source output of 12,629 tons per year. Thus, VMT reduction alone would be insufficient to attain oxidant standards. A reduction in present hydrocarbon emissions from stationary sources and strict control of future hydrocarbon emissions from stationary sources will be necessary to achieve oxidant standards.

Other general points concerning air quality include the fact that the first air pollution alert for the County occurred from July 9 to July 11, 1973. Ozone concentrations reached a maximum of 0.145 ppm at one of the three monitoring stations in the Richmond area. The principal source of pollutants was vehicular traffic. No abnormal increase in public health problems was noted during this period. In general, air quality in the western part of the County can be assumed to be significantly better than that in the eastern, more urbanized part.

3. Topography and Geology

a. Topography

The Falling Creek Service Area is centrally divided by the Fall Zone into two distinct physiographic provinces. These are shown in Map 4. The western section, including the Triassic units, is the highly eroded Piedmont plateau. The general terrain has a southeastern slope with low hills dominating the landscape. This area has recently undergone a slight uplifting, thus the rivers are young and narrow with high erosion potential. Stream density is high with channel slopes averaging three feet per mile, flowing southeast.

The eastern third of the Service Area lies in the Coastal Plain Province. The topography of this region is characterized by its very slight relief. Streams are typically more mature in age than those of the Piedmont Province. Coastal Plain streams are slow and meandering, with average bed slopes of only one foot per mile. Stream density is lower than in the adjacent Piedmont and is influenced daily by tidal flow up the James River.

The Fall Zone is a transition area dividing the typically hilly Piedmont plateau from the flatter Coastal Plain. This north-south striking zone indicates the farthest inland extent of the ocean's encroachment in recent history. This line determines the limit of tidal influence on present major river flow.[1] The Fall Zone covers a small geographic area characterized by steep, narrow streams of high erosion potential with average channel slopes of ten feet per mile or greater.

b. Geology

The two basic geologic systems of the Falling Creek Service Area shown in Map 4 correspond to the surficial Piedmont and Coastal Plain Provinces. Most of the Piedmont Province is underlain by Triassic sedimentary rock of the "Richmond Basin". In the Fall Zone, the Piedmont strata of crystalline igneous, metamorphic and sedimentary rocks dip steeply beneath unconsolidated superjacent Cretaceous and Tertiary sediments of the Coastal Plain. Basement rock of the Coastal Plain dips less steeply seaward and is overlain by marine and erosion-sediment deposits. These sediment layers reach depths of 400 feet near the James River. The most prominent sediment strata, with increasing depth, include the Columbia group (Pleistocene), the Chesapeake group (Miocene), the Pamunkey group (Eocene), and the Potomac group (lower Cretaceous). Strata beds slope southeastward at a rate of 25 to 30 feet per mile. Groundwater capacities, related to geologic strata, are discussed below.

4. Soils

Soils of the Falling Creek Service Area are commonly: moderately acidic to very acidic, well leached, sandy loam in texture, and low in organic matter. Approximately 95 soil types have been identified in the Service Area.[2]

Generally, soil types correspond to geologic substrata. Soils of the Coastal Plain Province generally have better building qualities and bear more groundwater than the neighboring soils of the Piedmont Province.

5. Hydrology

a. Surface Water - Streams

The Service Area, as shown in Map 2, includes the Falling Creek drainage basin and a portion of the Swift Creek watershed north of Pocahontas State Park. Minor tributaries include the Pocoshock and Pocosham Creek and portions of Kingsland and Grindall Creeks.

There are no natural lakes in the Service Area. However, two major manmade reservoirs, discussed in detail below, serve as public water supplies for Chesterfield County: the Falling Creek Reservoir and the Swift Creek Reservoir, with a combined surface area of approximately 1,820 acres (7.36km^2).

A stream quality monitoring program presently being conducted by the Virginia State Water Control Board (SWCB) includes Falling Creek, Swift Creek and the James River. Although sampling was begun in February, 1970, each station does not monitor all stream characteristics. Thus, the figures in Table B-1 are averages of samples taken over a four year period, yielding good estimates for current stream water quality.

Following the stream data in Table B-2 are public water supply standards, enforceable at the raw water intake point, which are also applicable to designated (i.e., public water supply) stream segments. Figure B-1 shows the location of these sampling stations.[3]

High concentrations of iron (Fe) and manganese (Mn) are noted and can be attributed to natural soil and geologic contributions. Mercury (Hg), with one high average for each stream, cannot be so directly accounted for, although industrial use and agricultural application are known to be primary sources of this metal.

Effects of impoundment by the Swift Creek Lake in Pocahontas State Park are evident in increased levels of arsenic (As), cadmium (Cd), and temperature, and a decrease in D.O.[4]

The most comprehensive study of the water regime of Chesterfield County is contained in the James River Basin Study.[5] There are a number of Federal and State laws governing the use of public water ways, in addition to the Table B-2 standards.[6]

b. Surface Water - Falling Creek Reservoir

Falling Creek Reservoir, older and smaller than Swift Creek Reservoir, was built in 1953 with a surface area of 120 acres (0.486 km^2) and a volume of 300 million gallons (1.13 million m^3). The maximum depth of the Reservoir near the dam is approximately 25 feet (7.6 m), with an average of 7.2 feet (2.3 m).

The 54 square mile (139.9 km^2) drainage basin, as shown on Map 2, includes residential, agricultural, and commercial land use, as well as open spaces. The sub-basins of Pocoshock and Pocosham Creeks also drain into Falling Creek. Based on a conservative average streamflow of 1.1 cfs (0.03m^3/sec) per square kilometer, the mean inflow to the Reservoir is 59.4 cfs (1.68m^3/sec). The flushing rate for this Reservoir is 7.8 days.[7] Based on these parameters and nutrient loading, the Falling Creek Reservoir is presently highly eutrophic.

c. Surface Water - Swift Creek Reservoir

Swift Creek Reservoir, created in 1964, is the largest reservoir in Chesterfiled County with a surface area of 1700 acres (6.88 km^2) and a total volume of 5.2 billion gallons (19.68 million m^3). The average depth is 9.4 feet (2.86 m), with a maximum depth of 28.5 feet (8.69 m). The 65 square mile (168 km^2) drainage basin is primarily wooded, with scattered low-density housing and sparse agriculture. Based on a mean inflow of 71.5 cfs (2.02m^3/sec), the flushing rate of the Reservoir is 113 days. This value, although much larger than the rate for Falling Creek, is still a very fast flushing rate and is exemplified in meso-eutrophic conditions now present in the Reservoir.

The water qualify problems facing the two County reservoirs are inherent to all artificial impoundments, and stem from the basic differences between free-flowing streams and relatively stagnant reservoirs. Appendix D discusses reservoir water quality modeling in general and attempts to estimate the existing water quality of the reservoirs based on presently accepted techniques.

d. Groundwater

Groundwater occurs in the Service Area under both water table and artesian conditions.[8] As is the case for soils, the groundwater hydrology can be divided into two distinct areas corresponding to the physiographic provinces of the area, the Piedmont and the Coastal Plain. Map 4 shows existing wells in the Service Area. Although specific withdrawal rates are undeterminable, inherent capacities, based on geology, are included. The Piedmont Province (including the Triassic geologic region) and the Fall Zone maintain limited quantities of groundwater available in granite and metamorphic cracks. Overlying soil layers may increase local yields to sustain rates of 10-50 gallons per minute with higher yields possible at depth.[9] These shallow surface wells penetrate the water table at a depth of approximately 10 to 20 feet below ground level.

The water table system of the Coastal Plain Province is located in the Pleistocene terrace deposits of sand, silt and clay, reaching a maximum sustainable yield of 50 gpm. These Pleistocene deposits average 30 feet in depth and rest on the Miocene aquiclude[10], which separates the surface water table from the subsurface artesian aquifer[11] systems.

Although existing data on surface water well quality is scarce for the Service Area, a County-wide search indicates private wells may commonly exhibit a high nitrate concentration. However, none of the available samples approach the State and Federal Water Quality Standard of 10 mg/1.[12] Often the nitrate contamination is related to improper installation or maintenance of a nearby septic system.

The subsurface artesian systems are a series of unconsolidated sediments starting at the Fall Zone and dipping east, below the Coastal Plain Pleistocene deposits. These sandy marine deposits are excellent water bearing aquifers and provide a major reserve of water for all of Southeastern Virginia. An Act of the Virginia State Water Control Board declared Southeastern Virginia (Chesterfield County not included) a Critical Groundwater Area on January 27, 1975.[13] The basic purpose of this action was "...the adoption of a plan for management of water resources in Southeastern Virginia."[14]

6. Biology

Chesterfield County provides natural habitat for a great diversity of wildlife.[15] The Service Area exhibits no special breeding habitats, nor does it support any rare or endangered species.[16]

The Falling Creek Service Area lies within the eastern temperate deciduous forest biome which covers most of North America east of the grasslands of the plains states and south of the Canadian coniferous forest. This biome is subdivided into several climax and subclimax forest types. The oak-hickory forest type is present in much of Chesterfield County. The oak-pine and pine forest represents immature successional stages of the oak-hickory forest. In the past, the pine forest stage has been maintained for its commercial value.

The aquatic biota that are known, from fish kills in Falling Creek, consist of the following fish: large-mouth bass, bluegill, carp, eel, white sucker, channel catfish, brown bullhead, black crappie, bowfin, herring, shad and needle nose gar.

7. Environmentally Sensitive Areas

In 1972, the Virginia General Assembly enacted Senate Bill 436, directing the Division of State Planning and Community Affairs to conduct a study of Virginia's critical environmental areas. Three areas were defined in Chesterfield County: the James River, the Appomattox River and the Swift Creek Reservoir. The Swift Creek Reservoir, and nearby Otterdale Branch, is the only designated area totally within the Service Area. This area, defined as a natural area in the midst of an urbanizing region, was noted to have significant recreational potential. A further proposal that the area surrounding the Reservoir be set aside as a park was made by the Richmond Regional Planning District Commission (RRPDC). However, neither recommendation was adopted by the Planning District's local governments. In light of this present lack of regional protection programs, it becomes more critical for the County to assume a role as the primary regulatory body for the Reservoir's protection. Although not designated by the State as a critical area, the Falling Creek Reservoir also requires immediate attention, as its function as a water supply is threatened by dense development in its watershed.

The Corps of Engineers has prepared floodplain information on the Pocoshock and Pocosham Creeks (1971), Falling Creek (1972) and Swift Creek (1974). Sparse development presently exists on the floodplains, consisting mainly of residential structures. Geographic delineation of areas which would be inundated by a 100-year flood[17] is shown in Map 2.[18]

Using criteria developed by the Marine Resource Commission, it has been determined that tidal wetlands, or marshes, do not exist in the Service Area.[19]

A location of critically steep slopes (greater than 25 percent) is included in Map 2. These areas have extremely high erosion potential and should be protected.

Discussions of all of these topics are included in the discussion of environmental effects (Section III C.) below.

B. MAN-MADE ENVIRONMENTAL SETTING

1. Land Use

a. Existing Land Use

The Falling Creek STP Service Area is part of the expanding "urban crescent" from Washington, D. C. through Richmond to the Tidewater area. This crescent follows I-95 and I-64 and contains a majority of Virginia's population and economic activity. Indeed, this urban crescent is considered to be the southern segment of the "urban megalopolis" which, it is predicted, will extend from Boston to Norfolk.

Land use in the Service Area is depicted in Map 6. The northern and eastern sections, which adjoin Richmond, have already been largely developed; the western section remains largely forested. Countywide distribution of land use is shown in Table II-1. Though primarily in the eastern section of the County, industrial land use has grown more rapidly than any other category between 1971 and 1973.

Development in the Service Area has been largely single family residential, although commercial development is occurring along Routes 60 and 360. Agricultural land, centered in the southern and western parts of the County, occupies a rather small part of the Service Area. Countywide, both the number of farms and total farm acreage have decreased during the last two decades. Hay, corn, and soybeans are the prime products, while poultry is the principal livestock.

Although the economy of the County is diversified, the main employment and service centers are Richmond and Petersburg-Hopewell. The manufacturing sector is growing most rapidly, and provides approximately 80 percent of the County's industrial wages. Only 1.4 percent of the civilian work force is employed in agriculture.

Major recreational facilities are summarized in Table II-2. In addition to these, a 164-acre park along U.S. Route 60 and Courthouse Road is being developed by the County to provide lighted sports areas, picnic facilities and general play areas. Thirty-five private recreational sites are scattered throughout the County, amounting to an additional 1,000 acres.

One of the primary transportation corridors in the County is the north-south corridor between Richmond and Colonial Heights. Within this corridor are Interstate 95 and Route 1-301. The Chippenham Parkway forms a boundary around the southwest part of Richmond. The main east-west routes are Routes 60 and 360. In January, 1975, the County employed, through the Richmond Regional Planning District Commission, a consultant to study the potential for mass transit in the Coun-

TABLE II-1
Distribution of Land Use in Chesterfield County for Years 1971–1973

	1971		1972		1973	
	Acres	Percent	Acres	Percent	Acres	Percent
Residential - Single Family	14,031	4.9	18,125	6.3	18,740	6.5
Residential - Multiple Family	661	0.2	760	0.3	810	0.3
Commercial	750	0.3	930	0.3	940	0.3
Industrial	1,210	0.4	1,360	0.5	2,780	0.9
Public*	11,070	3.8	11,080	3.8	11,140	3.8
Semi-Public	—	—	2,448	0.8	2,435	9.7
Streets	6,310	2.2	6,370	2.2	6,580	2.3
Utilities	1,826	0.6	1,826	0.6	1,826	0.6
Vacant, Argricultural, Other	249,582**	87.6	242,551	85.2	241,189	76.5
Total	285,440	100	285,440	100	285,440	100

*Includes Pocahontas State Park

**Includes Semi-Public land (no figure available for 1971)

TABLE II-2
*Major Recreational Facilities in Chesterfield County, Virginia**

Name	Control	Area in Acres Total	Lake	Recreational Activities
Presquile National Wildlife Refuge	U.S. Fish & Wildlife Service	1,329		Picnicking
Dutch Gap Landing	Va. Game & Inland Fisheries Commission			Fishing Boating
Pocahontas State Park	Va. Div. of Parks; Va. Div. of Forestry	7,238	181	Fishing, Camping, Picnicking, Boating, Swimming, Hiking, Riding, Forest, Nature Study
Bosher's Dam	C&O Railroad		425	Fishing, Picnicking, Boating
Chesterfield County Reservoir	Chesterfield County		154	Fishing, Boating
Falling Creek Reservoir	Chesterfield County		120	Fishing, Boating
Lake Chesdin	Appomattox River Water Authority		3,060	Fishing, Boating
Swift Creek Reservoir	Chesterfield County		1,700	Fishing, Boating
Lakeview Lake	Colonial Heights		100	Fishing, Camping, Picnicking, Boating

*From: James River Basin: Comprehensive Water Resources Plan, Volume I. Planning Bulletin 213.

ty. It has been found that the moderate-density development in the County is not conducive to regularly-scheduled bus routes; only work trips on an express or semi-express basis along radial routes to Richmond would be feasible at this time. It appears that as development intensifies, bus service along important routes will become feasible, reducing travel and energy costs, and improving air quality in several areas of the County.

b. Future Land Use

Projections for future land use in the Service Area are shown on Map 7. A change in residential land use is projected from predominantly single family to a mixture of single and multi-family dwellings. This is predicted to occur primarily in the northern and eastern sections of the County, and will be served in the northern section by both the proposed Route 288 and the Powhite Parkway. Distributions of future land uses in the entire County is shown in Table II-3.

Commercial development, primarily clustered shopping centers, will occur along major highway corridors. Industrial expansion will occur mainly outside the Service Area. Vacant and agricultural land will decrease as development takes place.

TABLE II-3
Distribution of Future Land Use in Chesterfield County[1]

	Area in Acres 1975	1980	1985	1990	1995	2000
Residential						
Single Family	20,500	23,600	25,000	29,300	33,700	38,500
Multi-Family	930	1,191	1,580	2,040	2,600	3,300
Commercial	1,050	1,440	1,880	2,400	3,000	3,500
Industrial	2,920	3,600	4,270	4,860	5,500	6,600
Public & Semi-Public[2]	6,420	8,190	9,800	11,400	13,100	15,400
Streets	7,350	9,850	13,140	17,160	21,900	26,400
Utilities	5,122[4]	6,066[3]	7,021[4]	7,976[3]	8,986[3]	9,491[4]
Total Developed Land	44,292	53,937	62,691	75,136	88,786	103,191
Other	241,148	231,503	222,749	210,304	196,654	182,249
Total Land Available	285,440	285,440	285,440	285,440	285,440	285,440

[1]From: Chesterfield County Planning Department, February 1974
[2]Does not include Pocahontas State Park
[3]From: James River Comprehensive Water Quality Management Study, Volume VII-2, Section B.
[4]Estimated from available data

Although only 1.4 percent of the civilian work force is now employed in agriculture, an annual decline of 2.6 percent in agricultural jobs is predicted for the present decade.

2. Historic and Archaeological Sites

Although there are presently no historic sites in the Service Area on the National Register of Historic Places, the Virginia Historic Landmarks Commission is in the process of preparing the necessary paperwork for adding one, Traebue's Tavern. The Tavern is located on Old Midlothian Turnpike (Route 60), and is shown on Map 5 as site number 24. In addition, a number of historic sites deemed "worthy of special concern" by the Richmond Regional Planning District Commission are located within the area. Table II–4 lists these sites, as shown in Map 5.

TABLE II-4
Historic Sites in Chesterfield County

1. Aetna Hill	14. The Hermitage
2. Bellwood Mansion	15. Melrose
3. Belmont Manor	16. Midlothian Mines
4. British Camp Farm	17. Montevideo
5. Brookbury Farm	18. Mt. Hermon Baptist Church
6. Chesterfield Railway Bed	19. Old Hundred Farm
7. Clay House	20. Old Stone Bridge
8. Cole's Free School	21. Railey Hill
9. Cole's Tavern	22. Salisbury
10. Ellet's House	23. Skinquarter
11. Falling Creek Iron Foundry	24. Traebue's Tavern
12. First Tomahawk Baptist Church	25. Twin Oaks
13. Ft. Darling	26. Windy Bend

NOTE: Numbers refer to Map 5.

There is no County policy that actively takes steps to preserve historic sites. Procedures exist, however, at the County level, which can place restrictions on land development to buffer the impact of proposed development on existing development. Such restrictions would probably be imposed in cases where public interest in buffering the impact of proposed development on historic sites is evident. Other than this, either the private sector or State and Federal action is relied on to identify and preserve historic places. Virginia accepts easements on land containing historic sites which are on the National Register, thus allowing preservation of the sites. Federal funds are available for renovation of historic sites which are on the National Register. In summary, the preservation of historic places in Chesterfield County can best be assured through efforts initiated by private individuals or groups.

3. Existing Wastewater Disposal Facilities

a. Septic Tanks

Residential developments currently served by septic tanks are shown in Map 8. Poor performance to date is indicated by the categories "malfunctions" and "repairs". Malfunctions are defined as those septic tank problems which have been reported by the owners, while repairs as those malfunctions which have been corrected by the County Health Department. Chesterfield County considers this information an understatement of the need for sewers, for several reasons:

1) Owners tend to report only the worst problems;
2) Health Department surveys in several problem subdivisions have revealed a higher number of failing septic tanks than had been reported by owners;
3) Many subdivision are too new to have experienced many failures, although in several years the problems may increase greatly; and
4) Conditions of soil, topography and lot size often make repairs costly, and sometimes almost impossible.

Despite these facts, no known public health problems, aquifer contamination, or well contamination from properly constructed wells, have occurred in the County.

b. Sewer Service

In 1962 the County began to install a centralized sewerage system. Within the Service Area are 170 miles of public sewers and the 6 MGD Falling Creek STP. Map 3 shows the routings and capacities of both existing and proposed lines. There are four natural drainage basins which constitute the Service Area: Pocoshock Creek, Pocosham Creek, Falling Creek and Upper Swift Creek.

The Pocoshock Creek basin comprises 5,100 acres and contains approximately 5,044 people, all within the County. One third of the 1,261 housing units are served by public sewers, although 80 percent of the basin is served by trunk sewers. All trunk sewers have adequate capacity to accommodate projected population in the basin.

The Pocosham Creek basin includes 2,003 acres in Chesterfield County and 1,977 acres in Richmond. There are approximately 4,500 people, and one fourth of the 1,400 housing units in the basin are served by public sewers. Phase III of the Sewerage Program will include parallel trunk lines in order to accommodate the ultimate design density of 12.5 persons per acre.

The remainder of the Falling Creek basin, (excluding its tributary Pocoshock and Pocosham basins) occupies approximately 30,250 acres, of which 930 are located in Richmond. The County portion of the basin has a population of 29,976; one half of the 7,494 housing units are served by public sewers.

The Upper Swift Creek basin contains 460 housing units, none of which is served by public sewers. However, future development around the Swift Creek Reservoir has 6,284 taps reserved by contract out of the rated 18,070 for the 6 MGD Falling Creek Plant. This represents one third of present capacity and one sixth of the proposed 12 MGD capacity. Ultimate development in the basin is projected to need 100 miles of trunk sewers and a wastewater flow of up to 50 MGD. A force main extending from the Bailey Bridge Pump Station to the gravity line at Genito Road will convey the wastewater flows into the Falling Creek basin, and eventually to the Falling Creek Plant.

c. Private Sewage Treatment Plants

The Midlothian High School has a sewage treatment plant providing secondary treatment and chlorination. It is the only such plant in the Service Area.

4. Population and Wastewater Flows

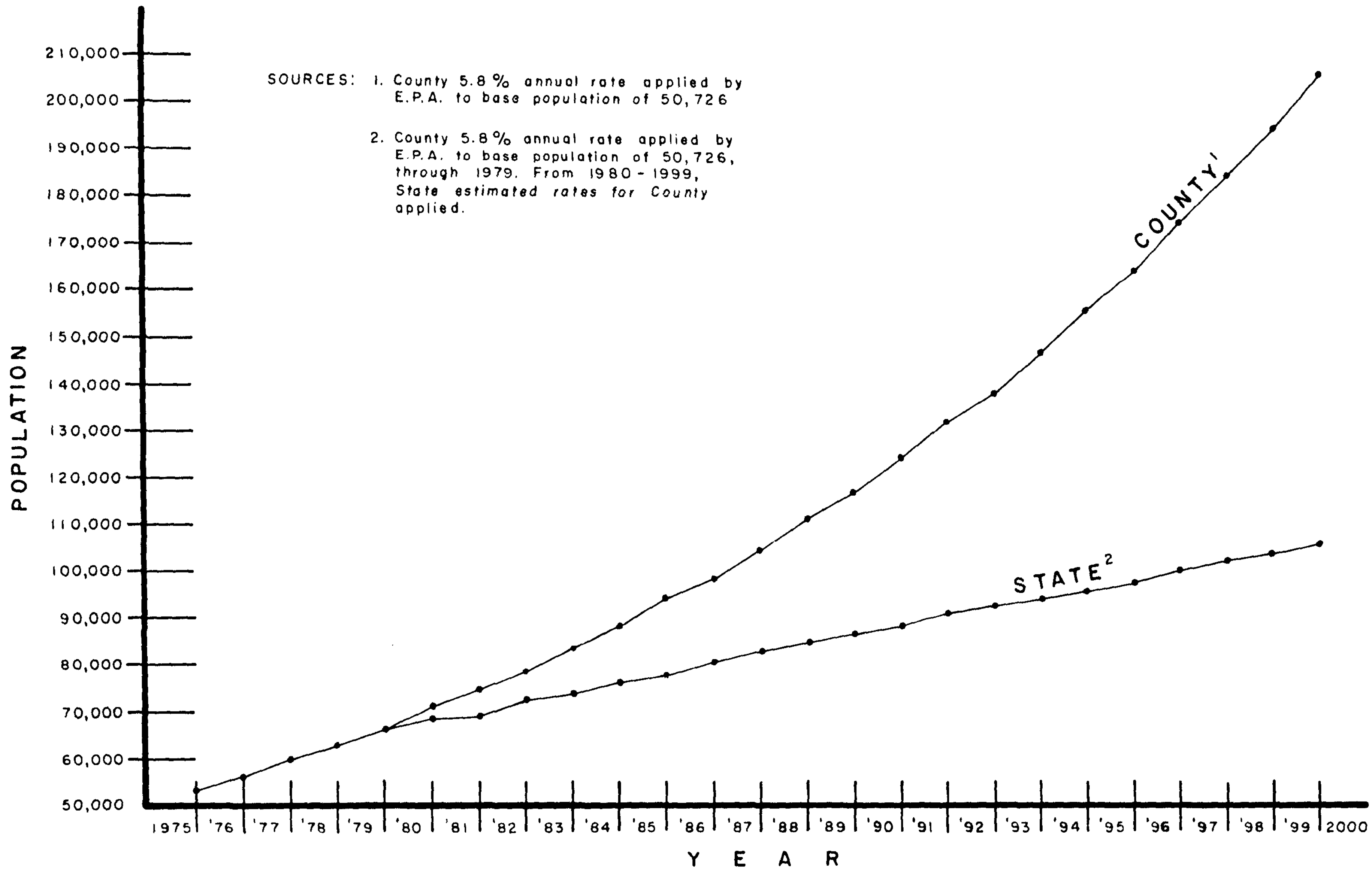
a. Present and Projected Population

Figures through 1974 indicate that the County portion of the Service Area contains 50,726 persons, assuming 100 percent occupancy of recorded lots. Figures prior to 1974 are difficult to estimate for the Service Area. If the Richmond portion of the Service Area is included (8,881), the total present population is 59,607. As of March, 1975, 23,281 persons in the County portion are being served by public sewers, and 27,445 by septic tanks. Because all persons in the Richmond portion are served by public sewers, the total Service Area population served is 32,162. The annual growth rate of 5.8 percent expected by the County, and the lower rates expected by the State DSPCA, result in the two population projections tabulated for the County portion of the Service Area in Table F–1 and shown in Figure II–2. The 5.8 percent rate represents the average annual County growth from 1950 to 1970. Growth since 1970 has averaged a higher rate, due to general suburban growth trends and some population exodus from Richmond. However, due to the risks of projecting the short-term higher rate into the future, the 20-year average has been chosen. Section III–B below relates these two population projections to annual increases in wastewater flowing to the Falling Creek STP.

b. Wastewater Flows

The present flow to the Falling Creek STP averages 3.37 MGD. Table II–11 lists components of this flow.

Future projections of flows are shown in Tables III–9 and III–10 and in Figure III–5. The County's projections are based on a constant 5.8 percent growth rate and a two-stage schedule for connecting existing development: from 1975 to 1980, ap-



ESTIMATED TOTAL POPULATION OF FALLING CREEK SERVICE AREA

FIGURE II-2

TABLE II-5
Flows to Falling Creek STP, October, 1974

Water Consumption by Users of Public Sewers in the Service Area	2.5 MGD
Infiltration (500 gallons per inch-mile X 1715.9 inch-miles)	0.87 MGD
TOTAL	3.37 MGD

Source: County Engineering and Utilities Department

Note: 2.5 MGD is that part of total water consumption that enters the sewer system. Additionally, a schedule of inspection of sewer lines to determine actual infiltration and inflows has been prepared and will be implemented in the near future.

proximately 12 percent of lots now served by septic tanks (945 of 7,700 lots,or approximately 3,252 of 27,445 persons) will be connected to public sewers each year; this schedule would extend service to 60 percent by 1980. The specific subdivisions to be connected are listed in Table F–2. In the second stage, the remaining 40 percent will be connected at a rate of roughly 153 lots, or 540 persons, per year. Assumptions used are a 100 GPCD flow and servicing of all new growth. The results are: 6 MGD reached around February, 1979; and 12 MGD reached approximately July, 1989. A discussion of these assumptions, and how they differ from an alternate low-growth set of assumptions, is in Section III–B.

5. *Water*

a. *Water Supply*

Chesterfield County owns and operates its own water supply system, presently serving approximately 74,000 residents (64 percent of the County.[20] Water for the system is obtained primarily from the County reservoirs on Falling and Swift Creeks. These two reservoirs supply over 80 percent of the total County water demand. Lake Chesdin, operated by the Appomattox River Water Authority (ARWA) on the Appomattox River, also supplies water to Chesterfield County, one of ARWA's members. Groundwater wells provide water to some of the more remote developments, but the total contribution is slight, as Table II–6 indicates. Accurate water supply and demand figures for the Service Area alone are not available.

TABLE II-6
Water Use in Chesterfield County
1974-1975 by Public Source

	Withdrawal[1] (Million Gallons per day)	Present Treatment Capacity
Surface Water		
Swift Creek Reservoir	3.1-5.3	10
Falling Creek Reservoir	2.6-2.7	3.0
Lake Chesdin	1.7	10[2]
Groundwater[3]		
Wagstaff Circle Well	0.043	
Physic Hill #1 & #2 Wells	0.003	
TOTAL	7.4-9.7	

[1]Low value is January, 1975 average withdrawal; high value is July, 1974 average withdrawal.
[2]Allocated to Chesterfield County.
[3]James River Basin - Comprehensive Water Resources Plan.)

As public water service in the County is expanded, reliance on local wells will continue to decline.

The ARWA allocates Lake Chesdin water to Colonial Heights, Petersburg, Dinwiddie County and Chesterfield County. Although present use by Chesterfield County is only 1.7 MGD,[21] the County has rights to purchase up to 10 MGD.

b. *Projected Water Demand*

County water use averages between 7.4 and 9.7 MGD. With a daily per capita use of 63 gallons[22] and both high and low population growth rates (as explained in Section III–B.), projected average and peak water demand[23] for the County through the year 2000 can be determined.[24] Figure II–3 indicates that by 2000, water demand at the 5.8 percent growth rate will be double the demand predicted by the lower growth rate.

With present treatment capable of supplying 23.0 MGD to Chesterfield County, it is apparent that the year 2000 average daily demand can be met, while peak demand will be met through 1998 without any further expansion of water treatment facilities.

Several studies have projected water supply and demand in the Richmond area.[25] The COE study concluded that with proper planning by the ARWA, the Richmond metropolitan area, including Chesterfield County, will not experience deficits within the foreseeable future. Table II–7 contains the major public water sources for the urban metropolitan area (UMA). Thus, the Appomattox River will probably be the major water source for Chesterfield County. With the existing impoundment capable of supplying 100 MGD, and with the potential to increase this capacity,[26] the ARWA has sufficient capacity to serve its member communities.[27]

TABLE II-7
Water Supplies for the Richmond UMA

Major Sources*	Present Treatment Capacity (MGD)	Safe Yield (MGD)
James River	66.0	168.0
Appomattox River	23.0	—
Lake Chesdin	24.0	100.0
Swift Creek Reservoir	10.0	12.0
Falling Creek Reservoir	3.0	3.6
South Anna	1.0	1.3
TOTAL	127.0	284.9

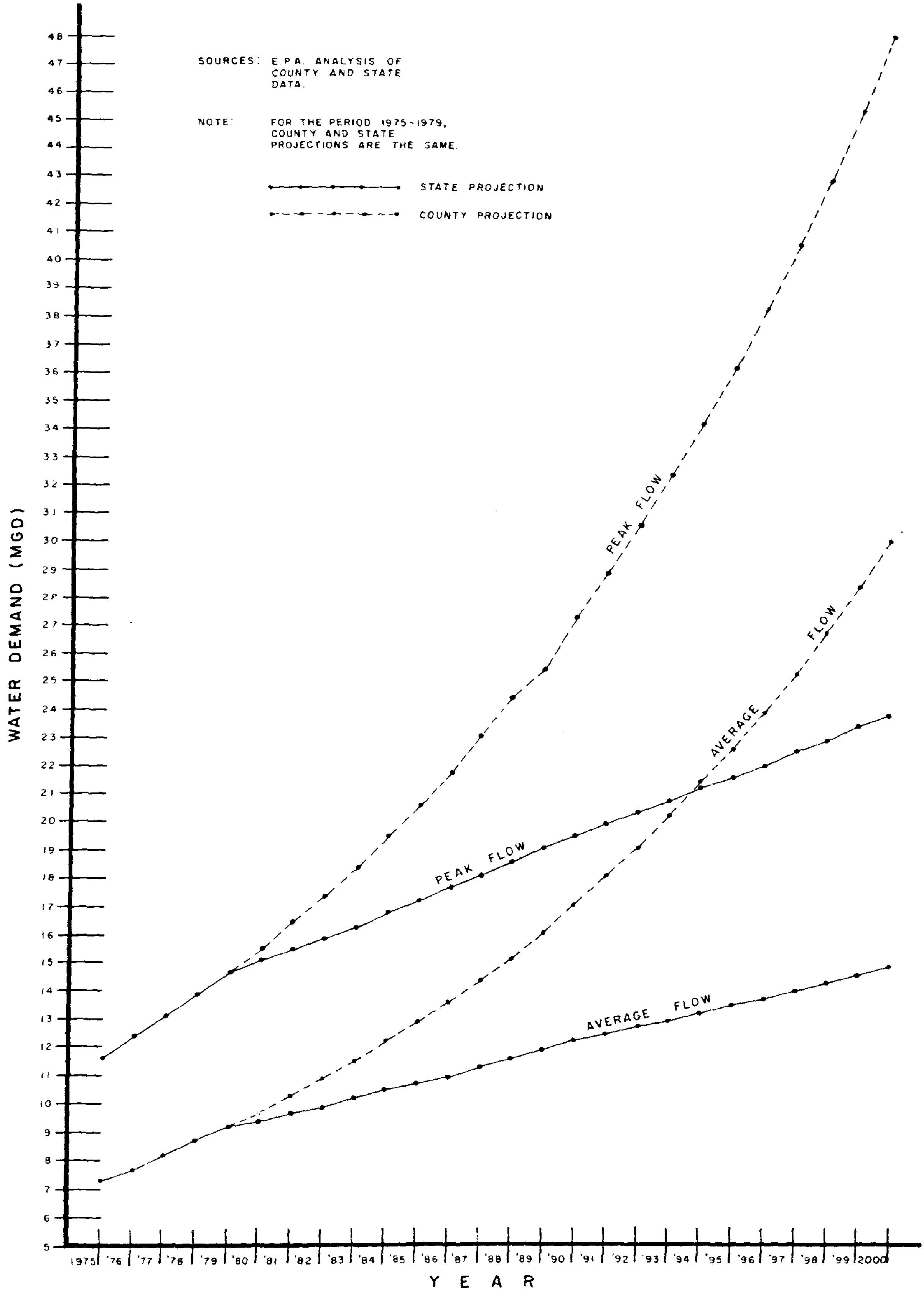
*Excluding local public wells (1.0 MGD)
Source: Corps of Engineers, "Northeastern United States Water Supply Study", 1973.

6. *Planning and Selected Land Use Ordinances*

a. *Federal*

One of the important Federal influences on land use in the Service Area is the Flood Disaster Protection Act of 1973, which expanded the National Flood Insurance Program. Its land use significance derives from its requirement that communities in the Program enact regulations governing land use within the 100-year floodplain, as identified by the U.S. Department of Housing and Urban Development. Chesterfield County is now in the second of five phases required for implementation of the Program. Areas of special flood hazard have been identified by the Corps of Engineers and HUD (see Map 2), and development within such areas at the time of identification (but not added later) has been offered flood insurance. The floodway has not yet been identified. The County floodplain land use control measures that have been adopted have met the Program's requirements.

Periodic reviews by the Federal Insurance Administration will ensure future compliance. In general, County policy discourages any development in the floodplain, and the pressure for such development in recent years has accordingly declined.



PROJECTED WATER DEMAND
CHESTERFIELD COUNTY, VIRGINIA

FIGURE II-3

Where floodplain construction is proposed and found to be necessary, the County's control measures provide that the potential hazard from the construction is minimized.

Section 404 of the Federal Water Pollution Control Act Amendments (FWPCA) defines wetlands in a way which will expand Federal jurisdiction in wetlands protection.[28] Under the proposed definition, inland wetlands will be subject to the same Corps of Engineers permit and EPA review process that tidal wetlands now are. Adoption of the expanded definition is expected during the summer of 1975. Until then, Federal authority does not extend to inland wetlands.

The roles of the Clean Air Act and other sections of the FWPCA are discussed in the following sections.

b. State

The State Water Control Board's (SWCB) influence on land use has expanded in recent years. Their regulation of effluent discharges into surface or underground waters, accomplished with the advice of the State Department of Health, affects the locations, amounts and types of development. Also in cooperation with the Department of Health, the SWCB is responsible for the conservation, protection and utilization of groundwater resources. Under the Groundwater Act of 1973 (Refer to Section II.A.5.d.), designation of critical groundwater areas and regulation of groundwater withdrawals both affect land use decisions. Future work includes developing approaches for the protection of water supplies and the attenuation of non-point source pollution (under provisions of the Safe Drinking Act of 1974 and Section 208 of the FWPCA respectively).

The Erosion and Sediment Control Law of 1973 resulted in the promulgation of the *Virginia Erosion and Sediment Control Handbook* by the Virginia Soil and Water Conservation Commission. This Handbook provides standards, guidelines and criteria to control erosion and sedimentation. Chesterfield County has an Erosion and Sedimentation Control Ordinance which is not yet in full compliance with the State standards.[29]

Erosion control practices in Chesterfield County would be more successful if the County's regulations complied fully with the State standards, and if they were regularly enforced. Ineffective attempts at erosion control exist throughout the County,[30] and may be expected to continue until the State standards are met and proper enforcement of them by the County occurs. In this regard, adoption of State standards will provide citizens with a legal mechanism to hold the County responsible.

The Wetlands Protection Act of 1972 charges the Virginia Marine Resources Commission with preserving tidal wetlands. Freshwater wetlands do not receive comparable protection. However, as mentioned above, revised EPA definition of wetlands under Section 404 of FWPCA will expand State as well as federal activity in protecting freshwater wetlands.

Critical environmental areas have been delineated by the Division of State Planning and Community Affairs (DSPCA). The Swift Creek Reservoir and nearby Otterdale Branch Park Site is the only area so designated in the Service Area. The recently enacted Land Use Tax Act offers reduced taxation for certain land uses such as agriculture and forest. Although it is too soon to assess the effects of this Act, it represents the only State mechanism for preserving agriculture or forest lands (Chesterfield County has similar taxation legislation, which is discussed below).

The 1966 Virginia Open-Space Land Act granted authority to some State agencies and all counties and municipalities to acquire or designate property for use as open space land. The Scenic Highways and Virginia Byways Act allows for designation, preservation and appropriate development of scenic roads. Development of design standards for ensuring adequate capacity of roads has been done by the Department of Highways. Additionally, the Virginia Advisory Legislative Council (VALC), created by the General Assembly, has formed a Land Use Policies Study Committee. Its 1974 report, "Land Use Policies", reviews land use problems and existing programs and mechanisms affecting land use, and makes recommendations for their improvement.

The Virginia Air Pollution Control Board (APCB) is responsible for carrying out several provisions of the Federal Clean Air Act, as amended. Chesterfield County is in the State Capital Intrastate Air Quality Control Region (AQCR) and the Richmond Air Quality Maintenance Area (AQMA).[31]

EPA Guidelines for the development of AQMA programs suggest that a number of land use and planning measures be considered in maintaining air quality, such as zoning approvals, transportation controls, regional development planning, and emission density zoning. At the present time, the State Air Pollution Control Board is considering these guidelines for the Richmond AQMA, and is expected to implement a number which will affect land use in the Service Area.

c. Richmond Regional Planning District Commission (RRPDC)

Created by the Virginia Area Development Act of 1968, Planning District Commissions (PDC) perform planning functions as well as encourage and assist governmental subdivisions to plan for the future. Each PDC is required to prepare a comprehensive plan; all subsequent RRPDC policies or actions must be consistent with the plan. Although advisory only, the RRPDC has issued several plans and reports dealing with water, sewer, transporation, open space and regional development, and agriculture.

The RRPDC in cooperation with the neighboring Crater PDC has been designated as the Areawide Planning Agency, under Section 208 of the FWPCA. Under Federal sponsorship, an Areawide Waste Treatment Management Plan is being developed. Guidelines and regulations will be issued relating to structural and non-structural methods of controlling point and non-point sources of water pollution.[32] Since Chesterfield County will participate in the formulation of the plan and regulations, additional land use controls in the areas of agriculture, construction activity and silvaculture may be expected within the next several years.

d. Chesterfield County

In accordance with Chapter 15 of the *Code of Virginia* Chesterfield County has formulated a comprehensive plan, a zoning ordinance, and a subdivision ordinance. The plan consists of the 1995 General Plan (Map 7). The subdivision regulations (Chapter 16 of the *Chesterfield County Code)* are supplemented by the "Policies and Guidelines for the Preparation of Subdivision Plans and Site Development Plans", which deals in detail with drainage, erosion and sedimentation, road design, curbs and gutters and floodplains. Chapter 20 of the Code is the Zoning Ordinance; Map 9 depicts present zoning in Chesterfield County. Other sections of the Code deal with sanitary regulations regarding sewage disposal.

The treatment of floodplains in the "Policies and Guidelines. . . " is particularly significant. The County allows stream modification (e.g., widening, deepening, realignment, bed clearing) as a means to reduce increased stream flows and flooding caused by development. However, such modifications may lead to other problems, such as destruction of stream habitat for fish and increased natural erosion and siltation. Stream modification is merely a treatment of a symptom - flooding - rather than a cause - improperly controlled development. The Virginia Commission of Game and Inland Fisheries has indicated opposition "to any stream modification activities leading to significant environmental damages, except under exceptional circumstances where an overriding necessity could be established".[33] County policy encouraging retention and controlled release of storm waters will help treat the cause, but the relative importance of storm water retention, as opposed to stream modification, will depend on the degree to which the County chooses between these alternatives.

The fate of inland wetlands, until the proposed Federal revisions (referred to above) are implemented, rests with the County. As there is no specific reference to wetlands preservation in existing County regulations, the discretion of the Planning Commission and the Board of Supervisors is of central importance. When Federal jurisdiction is realized, the County will continue to play a role in such preservation.

The County has recently enacted a land use tax ordinance which permits land used for agriculture, forest, or open space to be appraised for these uses rather than at actual market value. This ordinance is one of the few mechanisms available to the County government for preserving land in a non-developed state.

CHAPTER II - FOOTNOTES

1. Since navigation was impossible beyond this point, it was common for towns such as Richmond and Petersburg to form along the major rivers below the rapids of the Fall Line.

2. A complete listing of Chesterfield County soils is found in *Soils of Chesterfield County*, a 1970 publication by the Agronomy Department of the Virginia Polytechnic Institute and State University and Chesterfield County, in cooperation with the Soil Conservation Service.

3. For reference, the confluence of Falling Creek with the James River is at mile 102.5 and the outfall of the Richmond STP is at mile 108.2. This STP, currently at a 55 MGD capacity, is the subject of an EPA Step 1 Facilities Planning Grant application.

4. A more detailed discussion of the effects of impoundments on water quality is given in Appendix C.

5. The James River Comprehensive Water Quality Management Study was initiated by the Virginia State Water Control Board. Section 3 (c) of the Federal Water Pollution Control Act, as amended, authorized EPA to be a co-participant. Thus, the study has become known as the "3(c) Study". The purpose of the "3(c) Study" is to develop and implement a program to manage the water resources of the lower James River Basin.

6. Federal legislation: Rivers and Harbor Act of 1899, The Federal Water Pollution Control Act of 1956, Water Quality Act of 1956, Federal Water Pollution Control Act of 1970, Federal Water Pollution Control Act Amendments of 1972.

State legislation: Virginia Environmental Quality Act, Scenic Rivers Act, Critical Environmental Areas, State Water Control Law, State WCB/Division of Mineral Resources, Virginia Wetlands Act.

7. By dividing the reservoir's volume by the inflow (assumed equivalent to outflow), a parameter called the hydraulic flushing rate is determined which indicates the time incoming nutrients will remain in the reservoir before being flushed from the reservoir outlet.

8. Deep subsurface water under high pressure from the higher elevation of its surface outcrop.

9. James River Basin Study, Volume VII–4, Part B, October, 1972.

10. An aquiclude is an underground layer of impermeable rock, restricting water transport.

11. An aquifer is an underground layer of permeable rock containing water.

12. 10 mg/1 has been set to insure public health on the basis of adverse physiological effects on infants and poor removal efficiency from standard water treatment processes. (Water Quality Criteria 1972 EPA-R3-73-033, March, 1973).

13. Section 62.1-44.95(a) of the Groundwater Act of 1973, Chapter 3.4 of the Code of Virginia (1950). This declaration was based on the allegations that: 1) The Southeastern Virginia Groundwater Advisory Committee found that groundwater withdrawals exceeded the recharge rate. 2) Many existing wells in Southampton County have been lost or have required reconstruction due to lowering of the water table. 3) The loss and reconstruction of wells was having a serious economic effect on the citizens of Southampton County. 4) The former Division of Water Resources had recommended the adoption of a plan for management of water resources in Southeastern Virginia. The included area consists of the counties of Prince George, Sussex, Southampton, Surry and Isle of Wight together with all towns included within their boundaries and the cities of Suffolk, Portsmouth, Norfolk, Chesapeake, Virginia Beach, Hopewell and Franklin.

14. The initial program will include: 1) Monitoring of water levels and quality. 2) Monitoring the salt-water interface. 3) Establishment of a permit system for industrial users of greater than 50,000 gpd.

15. Detailed descriptions of local topography and wildlife habitats can be found in the Environmental Assessment of Chesterfield County.

16. A detailed listing of wildlife in this region is available from *A Checklist of Virginia's Mammals, Birds, Reptiles and Amphibians*, 1959, Virginia Commission of Game and Inland Fisheries.

17. A 100-year flood is a flood having an average frequency of occurrence in the order of once in 100 years.

18. More detailed descriptions of the above mentioned floodplain studies can be obtained from the Norfolk District, Corps of Engineers.

19. Refer to Section II.B.6.a. for discussion of floodplains and wetlands.

20. As of February, 1975, based on 24,583 units served.

21. Average daily consumption for 1974.

22. Summary Report, by Chesterfield County, October 30, 1974.

23. Peak demand is defined as 160% of the average flow.

24. Assuming County water service will be provided to 100% of the County residents.

25. Corps of Engineers, "Northeastern United States Water Supply Study," 1973; Richmond Regional PDC, "Richmond Regional Water Plan," 1970; Virginia SWCB, "3(c) Study," VII-5, 1972; and Corps of Engineers, Norfolk District, "James River Basin Report," 1974.

26. Development above the dam is being restricted to preserve the option of building a second impoundment in the future (Genito Reservoir).

27. A feasibility study is being done by Henningson, Durham & Richardson, "Environmental Impact Assessment: Preliminary Report, Potential Water Supply Study for Southeastern Water Authority of Virginia."

28. 40 CFR Part 230, May 6, 1975.

29. The schedule set by the 1973 Law gives the County until July 1, 1975 to comply; progress has been made toward this end. If this deadline is not met, the James River Soil and Water Conservation District will be charged with assuring compliance. If compliance is not achieved by January 1, 1976, the State Soil and Water Conservation Commission will assume responsibility.

30. Several members of the local Sierra Club have stated that additional enforcement staff are needed, especially during the period of extensive sewer and residential development. Additionally, observations by EPA personnel and discussions with State officials have confirmed the need for better erosion control.

31. An AQCR is an intra- or interstate area designated under Section 107 of the Clean Air Act for the purpose of carrying out State Implementation Plans for achieving the National Ambient Air Quality Standards throughout each state.

An AQMA is an area which has been designated as not capable of meeting one or more of the National Ambient Air Quality Standards by 1977.

32. A non-point source of water pollution is one which does not flow from a pipe. They are therefore more difficult to control. Examples are urban and agricultural runoff.

33. Raymond Corning, "Channelization: Shortcut to Nowhere" in *Virginia Wildlife*, February, 1975.

III. EVALUATION OF PROPOSED ACTION

A. DETAILED DESCRIPTION

In 1963, Chesterfield County constructed a 3MGD primary sewage treatment facility at the confluence of Falling and Grindall Creeks. Expansion and upgrading to 6 MGD with secondary treatment by activated sludge was completed in 1971.

As proposed in Chesterfield County's Phase I program and shown in Figure III-4, the proposed project consists of an expansion of plant capacity from 6 to 12 MGD and an upgrading beyond secondary treatment efficiency. The degree of treatment for the proposed project has been determined by the Virginia State Water Control Board (SWCB), allocating a maximum BOD loading from the plant of 1,200 pounds per day to the James River. To meet this requirement, a BOD removal efficiency of 95 percent is necessary. A removal of 95 percent phosphorus and 99 percent suspended solids will also be obtained in the advanced wastewater treatment.

Table III–8 describes the proposed design criteria for the Falling Creek STP. The plant will retain the existing conventional activated sludge biological system to achieve secondary treatment.

TABLE III-8
Design Criteria for Falling Creek Treatment Plant

Design Flow:	12.0 MGD
Type of Plant:	Biological (Conventional Activated Sludge) and Physical/Chemical
Influent Characteristics:	BOD = 240 mg/1
	SS = 240 mg/1
	PO = 10 mg/1

Primary Settling:
  Size of Clarifier - 50 feet dia. X 10 feet s.w.d.
  Number of Clarifiers - 8
  Surface Settling Rate - 763 gal/ft² /day
  Detention Time - 2.5 hours
  Weir Overflow Rate - 9500 gal/1 in.ft./day
  BOD Removal - 30%

Aeration Basins:
  Number of Basins - 4 (Rectangular)
  Size of Basin - 164 ft. X 34 ft. X 15 ft. s.w.d.
  Type of aeration - diffusers
  Detention Time (without return sludge) - 5 hours
  CFM Air/# BOD removed - 1150

Final Settling:
  Size of Clarifier - 96 ft. X 25 ft. X 9 ft. s.w.d.
  Number of Clarifiers - 8
  Surface Settling Rate - 700 gal/ft² /day
  Detention Time - 2.5 hours

The AWT design will use the following unit processes to achieve 95 percent BOD and solids reduction.

  Chemical Feed of Alum
  Reactor Clarifier
  Mixed Media Filtration
  Chlorine Contact Tank
  Sludge Thickeners
  Sludge Digestion
  Vacuum Filtration
  Landfill

In the activated sludge process, waste is biologically stabilized in a reactor under aerobic conditions. Air is supplied by either diffused or mechanical aerators. In the reactor, the wastewater is brought in contact with an active biological mass which is capable of assimilating and stabilizing the waste. After the waste is treated in the reactor, the combination of liquid and biological mass which results is separated. The liquid portion proceeds to downstream treatment processes. A portion of the biological mass is returned to the reactor and the remaining portion is treated via sludge handling processes.

The first step of the advanced wastewater treatment (AWT) will use alum as a chemical coagulant to provide additional phosphorus, BOD and suspended solids removal. This will be followed by mixing and settling using reactor clarifiers. Further BOD and suspended solids removal will be obtained by mixed media filtration before final chlorination and discharge.

The point of effluent discharge for both the existing and proposed facilities is on Grindall Creek, approximately 1,500 feet (457 m) upstream from its confluence with Falling Creek. From here, effluent will travel an additional 1,300 feet (396 m) to the James River.

The sludge handling process consists of a gravity thickener which is the receiving tank for sludge removed from the primary clarifiers and waste-activated sludge from the biological system and filter backwash solids. A gravity thickener resembles a stirred sedimentation basin, but is deeper and capable of producing a solids concentration of 8 percent or greater.

At this point, the solids are still unstable with respect to biological action. The thickened sludge is then anaerobically digested, which stabilizes the sludge, making it suitable for landfilling or spreading without the problem of septicity. In anaerobic digestion, anaerobic organisms break down complex molecular structures of the solids and release much of the bonded water, while obtaining nutrients and energy from the conversion of the raw solids into more stable organic and inorganic solids. In addition, anaerobic sludge digestion reduces the number of coliform organisms by 99.8 percent in 30 days.

Next, the conditioned sludge will be mechanically dewatered by vacuum filtration. This combination of sludge handling processes will produce a final product of 30 to 40 percent solids, a relatively dry cake.

Final sludge disposal will be accomplished by trucking from the plant to the two presently used County sanitary landfills in Bon Air and Chester.

B. PLANT CAPACITY ISSUES: GROWTH RATES AND WASTEWATER FLOWS

The bases for estimating future sewage treatment plant capacity are the growth rate of the population to be served and the per capita sewage flow of that population. It is not possible to predict with certainty either of these figures. Instead, sets of assumptions which yield a range of projections have been made. Table III-9 lists these two sets of assumptions. It follows from

TABLE III-9
Assumptions Concerning Wastewater Flows, High and Low Estimates

High Estimate

1. Constant annual growth rate of 5.8 percent, all serviced.
2. Service Area population in 1975 is 50,726.
3. Per Capita Sewage Flow is 100 gallons per day, in accordance with suggested State guidelines.

Low Estimate

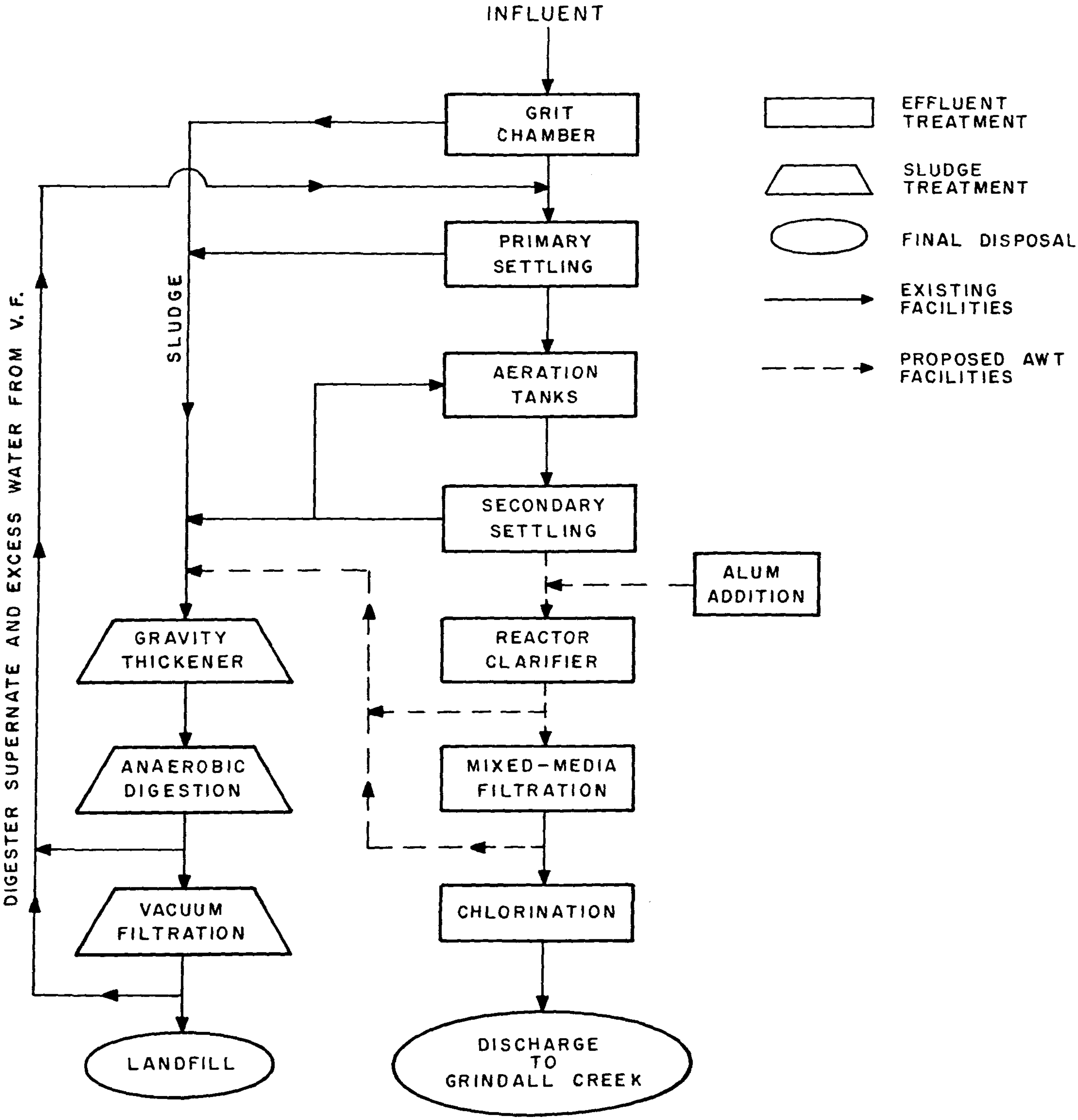
1. Varying annual growth rate, all serviced:

1975-1979	5.8 percent	1990-1994	2.1 percent
1980-1984	2.7 percent	1995-1999	2.0 percent
1985-1989	2.6 percent		

   The rates from 1980-1999 were provided by the Virginia Division of State Planning & Community Affairs.
2. Service Area population in 1975 is 43,117 (assumes 85 percent of the recorded lots are occupied).
3. Per Capita Sewage Flow is 80 gallons per day.*

Water consumption (from County)	63 gal/day
Commercial and school (from County, approximately 13 percent of residential)	8.1
Infiltration (based on new standard as 20 percent of old standard)	5.4

*EPA analysis based on actual rather than general values.



FALLING CREEK SEWAGE TREATMENT PLANT
EXISTING and PROPOSED PROCESSES

FIGURE III-4

these that the proposed design capacity of 12 MGD would be reached in different years, depending on the choice of high or low assumptions.

Tables III-10 and III-11 below show the high and low estimates of annual increments of the Service Area population and wastewater flows. Both estimates include the same annual increment of existing (i.e., 1975) population that will be connected to the system, derived from the County plan for servicing existing needs. Both also assume that there will be no increase in the flows from Richmond. The additional assumptions for the high estimate of wastewater flow are shown in Table III-9.

The differences between the high and low estimates for "new population growth added" are thus the result of different growth rates and different population bases. The differences in "total flow added" are due to the different per capita sewage flow figures applied to different "total population added" figures. "Cumulative total flow" shows the total flows expected by the end of each year. Figure III-5 is a graphic representation of these last columns.

TABLE III-10

Annual and Cumulative Changes in Service Area Population Being Served And Wastewater Flows, Using High Growth Estimates

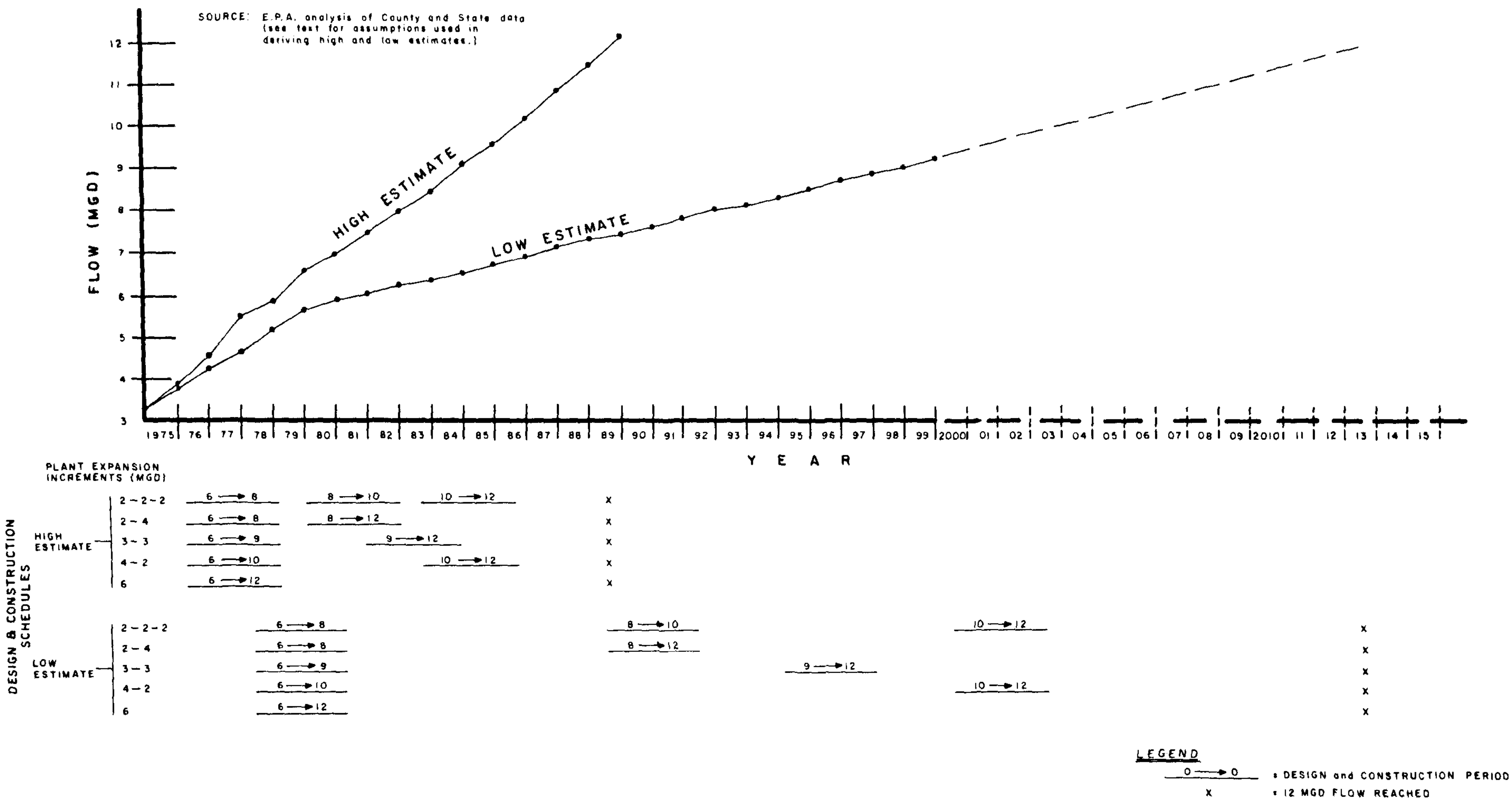
Year	"1975" Population Connected to STP[1]	New Population Growth Connected to STP	Total Additional Population Connected to STP	Total Additional Flow (MGD)[2]	Cumulative Flow (MGD)
1975	3252	2942	6194	0.62	3.99
1976	3252	3112	6364	0.64	4.63
1977	3252	3293	6545	0.65	5.28
1978	3252	3484	6736	0.67	5.95
1979	3252	3686	6938	0.69	6.64
1980	540	3900	4440	0.44	7.08
1981	540	4126	4666	0.47	7.55
1982	540	4365	4905	0.49	8.04
1983	540	4618	5158	0.52	8.56
1984	540	4886	5426	0.54	9.10
1985	540	5170	5710	0.57	9.67
1986	540	5469	6009	0.60	10.27
1987	540	5787	6327	0.63	10.90
1988	540	6122	6662	0.67	11.57
1989	540	6477	7017	0.70	12.27

1. Population that exists in 1975 but which has not yet been contributing flow to public treatment facilities.
2. Total Flow Added - (Total Population Added) (100)

TABLE III-11

Annual and Cumulative Changes in Service Area Population Being Served and Wastewater Flows, Using Low Growth Estimate

Year	"1975" Population Connected to STP	New Population Growth Connected to STP	Total Additional Population Connected to STP	Total Additional Flow (MGD)[2]	Cumulative Flow (MGD)
1975	3252	2501	5753	0.46	3.83
1976	3252	2646	5898	0.47	4.30
1977	3252	2799	6051	0.48	4.78
1978	3252	2962	6214	0.50	5.28
1979	3252	3133	6385	0.51	5.79
1980	540	1543	2083	0.17	5.96
1981	540	1585	2125	0.17	6.13
1982	540	1628	2168	0.17	6.30
1983	540	1672	2212	0.18	6.48
1984	540	1717	2257	0.18	6.66
1985	540	1698	2238	0.18	6.84
1986	540	1742	2282	0.18	7.02
1987	540	1787	2327	0.19	7.21
1988	540	1834	2374	0.19	7.40
1989	540	1881	2421	0.19	7.59
1990	540	1559	2099	0.17	7.76
1991	540	1592	2132	0.17	7.93
1992	540	1625	2165	0.17	8.10
1993	540	1659	2199	0.18	8.28
1994	540	1694	2234	0.18	8.46
1995	540	1647	2187	0.17	8.63
1996	540	1680	2220	0.18	8.81
1997	540	1714	2254	0.18	8.99
1998	540	1748	2288	0.18	9.17
1999	540	1783	2323	0.19	9.36



ESTIMATED WASTEWATER FLOWS TO FALLING CREEK STP, BY YEAR,
AND ASSOCIATED DESIGN AND CONSTRUCTION SCHEDULES

FIGURE III-5

It can be seen that the following flows will be reached at the approximate dates shown:

TABLE III-12
Estimated Dates When Various Flows Are Reached

Flow Reached (MGD)	High Estimate	Low Estimate
6	Feb., 1979	Mar., 1981
8	Dec., 1982	June, 1992
9	Nov., 1984	Jan., 1998
10	Aug., 1986	July, 2003
12	July, 1989	Dec., 2013

The implications of these waterwater flow increases for the STP design and construction process are shown below the graph in Figure III-5. The time alloted for design and construction (assumed to be three years) is represented by the heavy lines, for high and low estimates, and for all selected expansion increments, i.e., 2, 3, 4 and 6 MGD. The space between each line shows the time between construction completion of any increase and the beginning of design of the next incremental increase. Another way to look at this concept is to examine the planning period (defined here as that period, in years, beginning when the expanded plant begins treating flows and ending when the expanded capacity is completely utilized) for each of the selected expansion increments with the same high and low estimates identified above. This is done in Table III-13.

TABLE III-13
Planning Period for Selected Expansion Increments, Low and High Growth Estimates

Plant Expansion (MGD)		Planning Period (Yrs.)	
Increment	Expansion	High Estimate	Low Estimate
2	6 to 8	3.8	13.5
(each time)	8 to 10	3.7	10.5
	10 to 12	3.0	10.0
2, then 4	6 to 8	3.8	13.5
	8 to 12	6.7	20.5
3, then 3*	6 to 9	5.7	19.0
	9 to 12	4.8	15.0
4, then 2	6 to 10	7.5	24.0
	10 to 12	3.0	10.0
6**	6 to 12	10.5	34.0

*Example: Expand initially from 6 to 9 MGD. Under low-growth assumptions, the 9 MGD capacity would be reached in 19 years; this capacity would be reached in only 5.7 years under the high-growth assumptions. At this point, the second expansion from 9 to 12 MGD would be made.
**Note that for all increment sequences, 12 MGD is reached in 10.5 years under the high estimate, and 34 years under the low estimate.

Factors pertinent to choosing an appropriate planning period are: a normal planning period for cost-effectiveness analysis is 20 years; and the consequence of an unexpected growth rate reduction, (i.e., an over-designed plant with excess capacity) is of greater magnitude under high growth conditions than low. Shorter planning periods under high growth conditions can thus reduce the size of this consequence.

C. EVALUATION OF ENVIRONMENTAL IMPACTS OF THE PROPOSED ACTION

1. Hydrology

a. General

The removal of subsurface discharges of private home septic systems will result in a significant long-term beneficial impact on groundwater quality. Initial results will be improved water quality in local domestic wells. In time, a general improvement of groundwater will be prevalent, ultimately benefiting the quality of surface waters. Elimination of septic tank discharges will also prevent the potential contamination of water-supplying aquifers by transport through faults and cracks in the subsurface geology.

A negative impact on surface water quality will be the additional pollutants resulting from development within the Swift Creek and Falling Creek watersheds. Augmented by highly erodable soils in the western Piedmont Province, sedimentation and erosion could play a substantial role in accelerating the eutrophication process within the reservoirs. The containment of non-point source pollution (construction, agricultural and other unchanneled storm water runoff) must adhere to established State and County erosion and sedimentation controls to minimize the detrimental effect on stream and reservoir quality.

Swift Creek Reservoir is presently in a state of moderate eutrophication. As development intensifies in the Reservoir's drainage area, including the Brandermill planned development, further deterioration of water quality will occur. Several monitoring programs have been established to identify present and future water quality, and to formulate management alternatives for the maintenance and protection of the Reservoir.

Falling Creek Reservoir, Gregory's Pond and Swift Creek Lake will receive increased sediment and nutrient loadings in varying amounts. Due to its function as a water supply, concern is directed toward the Falling Creek Reservoir. With increasing development density in the watershed of a presently highly eutrophic reservoir, management must consist of both in-lake treatment and land development controls for future protection.

Gregory's Pond and Swift Creek Lake are primarily recreational; they also act for minimal flood and sediment control. Gregory's Pond will receive increased sediment loadings from upstream development and sewer line construction north along Falling Creek to the Salisbury subdivision. Swift Creek Lake, located within Pocahontas State Park, will be affected by the construction of the Bailey Bridge pump station and sewer line below the Swift Creek Reservoir. The possibility of sewerage overflows at the pumping station in wet weather is remote. However, proper construction practices should minimize this problem. As the water quality in Swift Creek Reservoir deteriorates, so will the discharge of water below the dam, ultimately affecting water quality downstream.

An additional adverse effect of the project will be the increased discharge to Grindall Creek. Although the STP effluent will cause some local degradation of Falling Creek, the 12 MGD discharge will not violate water quality standards and should not exceed the allowable 1,200 pounds BOD loading allocated by the Virginia SWCB.

All surface waters are protected by County and State regulations.[34] Policies have recently been adopted by the County establishing regulations for storm water retention, off-site drainage, floodplain development and site development plans.[35]

The County should also consider adopting a policy on buffer zones surrounding streams. Buffer zones are areas of vegetation, ranging from 50 to 300 feet wide, on either side of the stream. The vegetation is beneficial for many reasons. First, the dense root-mat helps hold the soil in place. Second, the foliage and plant litter filters out sediment from stormwater overland flow. Vegetation also dissipates the erosive energy from raindrops, an important contribution to erosion and sediment control. Certain reeds and bulrushes have the capability of absorbing specific metal and detergent pollutants detrimental to water quality. Vegetation has advantages over mechanical stabilization such as adaptability to changing natural situations and lack of a maintenance requirement. Finally, naturally vegetated buffer zones provide habitat for wildlife, and allow increased infiltration of stormwater, thus reducing flooding.

b. Swift Creek Reservoir and Brandermill

1) Swift Creek Reservoir

Swift Creek Reservoir is in an unstable state of eutrophy. The rate of eutrophication is highly dependent on the morphology of the lake. A large part of the Swift Creek Reservoir is penetrated by sunlight, the basic requirement for algae productivity. Thus, even with the beneficially short flushing rate,the Reservoir has a high potential for accelerated eutrophication. In attempts to obtain a more specific evaluation of existing conditions, three programs have been established to monitor water quality in the Reservoir and its tributaries.[36] This is the initial step in accurately projecting future conditions. While these studies are not completed, a eutrophication model has been constructed using existing water quality data referenced in Appendix D. While the primary use of Swift Creek Reservoir is as a water supply, recreational and open space amenities play an important role in the Reservoir's usefulness.

Protection of the water supply function of the Reservoir dictates the recreational uses available to the public. At present, body contact sports and use of internal combustion engines are prohibited. However, public fishing is permitted on the Genito and Woolridge Road turn-outs. Although fishing and non-engine boating are allowed on the Reservoir, permission from private landowners must be obtained to legally launch any water craft from the shore or to fish from locations other than the above mentioned turn-outs.

This is the extent of permitted recreational uses upon, in, or around the Reservoir, and there are no contemplated changes affecting recreational uses now or in the near future.[39] Secondary purposes of the Reservoir include flood water storage, sediment control and downstream water quality control.

Now under construction in the the Nuttree and Swift Creek drainage basins is Brandermill, a 2,580 acre development, of which 1,600 acres are located along the southern and eastern shores of the Swift Creek Reservoir. Because this development has the potential to significantly impair the present quality of the Reservoir and its viability as a County water supply, it is important to determine impacts which might result in the Reservoir. A study has been performed by the Eutrophication and Lake Restoration Branch of the EPA Pacific Northwest Environmental Research Laboratory to review conditions of the Reservoir and project the influence of the development on water quality. Although little can be stated regarding future conditions within the Reservoir, it was found that the presently eutrophic lake would continue to degrade, and that any development in the watershed would accelerate the natural rate of eutrophication.[37]

A tool used to predict reservoir water quality is the eutrophication model, used in Appendix D to assess present Reservoir quality. Discussed in Appendix D-3, it is apparent that, based on existing information, the effect of the development will be to markedly advance the state of eutrophy in the Reservoir. The increase in Reservoir nutrient and organic matter accumulation will result in more frequent algal blooms, causing potential taste and odor problems associated with anaerobic conditions. The aesthetic value of the Reservoir will also decline with increasing turbidity and color.

The nutrient loading attributable to the Brandermill development can be substantially reduced by comprehensive planning and construction restrictions. Thus, to understand the existing role of the development on the quality of the Reservoir, a description of the development and its significance is presented.

2) Brandermill

Brandermill, a Sea Pines of Virginia, Inc. planned community development (PCD), is a long-term, three-phase program to be constructed over the next twenty-five years. It will encompass 7,000 acres of the Swift Creek and Falling Creek drainage basin. The first phase, to be completed in the late 1980's, will occupy 2,580 acres in the Swift Creek watershed and accommodate 15,000 to 20,000 persons.

In April of 1974, a four week study was conducted by faculty members of V.P.I.-S.U., at the request of the Chesterfield County Board of Supervisors, to assess the relationship of the development to the environmental integrity of the Reservoir and its watershed.[38] A summary of relevant points from this study are addressed below.

1. Three general land use alternatives are associated with the watershed. They are:
   (1). protected open space;
   (2). highly managed developments; or
   (3). piecemeal development.

It is concluded that alternative (1), or a combination of (1) with (2) will not necessarily lead to adverse effects on the concerned area.

2. The necessity of a comprehensive management system, based on a County land use policy involving the total watershed, is emphasized as a mandatory tool to maintain the environmental quality of the area.

3. The impact of Brandermill on both the Reservoir and Nuttree Branch (a tributary joining Swift Creek below the Reservoir) is directly related to the management program implemented by the developer. This includes monitoring and controlling of sediments, nutrients, pesticides, oils, debris, trash and other common urban pollutants. Also to be included in a comprehensive management program are buffer zones, drainage system controls, site specific restrictions, storm water retention and phasing of site development.

In recognition of the sensitivity of the Reservoir area, the County Planning Commission recommended 37 development restrictions as conditions to the Brandermill zoning approval. Unanimously accepted by the Board of Supervisors, the conditions include comprehensive drainage and erosion and sediment control regulations. Relevant conditions, listed as they appear in the planning report, include:

"1. The applicant and/or developer will provide an accurate account of the drainage situation showing existing drainage and the impact individual tracts, as they are developed, will have on that tract as well as the surrounding area and water reservoir. The developer shall submit plans to the County Engineering Department which will provide for on and off site drainage control. The plans shall explain the method and show the facilities to be utilized in the hydraulic engineering of this project. These plans shall be approved by the Engineering Department prior to the issuance of any building permit or clearing of land. It is to be understood that the Engineering Department (subject to approval by the Board of Supervisors) may exert conditions, requirements or measures which it deems necessary to insure that proper drainage control is provided for and maintained. The approved drainage plans shall be implemented in whatever stages or phases are acceptable to the Engineering Department.

"2. For individual tracts as they are developed, the applicant and/or developer shall submit plans for erosion and sediment control to the County Engineering Department. Such plans are to be comprised of vegetative and engineering practices to be utilized as erosion and sediment control measures for the project. Generally such practices shall be used as those outlined in the "Erosion and Sediment Control Technical Handbook" published by the James River Soil and Water Conservation District. However, it is to be understood that additional requirements and measurements may be instituted by the Engineering Department upon review of the plans. The plans shall be approved by the Engineering Department prior to the issuance of any building permit. The plan's measures shall be implemented prior to the clearing of any land, cutting of any trees, or otherwise disturbance of the parcel's natural state.

"17. Any use whatsoever of the water in Swift Creek Reservoir or adjacent to it or within 200 feet of it shall be approved by all appropriate regulatory agencies including at the County level, the Engineering and Utilities Department. Such uses shall include but may not be limited to recreational uses, grading, clearing, docks, rip-rap along shore, water impoundments (other than that now existing), drainage structures, bulk heads, jetties, etc. The following horizontal setbacks from the horizontal location of water elevation (U.S.G.S) of the reservoir shall be established:

a. In all residential tracts, 100 feet to closest structure, 150 feet to closest parking area for more than two cars; and

b. In all Open Space/Recreational/Activity Centers and Village Centers ten feet to closest structure, seventy feet to closest parking area for more than two cars.

"18. The Planning Commission shall approve any plans for cut or fill (except for necessary public facilities) or structures within the 100 year flood plain along any creek. Such approval shall be based upon characteristics of the creek and the impact of the cut, fill, or structures upstream and downstream. The Commission may later delegate the review and approval of such plans to the Planning Director. The purpose of this restriction is to protect property improvements and maintain the County's continued eligibility for Federal Flood Insurance."

Incorporating these conditions, Brandermill has formulated its management program, which includes sediment retention basins, diversion channels, restrictive use of environmentally sensitive areas and various soil protection practices. A general summary of environmental controls to be incorporated in the construction is included in this EIS as Appendix I.

The proximity of Brandermill makes it impossible to prevent degradation of the Reservoir. However, the conclusion reached from the VPI report, the County's development conditions and Brandermill's program is that a joint comprehensive management program has been established which can minimize the adverse impacts on the Reservoir.

A large scale project, like Brandermill, will be a major source of pollutants to the Reservoir. However, in an area faced with inevitable growth, it is necessary to recognize the major differences in environmental effects between PCD's and less controlled development. One notable advantage of PCD's is that they are constructed by a single organization, and applicable restrictions will cover a larger area of development; this minimizes the amount of County supervision of developers.

Referring to the economics of artificial lake development, a recent report (Kusler, 1971) states:

"Planned unit developments[analogous to PCD's] are groups of dwellings with common rather than separate facilities for each lot. Traditionally, rows of lots have been laid out along lakes, each with its own access road, parking area, garage, yard, beach and dock. In contrast, "cluster developments", a type of planned unit development, place multi-family units around common open spaces. Clustering can preserve scenic beauty by maintenance of open spaces as parks or natural areas, reducing roads, beaches and docks through shared facilities, and careful site planning and landscaping. Group dwellings also facilitate installation of sewer and water systems.

"Most rural development imposes costs for new public facilities such as roads, parks, schools, police, firefighting equipment, libraries, waste disposal sites, and so forth. Usually local units of government must supply such facilities to piecemeal, lot-by-lot development.

"In contrast, units of government commonly are empowered to require subdividers of large tracts to install at their own expense the roads, sewers, water supply facilities, and sometimes parks and open spaces needed to service individual lots. A local unit of government must still supply more police to cope with weekend vacationers and more firefighters and equipment to protect new buildings. Although subdividers often provide internal roads, towns must extend or improve the external road system. If lots are used year-round, towns must provide snow removal.

"Should the artificial or natural water body fail to function as a watersport area due to faulty lake design or maintenance, towns may face a shrinking tax base, expensive lake rehabilitation and dam maintenance costs and the task of providing recreational facilities for thousands of lot owners.

"In addition to monetary costs, all rural lot-by-lot or subdivision development imposes environmental costs in destruction of scenic beauty, trees, wildlife, and ecological values. While artificial lake projects reshape essential valley character, the impact of large-scale subdivisions for natural shoreland areas is also serious and the cumulative effect of lot-by-lot development over time may be nearly as dramatic. In any context, pollution problems and destruction in environmental values may result."

The report concludes with the following comparison between PCD's and lot-by-lot development:

"While long-term problems of lake development deserve serious consideration, problems of piecemeal development of these or other lands, which is the likely alternative, must also be considered. Continued recreational development of the rural environment in one form or another seems inevitable, in light of constitutional restraints upon the regulation of private property and increasing recreation demands. To control development, government may need to purchase potential reservoir sites for park or conservation use in some instances and in others government rather than private developers may need to construct lakes if shoreland is to remain undeveloped."

In summary, results from existing modeling programs and studies conclude that Swift Creek Reservoir is presently eutrophic, a condition that will increase at an accelerated rate due to the construction of Brandermill and other developments. However, comprehensive monitoring and management, through a coordinated effort involving various State, County and local representatives, can assure the optimum protection from the development. With Brandermill occupying only four percent of the total watershed, such a management program will be of minor benefit to the Reservoir unless applied to all developments in the Swift Creek drainage basin.[40] As a minimum, these programs must include site-specific development restrictions, storm water retention, buffer zones, delineation of environmentally critical areas (including slopes, soils, floodplains and drainage swales), phased seasonal development to protect surface vegetation, and minimal removal of natural vegetation.

c. Falling Creek Reservoir

Falling Creek Reservoir and its drainage basin lie in an area presently undergoing the second fastest growth rate in the state. The Reservoir, built in 1953, is highly eutrophic with seasonal algal blooms and related taste and odor problems.

Since its formation, chemical treatment of copper sulfate ($CuSO_4$) has been applied to settle out suspended solids. An aeration system has also been installed and was used throughout the summer of 1974. It is expected that this system will continue to be used on a permanent seasonal cycle.

Development of a projected eutrophication model for Falling Creek has not been done for several reasons. Most basic is that the Falling Creek Reservoir is presently very eutrophic. These conditons are acknowledged by the County. The formulation of a model would only substantiate the present accepted practice of in-lake treatment, and thus would not contribute any new information.

With an increase of 16,000 persons (approximately 5,000 houses) in the watershed over the next five years, an increase in pollution associated with urban growth can be expected.[41] This additional loading to the Reservoir will increase anaerobic conditions in deeper waters with production of odoriferous manganese, iron and sulfates. Surface waters will support increasingly larger and more frequent algal blooms, with associated increases in turbidity, taste and odor problems.

The treatment of water from the Falling Creek Filtration Plant has increased in past years due to the necessary pretreatment processes. Although the cost has been absorbed by the County in the past, the ultimate costs are paid by the residents through local taxation. To minimize future treatment costs, it will be necessary to require stricter compliance with the County site development plans as well as the existing *Virginia Erosion and Sedimentation Control Handbook*[42] in dealing with future development in the watershed.

d. Treatment Alternatives for Water Supply Reservoirs

There are several water quality problems associated with reservoirs. For example, a reduction in stream flow velocity causes an increase in sediment deposition, thereby decreasing turbidity. This reduced turbidity, with the extended detention time, allows for increased biological growth resulting in algal-associated water quality problems. In a recent survey (Mackenthun and Kemp, 1970), 21 percent of 785 water supply managers reported water quality problems in lakes and reservoirs due to some form of algae. In an earlier survey (Task Group Report, 1966), 62 percent of all surface water supplies had algal-associated problems.

Another common problem associated with impounded waters is thermal stratification. This process involves warmer surface water (epilimnion) over-lying a cooler deeper hypolimnion. This stable condition, caused by the lighter warm waters, prohibits the circulation of the deeper hypolimnion. In time, the biological productivity of the restricted heavy waters uses the available dissolved oxygen, causing anaerobic productions of iron, manganese and sulfides (Symons, J. M., 1969). The reduction of the bottom sediments is the initial source of odor and taste problems in the water. These substances can cause a serious deterioration of finished water quality in times of heavy water use and low water levels (when hypolimnionic water must be used). During the spring and autumn, natural overturns of nutrients occur, causing complete reservoir mixing.

If the quality of finished water is to remain high, specialized, often expensive treatment processes must be used. Although a detailed discussion of lake restoration processes is beyond the scope of this EIS, a summary of treatment methods is included in Appendix J. Appendix K is a listing of Virginia State statutes authorizing specific lake management controls, and the governing body responsible for such assistance.

To improve water quality in lakes and reservoirs, many methods can be implemented which will substantially improve the quality of the water supply. However, without proper controls at the pollution sources, the result of this action will be continued reliance on in-lake treatment facilities at increasing water costs.

The primary goal of water quality management programs is source control of contaminants by site specific and County erosion and sedimentation control planning. In the immediate future, development within the reservoir (and lake) watersheds must be in strict compliance with County regulations in order to minimize the adverse effects of increased erosion. It is the obligation of the County to insure that control regulations are enforced for all developers.

2. Environmentally Sensitive Areas

a. Wetlands

Although no wetlands as defined by the Virginia Wetlands Act exist in the Service Area, several isolated inland wetland areas do exist. If these areas are located in a floodplain, County floodplain policy deters development from them. If these areas are not located in a floodplain, County site development, drainage and stormwater regulations apply: storm sewers or ditching is suggested to dry the areas. The County considers these wetlands to be a health hazard rather than an amenity.

Expansion of the STP will have no direct effects on these inland wetlands, but will treat flows from some development which destroys them. This secondary effect is not necessarily adverse. The elimination of a potential health hazard must be weighed against the preservation of an area capable of groundwater recharge, floodwater storage, runoff purification and wildlife habitat in order to determine whether such destruction is, on the whole, beneficial or adverse. In any case, since the number of such wetlands is small, the secondary effect of the STP expansion on them must be considered very limited.

b. Floodplains

As the STP does not lie within the Falling Creek floodplain, but rather next to Grindall Creek for which no floodplain has been delineated, the primary effects of the STP expansion on the flood conveyance function of the Grindall Creek floodplain will be negligible. The secondary effect of the STP expansion - induced development on floodplains throughout the Service Area - may both increase the flood potential to the development and impair the conveyance capacity of the floodplains, increasing flooding and flood damage downstream. However, due to present County policy, as discussed in Section II. B.6.a., development in floodplains seems likely to be minimal. Therefore most future damage will probably be due to development already on the floodplains, rather than to new development served by the STP. The minimal damages that will occur from new development will, however, be long term. The required flood-proofing will mitigate damages to the development itself. Increased downstream flooding, though probably minimal if there is limited development, is unavoidable.

c. Agricultural Land[43]

At the present time, the State and County land use tax acts are the only explicit mechanisms acting to preserve agricultural land. Failure to preserve such land may be considered a long term, relatively irreversible action. Determination of whether such a failure is adverse or beneficial, and whether enhancement of long term productivity has been sacrificed to local short term uses, would depend on the values placed on agricultural, residential and commercial land uses in light of local, state and national priorities. However, since the suitable agricultural land in the Service Area is slight compared to County areas to the south, and other counties in the Region, the development induced by the STP expansion will not significantly affect the overall Region's agricultural productivity.[44]

d. Artesian Aquifer Recharge Areas

On January 24, 1975, the Virginia SWCB declared Southeastern Virginia as a Critical Groundwater Area.[45] Groundwater in this area is supplied principally through artesian wells in deep geologic strata beneath superjacent Coastal Plain deposits. The source of these aquifers surface in eastern Chesterfield County in outcrops from Route 1 east and including the James and Appomattox floodplains.

Concern was expressed as a result of the 1972 James River 3(c) Basin Study that these artesian aquifers were being over-developed, resulting in groundwater depletion approaching critical proportions. However, an investigation of past recharge assumptions has revealed that principal aquifer water recharge is through vertical leakage, not aquifer outcrops.[46]

An investigation by EPA was initiated to review the relative importance of the aquifer outcrop areas. The results indicate that in order to accurately assess present conditions or to predict the effects of future actions on aquifer quality, a two-year study would be required.

The study also concluded that "...with proper well field construction and aquifer management, there can be full or total development without the problems of over-development." Although protective devices and development procedures necessary to protect the aquifer water supplies do not presently exist, the restriction of development on the floodplains (See Section II.B.6), representing significant recharge areas, offers some protection to groundwater recharge.

e. Woodlands

Forested lands are expected to decrease in the future. The amount of change is indicated roughly by the category "Other" in Table II-8. State and County tax laws allow for reduced taxation of forest areas, but it is uncertain what effect they will have on the rate at which these areas are converted to other uses. The STP expansion may encourage such land use conversion.

This long term, secondary effect is probably irreversible. However, considering the vast amount of forest area still projected to exist in the County by the year 2000, it would appear that such conversion has minimal effects. Therefore, long term productivity is also minimally affected.

f. Soils

The impacts of the proposed project on the soils of Chesterfield County are two fold: increased soil erosion from interceptor and residential construction, and a reduced number of septic tanks discharging effluent into the soil. Chesterfield County's future adherence to the State erosion and sedimentation control standards will minimize damage from residential construction. However, as stated in the Erosion Control section of the County's *Policies and Guidelines for the Preparation of Subdivision Plans*, "It is the developer's responsibility to make sure he is in compliance with the [County's] Erosion and Sedimentation Control Ordinance and Policy." The County does not routinely allocate staff personnel to enforce erosion control: personnel inspect suspected violations of standards usually only after a complaint has been made. If a violation is found, existing County guidelines do not authorize fines but allow denial of the building permit until the situation is corrected. In the past the main problems have been the long time elapsing between discovery of a violation and its correction (averaging two to four weeks), and the fact that the County has no control over erosion resulting from clearing of land, when no building permit is required. Under the proposed County guidelines, which will meet State standards, fines may be imposed from the day of discovery of the violation; the County has control over clearing of land in the above case; and the developer must raise a bond to cover the cost of all corrective measures deemed necessary by the County. However, discovery of violations will still rest primarily on citizens, with some help from routine inspections by County personnel. In summary, minimization of soil erosion from residential development will depend on conscientious efforts by the County and developers and voluntary inspection and monitoring efforts by citizens, within the context of somewhat flexible County and State guidelines which allow for legal action (see II.B.6.).

Interceptor construction is not bound by County or State standards, and so only those construction specifications imposed by the consulting engineer for the County upon his own activity will prevent erosion. Although some effort seems to have been made in this regard, citizen observations of erosion at sites of interceptor construction indicate that the adverse impacts of such construction may still be substantial.

The reduction in the number of septic tanks discharging effluent into the soil will eliminate localized instances of saturated and polluted soil. This impact will be beneficial and long term.

3. Biology

A primary, short-term, adverse impact of the project on the aquatic biota of the Service Area will result from increased erosion, sediment transport, and deposition during pipeline construction. This impact may be most severe on aquatic organisms inhabiting lakes and reservoirs receiving substantial sediment loads, such as in Falling Creek and Swift Creek Reservoirs, and Gregory's Pond. The impact can be minimized, however, by strict enforcement of erosion and sediment control regulations.

A primary, long-term, beneficial impact upon biota of tributary streams will be the improvement of water quality resulting from relief of septic tanks. Reduced effluent loading of these streams should allow them to return to more natural states.

A primary, long-term adverse impact upon the biota of the tidal section of Falling Creek will occur since the quality of the effluent from the Falling Creek Plant is not improved by mixing with Grindall Creek prior to reaching Falling Creek.

The effluent BOD of 30 mg/1 may overtax the reaeration capacity of this reach and produce anoxic conditions.

Addition of chlorine to effluent will have adverse effects upon both fish and benthic organisms in the reach of Falling Creek between Grindall Creek and the James River. Both the Virginia Commission of Game and Inland Fisheries and studies documenting adverse affects of chlorine on biota at effluent concentrations as low as 0.002 mg/1[47] agree on this point. However, the State Water Control Board and Health Department require an effluent chlorine residual of no less than 1.0 and no more than 1.5 mg/1 for purposes of pathogen control. Although study is underway by the State to find alternatives that will reduce or eliminate the residual requirement while still assuring protection of public health, none has yet been found sufficiently satisfactory to permit revision of the present requirement.

Several factors lend perspective in evaluating the adverse impacts of chlorine. One, since the Falling Creek represents only a minor migratory passageway for fish (e.g., herring and shad compared to the James River, overall migratory patterns should not be significantly affected. Second, the James River, itself of no better quality than Falling Creek and sometimes worse, is not adversely affected by flows from Falling Creek in a significant way. Third, if fish kills occur, the Falling Creek Plant as well as all others in the area will be examined by the State for possible chlorine residual reduction. Fourth, commercial shellfishing of the Rangia Clam occurs sufficiently far downstream from the City of Hopewell to be unaffected by the Falling Creek Plant. Finally, the residual will be monitored on a daily basis to ensure that it falls within the prescribed range of 1.0 - 1.5 mg/1.

A secondary, long-term, adverse impact on the aquatic biota of receiving waters may result from the pollution of ponds and reservoirs by urban runoff from development. Sediment derived from construction activities during development may present only a short-term impact, but long-term impacts may result from increased BOD loadings and organic pollution. These loadings may significantly reduce oxygen concentrations in ponds and reservoirs. Also, nutrients entering these impoundments from urban areas may increase phytoplankton production, and the respiration of these organisms and their degradation will further reduce dissolved oxygen concentrations. Oxygen concentrations can conceivably be reduced below the thresholds required to support many desirable aquatic organisms. Increased loadings of heavy metals, pesticides, petroleum products and refuse in urban runoff will also have an adverse effect upon aquatic life.

Since no endangered or threatened fauna inhabit the Service Area, the STP will not have significant primary or secondary effects on them. Non-endangered faunal habitat, however, will decrease as pipeline construction and residential and commercial development take place. It is possible that some fauna restricted to stream valley bottomland will disappear in localized areas. However, the County is presently protecting wildlife habitates at Pocahontas State Park, which provides 7,328 acres of prime wildlife habitat within the County.

Primary impacts on vegetation will be limited to the flora lost along the pipeline corridors, the pump station site and treatment plant site; this will not be significant. A long term effect on vegetation along pipeline corridors is the increased likelihood of growths of Japanese honeysuckle, resulting in the shading out of grass and the strangling of tree seedlings. Secondary effects from residential, commercial and transportation development consist of the loss of some vegetation.

4. Air Quality

Although sewage sludge will not be incinerated, preventing significant direct impacts on air quality, new development served by the expanded STP will affect air quality in the Service Area. A notable long-term adverse impact of the induced development will be the additional traffic-related pollution (primarily CO, NO_2, hydrocarbons and particulates) associated with the improvement of the local highway system. Proposed roads which will serve the new development include Route 288 (the Richmond circumferential) and the Powhite extension, along with widening of critical sections of Route 150 (Chippenham Parkway), Route 10, Genito Road, Huguenot Road and Turner Road.

Sulfur Oxides and Suspended Particulates:

As in the analysis of existing air quality, two types of air quality data, ambient quality and emissions, have been examined. Table III-14 projects ambient air quality for Chesterfield in accordance with the EPA "Rollback Model." It can be seen that the allowed annual increases are not even approached. In fact, projected concentrations for 1985 do not reach the levels permitted by the first year deterioration increment, 58.0 PPM for particulates and 41.6 PPM for SO_2.

TABLE III-14
Projected Ambient Particulate and SO_2 Levels, Chesterfield County

Pollutant	Year				
	1974[1]	1977[2]	1980[2]	1985[2]	2000[2]
Suspended Particulates, annual geometric mean, ug/m³	48.0	49.9	52.9	57.6	66.9
SO_2 annual arithmetic mean, ug/m³	26.6	27.7	29.3	31.9	37.0

Notes: 1. "Virginia Air", Virginia Air Pollution Control Board, Vol. 5, No. 1, March, 1975.
2. EPA 450/4/74-013, "Rollback Model".

The second method is in accordance with an earlier EPA guideline, the Emissions Limitation Plan (ELP), as contained in EPA's proposed rules for the "Prevention of Significant Air Quality Deterioration".[48] The ELP allows in Chesterfield County a 20 percent increase in the base year emission rate for particulates and SO_2. Comparison of this standard with projections for both pollutants in Table III-15 shows that even by the year 2000 the AQCR will still meet these standards.

TABLE III-15
AQCR Standards and Projections for Particulates and SO_2

Pollutant	Base Year[1] Emission Rate (Tons/year)	Allowable Increase (ELP)	Resulting Standard (Tons/year)	1985[2] Projection (Tons/year)	2000[2] Projection (Tons/year)
Total Particulates (Point & Area Sources)	779,666	1.2	935,599	814,625	857,266
SO_2	1,205,387	1.2	1,446,464	1,235,918	1,273,165

Notes: 1. National Emission Data System, 1975
2. Assumption is that point source emissions will remain constant and that area source emissions will increase in direct proportion to population.

Furthermore, even though Chesterfield County contains 15 percent of the land area and 16 percent of the population in the AQCR, it now contributes and will continue to contribute substantially less than this portion of both pollutants, as shown in Table III-16. This analysis of particulates and SO_2 corroborates the above: neither pollutant poses a problem for Chesterfield County through the year 2000.

TABLE III-16
Projected Particulate and SO_2 Emissions, By Source, Chesterfield County

Pollutant	Year	Point Source Emissions (Tons/year)	Area Source Emissions (Tons/year)	Total Emissions (Tons/year)	Percent of Total AQCR Projection
Particulates	1975	1,644	834	2,478	0.32
	1985	1,644	1,004	2,648	0.33
	2000	1,644	1,399	3,043	0.35
SO_2	1975	115,156	653	115,809	9.61
	1985	115,156	786	115,942	9.38
	2000	115,156	1,096	116,252	9.13

Notes: 1. Virginia Air Pollution Control Board, 1975
2. Assumption is that area source emissions will increase in direct proportion to population.

Carbon Monoxide:

Projections to the year 2000 of the localized traffic-induced concentrations of carbon monoxide on the same highway segments analyzed for existing concentrations show that the NAAQS of 35.0 ppm is not approached on any segment (Table A-6). It should be noted, however, that increased VMT generated by indirect sources (such as shopping centers) are not included. Possible localized violations of the standard from these sources must be examined during the planning for each.

Nitrogen Dioxide:

Projection of future NO_2 levels is not possible because of insufficient data. Even if this were possible, however, significant deterioration standards have not been set for this pollutant. The AQCR has been declared Priority I only for particulates and oxidants; NO_2 is not considered to be a principal problem.

Photochemical Oxidants and Hydrocarbons:

As shown in the hydrocarbon section of the existing air quality discussion (II.A.2.), present levels of hydrocarbons in conjunction with levels of oxidants pose significant difficulties in attaining photochemical oxidant standards by 1977. Any increases in mobile or stationary emissions will heighten this situation. In the absence of a concerted effort to reduce the present County hydrocarbon emission rate of 15,416 tons/year to the allowed 8,325 tons/year, or a change in the standard itself, the County may be expected to continue to exceed the standard. The reoccurrence of air pollution alerts is considered probable in the eastern, urbanized section of the County.

5. Public Health

Installation of a public sewerage system will reduce the potential health hazard represented by malfunctioning septic tanks. The possibility of enteric disease and the potential contamination of drinking and groundwater will be reduced. This beneficial impact is both short and long-term. For a fuller discussion of the advantages and disadvantages of septic tanks as opposed to a centralized sewage system, see the relevant parts of section IV.B.1.a. One short term adverse impact of the actual construction at the STP will be generation of dust, which will add to the background level of particulates in the air.

Another effect on public health arises from the County procedure for determining whether to extend service to an area. This procedure consists of a survey of the affected residents. If seventy percent or more desire service, the County will usually construct the lines. The exception to this general procedure is the plan devised by the County to extend sewer service to designated subdivisions within the next five years (1975-1980). As part of this plan, application has been made under the Housing and Community Development Act of 1974 to HUD for funding to install sewage facilities in several existing subdivisions. All subdivisions in the County's plan are listed in Table F-2. Comparison of Map 8 and Map 10 shows how the servicing of these subdivisions increases the amount of existing (1975) development served by the overall County Sewer Program. Of all the subdivisions which have reported malfunctioning septic tanks, only six subdivisions, representing nine malfunctions, are not included in the County's plan. Since EPA policy emphasizes meeting existing wastewater disposal needs before providing for future needs, such a program of service within five years is an essential condition for the granting of Federal funds. The remaining existing development unserviced by 1980 will be gradually connected to the system at the County designated rate discussed and tabulated in Section III.B. (i.e., 540 persons/year), subject to approval by 70 percent of affected residents in each area. These two factors are the primary determinants of how the County handles its long term public health responsibilities in regards to wastewater treatment.

6. Compatibility with the 1995 Land Use Plan

The physical expansion of the STP does not significantly affect the 1995 Land Use Plan. However, the interceptors carrying flows to the STP have significant effects on the Plan. Even though these interceptors are being locally funded, their integral connection with the STP requires that an analysis be made of their potential effects on the Plant.

Map 11 shows the 1995 Land Use Plan and the interceptor routes for Phases I, II and III of the County Sewer Program. The two large striped areas labelled A and B are lands within the Falling Creek drainage area projected to be vacant or in agricultural use even in 1995, even though the interceptors presently traverse these lands. This situation arises because the 1995 Plan was promulgated in October, 1972, when development seems to have been anticipated to locate more in response to the existing road patterns and the presence of Swift Creek Reservoir than to the planned interceptor routings. Development along Route 360, especially in the vicinity of Courthouse Road, together with the Swift Creek Reservoir developments, has necessitated extension of interceptors through the eastern expanse of vacant/agricultural land, labelled A. Development in Upper Falling Creek has required extension through the vacant/agricultural land labelled B. It is possible that the interceptors may result in substantial development of areas A and B. In such a case, the STP and interceptors will have induced development that otherwise might not have occurred and which is not anticipated by the Land Use Plan. Such an effect would be significant, especially if sewer service is extended to such development instead of to previously developed areas with existing problems. The effects of this will be heightened if such development necessitates increased expenditures for other community services - roads, police and fire protection, schools and so forth - that have not been planned for.

Several examples exist of development or rezoning that may have been induced by the presence or planned presence of the interceptors. These examples can be seen by comparing the 1995 Plan with Interceptors (Map 11) to the Existing Zoning, April 15, 1975 (Map 9). Within striped area A (vacant/agricultural according to the 1995 Plan), approximately 700 acres have already been rezoned single family residential. Within striped area B, approximately 600 acres have been rezoned to single family residential, 60 to industrial and 45 to commercial.

The most recent example of zoning contrary to the 1995 Plan is the Hancock rezoning case which occurred in the fall of 1974. In this case, sixty-four acres located just west of the intersection of Routes 360 and 621, previously zoned agricultural and proposed as agricultural on the 1995 General Plan, were rezoned light industrial (compare Map 7 to Map 9). With part of the property located on the shoreline of Swift Creek Reservoir, and all of it within the drainage basin, the property constitutes an environmentally critical area. Although the Planning staff recommended denial of the requested rezoning and a change instead to an application for conditional use for planned development (a simplified version of the 37 conditions placed on the Brandermill development), the Board of Supervisors approved the rezoning to light industrial, with only four minor conditions.

The question therefore arises whether this action will degrade the water quality of the Reservoir, and whether it is a precedent for future rezoning applications within the Reservoir drainage area. The departure of a proposed rezoning from the 1995 General Plan does not appear to affect significantly its chances for approval. In this situation, therefore, two conclusions result. First, the normal regulations governing land development anywhere in the County (e.g., soil erosion) must be rigorously enforced, Second, a management program for land use within the Reservoir drainage area (one is being developed by Ecol Sciences, Inc.) must be adopted and strictly enforced in order to prevent undesired degradation of the Reservoir.

This situation underscores a sentiment voiced in the recent conference on land use issues in Virginia:

> "...most people confuse adoption of a comprehensive plan with the reality of effective land-use control... Without implementation by selective rezoning and carefully drawn zoning and subdivision ordinances, the adoption of a comprehensive plan has little impact upon undesirable land-use trends. The hard decisions come after a plan is adopted... No amount of planning can stop more intensive development when good roads and sewage disposal facilities are readily available."[49]

In the case of Chesterfield, recent rezonings and the fact that the interceptor trunk lines have been sized to accommodate an average gross density of 10 persons per acre over every acre of the STP Service Area are the "hard decisions" which indicate that land use controls may be ineffective in locating development in the areas so designated in the 1995 Plan.

In summary, there exists a limited relationship between the Land Use Plan and County capital programming and budgeting for investments such as sewers. The Land Use Plan is a flexible guide for locating future development; the County does not consider itself bound by it. The location of sewers and roads (such as the proposed Powhite Expressway and Route 288), and amenities such as the Swift Creek Reservoir, may be expected to be the primary determinants of development locations in the future. The ultimate land use pattern thus can be expected to be more the result of other forces than of explicit land use planning as done so far by the County Planning staff.

7. Historic and Archaeological Sites

The primary impacts of both the STP and interceptors on historic sites in the Service Area will be minimal. Traebue's Tavern (site 24, Map 5) is not near an interceptor. Sites 6, 11, and 21 are near areas where construction has already occurred, and sites 11 and 21 have not suffered damage. Site 6, the Chesterfield Railway Bed, parallels Route 60 and has been crossed by the sewer system.

The impact of induced development on historic sites is difficult to predict. It will depend primarily upon the degree to which the public uses existing mechanisms cited in Section II.B.2. for preserving such sites. It is a fact that nationwide over the last several decades, governmental efforts to encourage historic preservation have not been effective: over one-third of the 16,000 structures listed on the Historic American Building Survey (started in 1933) are gone. As John Costonis, Professor of Law at The University of Illinois, has indicated, ". . . when all is said and done, private commitment typically stands as the sole barrier between preservation and demolition."[50]

8. Community Environment

Primary, short term effects on the general community environment of constructing the STP expansion include increased noise and atmospheric dust. During operation of the expanded STP, some additional noise will be produced. At all times, the distance to surrounding residential areas will render the impact minor. During the daytime, the relatively high ambient noise level due to nearby highway traffic will further reduce the impact of noise. Secondary effects include the increased noise and dust of residential and commercial construction, as well as the noise produced by increased vehicular traffic.

Odors emanating from the STP should be minimal with proper plant operation. Odors from the pumping station should have minimal effects because of its remoteness from residential areas. The beneficial impact of the STP will consist of the elimination of odors from malfunctioning septic tanks.

Recreation in the community environment will be affected in several ways. Insofar as the water quality of the tributaries upstream of the plant is improved because of the absence of septic tank effluent discharges, the STP expansion is considered to have a beneficial effect on fishing and general recreational activities. Construction and operation of the STP should have no direct effect on recreational facilities. On the other hand, two long-term secondary effects are adverse. Increased development may impair the quality of ponds and reservoirs through sedimentation, siltation, nutrient enrichment and urban pollutants such as oil and grease; this would decrease their recreational value as well. Second, development will reduce the amount of open space which provides wildlife habitat, hunting area and outdoor recreation area, in addition to its role as a buffer to intensified human activity.

Scenic impacts of the STP expansion include the slightly increased land area used for the facilities. However, trees bordering part of the property will provide some screening effect. The long term, scenic effect of residential and commercial development may be beneficial or adverse depending on each individual's personal viewpoint.

The areas served by sewers may be expected to be somewhat more dense than average County densities obtained in the past when septic tanks were the only means of waste disposal. Smaller lots and increased numbers of multi-family housing units may be expected to gradually change the visual character of the Service Area. If smaller and therefore less expensive lots lower housing prices or rents, those people of moderate income may find it easier to find a home in the Service Area. In fact, low and moderate income housing in the County requires public sewer service, as it cannot occur with large lot, septic tank development. If septic tanks only were used, a larger average lot size would prevail, allowing only those with high incomes to settle in the County. In addition, sewers can accommodate the same amount of growth with less reduction of farmland, open space and forest than can septic tanks.

Development at the increased densities allowed by sewers will increase the feasibility of mass transit. At the present time, only work trip buses on an express or semi-express basis along routes radial to Richmond are economically feasible. Increased use of mass transit will conserve energy and reduce air pollution.

Increased development will result in more traffic on all County roads, but especially Routes 60, 360 and 150. Since these routes are heavily traveled at rush hour, an analysis will have to be made at some point in the future of the need for increasing capacity. The proposed Powhite Expressway, when constructed, will absorb some of the traffic. Until completed, however, traffic and its attendent noise, odor and air pollution effects will continue to increase.

The County disposes of its solid waste at two landfills: Bon Air and Chester. Based on estimates for the growth in population, the increase of solid waste per capita, and increased aid to the City of Richmond for land disposal areas, the County predicts that the landfill at Chester will last six to seven more years and the landfill at Bon Air two to three more years. Plans have been completed with the City of Richmond and Henrico County to hire a consultant to study the best way to meet the needs of the area in the future. A 107 acre tract is available for purchase now and the County has other landfill areas that can be used.

9. Economics

A primary impact of the expansion of the STP is the local share of the cost of the expansion. With a Federal share of 75 percent and no anticipated State share, the remaining 25 percent (roughly $3.4 million) must be raised locally. The cost of the interceptor and collector sewers represents an additional burden of $18 million which will be paid by all County residents and businesses through repayment of bonds. Each resident who receives sewer service will pay a connection fee of at least $300; a yearly service charge of approximately $70, depending on the amount of water used; and an amount for installation of hook-in sewers that averages $400 but may vary from $250 to $1000. The total cost of sewers to each house may be compared to the median family income in the County-$11,174.

The cost of the interceptors and collectors makes it necessary for the County to maintain a 5.8 percent rate of growth on public sewers in order to meet bond obligations using sewer connection fees and service charges. If such sewer revenues are not sufficient to meet the bond obligations, the Board of Supervisors has pledged other tax monies. It is also true for the County that the average sewer connection fee and service charges (user charges) will not pay for the installation of public sewers after a subdivision is developed. This is due to the fact that such sewers must be installed in streets already built and must avoid infrastructure facilities such as water, electricity and telephone lines already in the ground. As a result, the County must actively pursue the sewering of subdivisions as they are built, in addition to meeting the needs of existing development, in order to meet fiscal demands. In fact, the County states that "A great concern is that development be on public utilities from the beginning so that when individual wells and/or septic tanks fail, as they inevitably will, the County will not be saddled with a large number of such situations to cause the County to be stretched fiscally to provide and maintain a healthy and safe environment."[50] The question of whether the user charge system of financing waste treatment induces unnecessary new growth, while at the same time making more difficult the attainment of the stated EPA objective of meeting the wastewater needs of existing development, is currently under study by EPA.

Secondary impacts may be discussed from two points of view. First, centralized sewage treatment is part of a growth pattern that can in some cases be a vicious circle leading to an excessive rather than an appropriate growth rate. The cost of sewers may induce additional new growth so that the user charges are able to pay for the sewers without becoming exorbitant. New growth will lead to increased County expenditures for supportive services and facilities. Increased expenditures may - and in Chesterfield, do - lead to demands for an increase in the tax base (i.e., commercial and industrial development) to pay for such expenditures. Commercial and industrial development most often requires sewers and centralized treatment. At this point the circle is complete. Any step in the pattern may be cited as logical justification for the next. Therefore, to aovid an uncontrolled growth spiral, it must be recognized that the solution to any step in the pattern may become itself a stimulus for continued growth.

Decisions as to sewering and the amount and location of commercial and high density residential development must be carefully weighed in light of these conflicting effects. Until such time as Chesterfield develops a cost-revenue methodology for assessing the net fiscal impact of growth on the County budget, as has been done elsewhere,[52] the ultimate effects of continued growth will remain very difficult to predict with confidence. Sea Pines of Virginia, Inc., has, as an example, performed such an analysis for the Brandermill development.

The second perspective for examining the economic impact of the project is that of the individual citizen. Property taxes have been rising in the last several years. On the other hand, there are three factors which might counterbalance this adverse effect. For one, the benefits from increased County expenditures might be perceived by the individual as being worth the increased taxes. Increased job opportunities might also be a byproduct of the growth that is causing increasing property taxes. Finally, expected increases in per capita income[53] might compensate for increased County taxes. In summary, the net secondary effect of sewer-supported growth on the economic condition of the individual citizen, as well as the County budget, must be considered a matter that would require more study before any final conclusions could be reached.

10. Natural Resources and Energy Use

A primary effect upon natural resources caused by the STP expansion is the use of building materials in the construction of the plant. Materials used during the operation of the STP such as chlorine, sand, chemicals and fuel constitute an additional irretrievable commitment. Of greater significance is the use of natural resources in satisfying demands occassioned by induced residential and commercial growth. This, however, is difficult to quantify and is a natural concomitant of growth wherever it occurs.

Water is a natural resource which can and should be conserved. Savings in home use are possible through a number of methods. A study done for the EPA, *Demonstration of Waste Flow Reduction from Households*, evaluates several methods.[54]

The primary effect of the STP expansion on energy will consist of the demand for electricity to run the plant. The electricity will be supplied by the Virginia Electric Power Company from its 1,383,000 Kw Chesterfield facility. The secondary effects - the demand by residential, commercial and transportation sources for energy - are more difficult to predict.[55] Implementation of energy conservation measures will depend on the individual developer and the building codes under which he operates. At present, Virginia's Uniform Statewide Building Code is the final authority. If Federal Housing Administration financing is involved, its minimum property standards apply, in addition to State regulations. The Virginia General Assembly is currently considering the feasibility of setting insulation standards for the Code. However, until such standards are set, the potential savings in residential energy use will depend solely on the present State Code and FHA standards.

The spatial design of development on a large scale affects energy usage. *The Costs of Sprawl*[56] shows that increased densities of development as well as community planning to increase compactness of developments both save energy. The saving derives from decreased residential heating and air conditioning requirements and decreased automobile use. The increased use of sewers in Chesterfield provides the potential for achieving this compactness and increased density of development. At the present time, the spotty land use pattern (see Map 6) does not show a concerted effort to attain compactness of development. However, the 1995 General Plan shows some improvement in compactness. In addition, increased densities are expected to prevail in the future with smaller lots and increased multifamily housing.

CHAPTER III - FOOTNOTES

34. The relevant regulations are: 1) Virginia Erosion & Sedimentation Control Handbook. 2) Chesterfield County, Chapter 16 A & B, Erosion and Sedimentation Control. 3) Proposed Richmond Regional 208 Areawide Planning Agency. See Section II.B.6 for detailed discussions of these regulations.

35. "Policies and Guidelines for the Preparation of Subdivision Plans and Site Development Plans for Roads, Drainage, and Erosion Control", adopted April 23, 1975 by Chesterfield County Board of Supervisors.

36. For description of the three programs, see Appendix G. Information and data are being collected and are therefore not available for inclusion in the Draft EIS. However, nitrogen and phosphorus loading rates, used in the Appendix D modeling process, have used EcolSciences' interim values as a data source.

37. However, the agreement between the County and the developer of Brandermill reserves to the County the right to control uses which will be detrimental to the use of the reservoir as a water supply.

38. The following is an excerpt from the final report: "With regard to the present water quality condition of the reservoir, there is little doubt that it is already eutrophic. It is experiencing heavy growths of green and blue-green algae, and will no doubt become more eutrophic with time. Any development in the area would accelerate the degradation of the reservoir."

39. The intent of the study was to identify all possible effects of the development, to provide alternatives to potential negative impacts, and to further suggest criteria for the implementation of building restrictions and controls. See Appendix H for the complete document.

40. In light of the Hancock rezoning case (Section III.C.6), it is apparent that presently a comprehensive watershed management program has not been formulated.

41. This would include: nutrients and sediments, pesticides, surfactants and oils.

42. Chesterfield County is now in the process of preparing its own Erosion and Sedimentation Control Ordinances. See Section II.B.6.

43. A July, 1974 report by the RRPDC ("Agricultural Land in the Richmond Region") states: "The nation's supply of land suitable for farming is decreasing.

"The local governments of the region are following a land use policy which promotes low density development. If this trend continues, particularly in the suburban counties of Chesterfield, Hanover and Henrico, large amounts of agricultural and forest lands will be devoured through the process of urban development.

"Based on certain assumptions, the State Department of Agriculture estimates that if present land development trends continue in Virginia there will be an inadequate supply of agricultural land available in the year 2000 to meet public demands for foodstuffs; there will be a deficit of 938,095 acres of suitable agricultural land."

44. Chesterfield County has approximately 6 percent of the Region's Class I agricultural land (the best farmland by the Soil Conservation Service national agricultural capability classification, with no limitations), 22 percent of the Region's Class II land (that with some limitations), and 26 percent of the Class III land (that with limitations that reduce the choice of plants, or require special conservation practices, or both). The Service Area, however, has only a minor portion of the County's Class I land. Most of the prime agricultural land is located in the southwestern section of the County, outside the Service Area. The STP and almost all of the interceptor lines are located in agricultural classifications IV through VII (not well suited for agriculture). Collectors and hence development occupy or are planned to occupy much of the remaining land, which is predominantly Class III with some Class II land.

45. Authorization by "The Groundwater Act of 1973," Chapter 3.4, Title 62.1, 1950 Code of Virginia.

46. See Appendix E. On an area basis, one unit of aquifer outcrop area will allow water to infiltrate at a rate 30 percent greater than an equivalent unit of coastal plain sediments. Thus, consideration has been given to protect these outcrops from future development. The Richmond Regional Planning District Commission is currently projecting water supplies and demands as well as estimating the effets of varied land use alternatives to determine the effects on groundwater quality and quantity.

47. Chesapeake Research Consortium, Incorporated, *Effects of Sewage Treatment Plant Effluent on Fish: A Review of Literature* (Center for Environmental and Estuarine Studies, University of Maryland, March, 1975), pages 46-62.

48. Originally proposed in 38 F. R. 18986 (July 16, 1973) and reproposed in 39 F. R. 31000 (August 27, 1974).

49. Horkan, George A., Jr., "Legal and Related Problems in Existing Land Use Controls," in *Land-Use Issues, Proceedings of a Conference*, Marshall and Ashton, eds. (Virginia Polytechnic Institute, Blacksburg, Virginia November, 1974), pages 64-65.

50. John J. Costonis, *Space Adrift*, University of Illinois Press, 1974.

51. Supplemental data from Chesterfield County, May 27, 1975.

52. Muller, Thomas and Grace Dawson, *The Fiscal Impact of Residential and Commercial Development: A Case Study*, (The Urban Institute, Washington, D. C., 1972).

Sternlieb, George, *Housing Development and Municipal Costs*, (Center for Urban Policy Research, Rutgers University, New Brunswick, New Jersey, 1973).

See also *Fiscal Impace of Land Development*, (Urban Institute, 1975).

53. Environmental Assessment, page 273.

54. Examples of these methods are: 1) Water requirements for toilet flushing can be substantially reduced by commercially available devices. Shallow trap toilets reduce flushing water by 25 percent and total home water use by approximately 7 percent, and are "definitely warranted for new homes or necessary replacements." Toilet insert devices which convert conventional toilets to a dual cycle operation (one high and one low volume flush) reduce flushing water by 18 to 26 percent and total home water use by roughly 3 to 8 percent. Due to their low initial costs and their ability to affect existing as well as new homes, these insert devices have special potential. 2) Flow limiting shower heads have the potential to reduce not only water consumption, but also hot water heating costs. 3) A system which reuses wash water for toilet flushing and lawn sprinkling reduces total home water use by 26 percent, or 3 to 4 times as much as toilet devices. 4) The bathroom flow reduction devices (#1 and #2) save the homeowner money: when compared with typical water use rates, the devices cost less than the price of the water saved. The wash water reuse system costs more than the price of the water saved, but if the price for treatment of wastewater by septic tanks in poor soil is added to the price of water, the reuse system costs less than this combined price of the water saved.

55. In the case of new residential development, various building practices largely determine the amount of energy required to heat and cool a house. Recent studies show that leakage through cracks and conduction through walls, floors and ceilings account for approximately 85 percent of all energy losses. Hence losses can be reduced "through the use of high quality materials and proper building techniques to reduce leakage; . . .installation of adequate insulation to restrict conduction losses; and . . .designing and siting the house in ways which minimize the negative impact of particular climatic conditions." (See David Myhra, "Let's Put an End to Energy Waste in Housing," in *Planning, the ASPO Magazine*, Vol. 40, No. 7, August, 1974).

56. *The Costs of Sprawl*, CEQ, HUD, EPA, April, 1974.

IV. ALTERNATIVES

Planning and designing a wastewater treatment system consists of a series of analyses and decisions which successively determine the area to be served, the capacity required, and the best way to collect, convey, treat and dispose of the area's wastes. When comparing alternatives for each of these system features, the most important criteria are engineering feasibility, cost-effectiveness, and environmental impact.[57]

The various system elements are interrelated such that the choice of one limits the possible choice of each of the others. Thus, for example, once the Service Area and its wastewater flows are defined, the candidate receiving streams must have the assimilative capacity and low-flow quantity to accept the treated effluent. Further, water supply intakes should be sufficiently distant from effluent discharges. The degree of treatment at the plant, and therefore the treatment processes and land requirements, are then chosen to prepare the effluent for the stream. There are many other examples of system interdependence involved in wastewater planning and design.

This chapter discusses alternatives from several points of view. Within the section on centralized alternatives are discussions of plant location, treatment processes, sludge processing and effluent disposal. Decentralized alternatives considered include various on-lot systems and package plants. Finally, because this environmental impact statement focuses on the amount of treatment expansion and the timing of the expansion of the Falling Creek STP, this chapter concludes with a cost analysis of the several feasible expansion increments identified in Section III.B. This information and the environmental impact data of Chapter III has been developed to help EPA decide whether the plant should be expanded immediately to 12 MGD - as proposed by Chesterfield County - or whether a modular expansion over many years would be more cost-effective and/or environmentally acceptable.

A. CENTRALIZED

A centralized approach to wastewater collection and treatment in the design Service Area consists of an extensive network of collector and trunk sewers conveying wastewater to a single treatment facility within one or adjoining drainage areas. Frequently, pump stations and force mains are components of a system where topography prevents the use of gravity flow.[58]

1. Location of Treatment Plant

In evaluating alternative locations for a plant to serve the Falling Creek Service Area, it is important to consider that location of new facilities at the existing 6 MGD facility will be more cost-effective than at a new site which cannot utilize what already exists.

Because the proposed project is a component of the County's Phase I Sewerage Improvement Program, a single regional treatment facility to serve most of Chesterfield County was considered. Such a plant would be required to treat approximately 15 MGD by the end of Phase I (1980), with a single discharge to the James River. While there are advantages inherent in consolidating all treatment at one location (e.g., less land and operating personnel required), the capital and operating costs associated with the greatly expanded conveyance and pumping facilities and the assimilative requirements of a single point discharge are fundamental disadvantages which are not easily overcome. In the absence of any significant advantages to this approach, a site more consistent with natural drainage patterns should be selected.

An examination of the fifteen drainage basins in Chesterdield County[59] shows that the four basins in the proposed Falling Creek Service Area (i.e., Falling, Pocoshock, Pocosham and upper Swift) contain about half of the County's housing units. Approximately 60 percent of these units are not served by public sewerage. These drainage basins can be served by treatment plants in various locations, although a location at the existing Falling Creek STP site maximizes both the use of gravity flow and use of existing facilities. Thus, again, in the absence of contravening information - economic, engineering, or environmental - there are no benefits to be derived by serving this proposed service area at a new site.[60]

2. Treatment Processes

To satisfy design requirements for an EPA construction grant, a proposed treatment facility must provide at least secondary treatmelt[61] and produce an effluent which conforms with the water quality standards of the receiving stream.[62] In most cases, there are many different treatment systems which are capable of meeting these requirements; the design engineer must choose the sequence of unit processes which most economically produces an accpetable effluent and sludge, consistent with land availability and demands of the components of the entire treatment process.

Table IV–17 lists the generally available treatment processes and the corresponding achievable removal efficiencies of BOD_5, suspended solids, and phosphates.[63] The proposed process - activated sludge with chemical precipitation and mixed media filtration - is capable of achieving the effluent limitations required by the State Water Control Board.

3. Sludge Processing

Sewage sludge is the relatively concentrated, residual organic and inorganic solids and water that is systematically separated from the wastewater during the treatment processes. As is the case for wastewater treatment, there are several alternative systems in use for the processing of sludge. The processes presently employed at the Falling Creek STP are anaerobic digestion, chemical conditioning, vacuum filtration and landfill disposal.

Five steps are involved in most sludge processing systems:

- Stabilization: reduction of volatile solids, destruction of pathogens, and conversion of some material to other forms.
- Conditioning and Recycling: preparation of the total sludge and water complex in order to reduce costs of dewatering.
- Dewatering: reduces thermal requirements if incineration is used or volume if incineration is not used.
- Reduction: reduces area required for ultimate disposal, reduces transporation requirements, prepares sludge residual for peuse on land, and sometimes recovers thermal energy for in-plant use.
- Disposal: ultimate depositing or application of the residual material on land or water.

Table IV–18 identifies the various unit processes available for each of the sludge processing steps.[64] From the many combinations possible, five alternative systems have been considered:

Alternate I (base case)	Anaerobic digestion, chemical conditioning, vacuum filtration, land fill.
Alternate II	Anaerobic digestion, chemical conditioning, vacuum filtration, dry land disposal.
Alternate III	Anaerobic digestion, liquid land disposal.
Alternate IV	Heat treatment, vaccum filtration, incineration Land Fill
Alternate V	Chemical conditioning, vacuum filtration, composting, dry land disposal.

Details of each of these alternatives as well as their costs, energy consumption, and environmental impact are discussed in Appendix L.[65] This information is summarized in Table IV–19, which also lists the major advantages and disadvantages of each.

It is recommended that sludge treatment facilities at the Falling Creek STP be designed in accordance with Alternate I - anaerobic digestion, chemical conditioning, vacuum filtration and landfill. This recommendation is based on lower costs, potential energy production and flexibility of disposal, offset by only a minor increase in consumptive land use. It is further

TABLE IV-17
Maximum Sustainable Sewage Treatment Efficiencies
(Percent Removal)

Process	BOD_5	Suspended Solids	PO_4
Primary Sedimentation	35 (1)	50 (2)	2-5 (use 3)
Conventional Activated Sludge	85-92 (depending upon design (3)	85-92	10-30
Contact Stabilization	85-90 (use 87)	85-90 (use 87)	20
Extended Aeration	85-90 (use 87)	85-90 (use 87)	8-15 (use 10)
Aerated Lagoon (with final settling)	87 (50-80 without settling)	85	<5
Trickling Filter	82-90 (use 87)	80-88 (use 85)	20-30 (use 25)
Secondary Coagulation and Filtration	94	99	95
Stabilization Pond	70-90 (use 80)	70-90 (use 80)	<5
Polishing Pond	3 Additional	3 Additional	0
Septic Tank-Sand Filter System	90-95	90-95	—

(1) Based on Area Overflow rate of 600 $\frac{GPD}{f^2}$,

(2) Removal of up to 60% is possible.

(3) For units designed in accordance with the "Ten State Standards," a value of 90% removal can be used.

TABLE IV-18
Available Sludge Unit Processes

	Stabilization	Conditioning	Dewatering	Reduction	Disposal
	Composting				
		Chemical Conditioning	Vacuum Filtration	Incineration	Landfill
	Aerobic Digestion				
Input Sludge		Elutriation	Centrifuge	Wet Air Oxidation	Liquid Land Disposal
	Anaerobic Digestion				
		Heat Treating 300-500°F	Drying Beds	Flash Drying	Dry Land Disposal
	Pasteurization 200°F				

TABLE IV-19
Comparison of Sludge Processing Alternatives for Expansion to 12 MGD

Alternative	Annual Cost Difference	Energy Difference (bbl oil/yr)	Advantages	Disadvantages
I (base)	(base)	(base)	- lower cost - highest energy production - no health hazard - flexibility of disposal route	- difficult to operate - no recovery of nutrients - consumptive land use
II	$ 29,000	200	- costs comparable to base - high energy production - recovery of nutrients	- difficult to operate - may not be sufficient land - pollution hazard from improper application
III	$215,000	2,500	- small energy production - recovery of nutrients	- difficult to operate - may not be sufficient land - pollution and public health hazard from improper application - highest cost
IV	$150,000	4,600	- costs comparable to base - reliable operation - no health hazard	- no recovery of nutrients - consumptive land use - minor art pollution - requires energy input
V	$106,000[2]	5,300	- recovery of nutrients	- may not be sufficient land - pollution hazard from improper application - requires energy input

Notes: 1. Land costs not included.
2. Does not include any costs for carbon carrier.

recommended that consideration be given to using a portion of the digested sludge for agriculture in the County.

4. Effluent Disposal

With the exception of the water removed from the treatment system with sludge, the partially-purified (e.g., 95 percent removal of BOD, etc.) water which is produced by the treatment process must be disposed. Three alternatives were considered for effluent disposal: surface discharge, land treatment and disposal, and deep or shallow well injection.

a. Surface Discharge

The existing Falling Creek STP effluent - and that of the proposed expansion - is discharged to Grindall Creek, approximately 1,500 feet from its confluence with Falling Creek. Falling Creek meets the James River 1,300 feet downstream from this confluence. Such discharges to a stream adjacent to the treatment plant is the simplest and least expensive means of effluent disposal.

A direct discharge to the James River near Falling Creek would have a more adverse effect on the river in a reach which experiences an oxygen sag. Further, the upstream water quality of Grindall Creek is lower than the quality of the effluent. Thus, it appears that in the short term (assuming a surface water discharge), the expanded Falling Creek STP should continue to discharge its effluent to Grindall Creek. However, it is likely that water quality of the James River (and/or Grindall Creek) will improve as upstream point and non-point pollution sources are better controlled. EPA recognizes that an outfall to the James River may become environmentally preferable within a few years, and will monitor this situation closely. The Areawide Waste Treatment Management Plan, authorized by Section 208 of the Federal Water Pollution Control Act Amendments, provides a mechanism for continued local and federal interest during the next years.

b. Land Treatment and Disposal

Land treatment of effluent from a secondary treatment facility such as the Falling Creek STP, provides another means of completing the wastewater renovation process without requiring a point discharge to surface waters. Land requirements of this process would probably dictate the use of a site in the less-developed western part of Chesterfield County.

Assuming the land treatment and disposal process would use spray irrigation, chlorinated activated sludge treated effluent (mixed media Filtration would not be necessary) would be pumped through a 36 inch diameter pipeline to an undetermined site about 20 miles away. Here, a 360 MG reservoir would store sewage up to 30 days if weather conditions do not permit spraying. Pumps would draw from this reservoir and distribute water to sprinklers in fields via a network of pipes.

The rate at which treated sewage can be applied to land depends upon the soil characteristics, topography, climate, effluent peaking tendencies, the ability of particular crops to utilize nutrients, and the concentration of nutrients and heavy metals in the sewage. Local conditions, rather than general guidelines, determine the proper application rate for a particular location. A pilot study would be necessary to determine the safe application rate, guidelines for runoff control and potential crop benefits.

To obtain a preliminary estimate of land requirements, it was assumed that corn would be grown and could utilize 140 pounds of nitrogen per year per acre. If treated effluent contains 20 mg/1 of nitrogen, 5,200 acres will be required to treat 12 MGD.[66]

Table IV–20 estimates the capital costs of the important physical components of the system; land costs are not included because of the sensitivity of price to the actual site chosen. Operating costs have not been estimated, but would be high because of energy requirements.

TABLE IV-20
Capital Costs For Major Components Of a 12 MGD Land Treatment System

Item	Present Cost[1]	Annual Cost[2]
36" diam. pipe, 20 mi[3]	$ 8,400,000	$ 792,000
Pumping stations, 2[3]	$ 2,200,000	$ 205,000
Distribution system[4]	$11,440,000	$1,080,000
Reservoir	$ 3,000,000	$ 283,000
TOTAL	$25,000,000	$3,460,000

[1]Not including purchase of land. Engineering News-Record Construction Cost Index = 2,200.
[2]7% loan for 20 years.
[3]Reference: "Cost Estimating Guidelines for Municipal Wastewater Facilities," EPA, 1972
[4]Based on a system in Charles County, Maryland.
Reference: "Survey of Facilities Using Land Application of Wastewater," July 1973.

Energy would be required to lift the water to the disposal site, overcome the pipe friction in transmission and to spray the water over the fields. The two pumping stations together would have to overcome a system head of almost 500 feet. Average energy costs would amount to the equivalent of 16,000 barrels of oil per year.

Environmental Impacts

Land Use. Under the assumptions made, over 5,000 acres of land would be committed indefinitely to sewage disposal. However, the syqtem would produce cash crops from nutrients which would otherwise be wasted.

The pipeline right-of-way is not expected to create serious difficulties because elevation requirements of a pressure pipeline are not critical.

*Public Health.*Land disposal would result in recycling treated effluent back into the County's water supply. In itself, this does not present a direct threat because a properly designed and operated land disposal system can produce a high quality effluent. However, an element of risk would be present from improper operation or unforeseen circumstances.

Water Quality. Land disposal would prevent BOD and nutrients from the Falling Creek STP from reaching the James River. However, the effluent BOD is predicted to be acceptable for discharge to the James River. Furthermore, the James River has not been shown to be sensitive to nutrients from sewage.

Aesthetics. The spraying site would have an appearance the same as any other irrigated field. No odors or other unpleasant effects are anticipated.

The major benefits of land treatment and disposal of effluent are the replenishment of groundwater supplies in the western part of the County and the use of waste nutrients for growing crops. An effluent discharge to (Grindall Creek and) the James River would be eliminated; however, the loading to the river is within the limitations of the James River Basin Study. The main disadvantage of a land treatment system is the high capital cost, higher than the Falling Creek STP itself. Further, because there have not been any land treatment systems of significant size operated in Virginia, smaller systems should, if practical, be designed and operated before several-MGD systems are used.[67] The experience gained will benefit systems of larger capacity.

c. Deep or Shallow Well Injection

Deep well injection requires the construction of a well which discharges into a formation far below the surface and isolated from any fresh water strata. The method is best used for concentrated, toxic waste which cannot be disposed of into surface waters because of low stream flows. In effect, it is a permanent storage method for totally unusable wastes.

Shallow well injection provides for a more useful benefit in the disposal of wastewaters. Effluent that receives sufficient treatment can be used to recharge groundwater sources. However, the method is usually employed where surface water discharges are not desirable.

EPA's policy on this method of disposal is stated in Administrator's Decision Statement No. 5, dated February 6, 1973. This policy is designed to protect subsurface formations from pollution or other environmental hazards, insure that engineering and geological safeguards are adequate, and to encourage development of alternative means of disposal which afford greater environmental protection.

The effluent from the Falling Creek STP will be suitable for discharge to the James River. Therefore, there does not appear to be sufficient cause to assume the uncertainties and risks of well disposal.

B. DECENTRALIZED TREATMENT ALTERNATIVES

1. On-lot Treatment Systems

a. Septic Tanks

Traditionally, when comparing the septic tank alternative[68] to centralized sewer service, it is assumed that septic tanks have a shorter design life than centralized service, and therefore are not a long-term solution of a community's waste disposal needs. In fact, the Virginia Department of Health prefers centralized service, wherever feasible, as the ultimate treatment method.

Research and operational developments in septic tank design and use have progressed sufficiently to require a close examination of septic tanks as a potentially viable long-term alternative to centralized sewer service. This discussion consists of a brief summary of these research and operational developments and the applicability of these developments to the Falling Creek Service Area.

Research and Operational Developments:

Research sponsored in the early 1960's by the Federal Housing Administration,[69] made a number of recommendations for preventing failure of septic tank percolation fields. Among these was the suggestion that the field needed rest periods to maintain a good infiltration rate. Following this suggestion, Fairfax County, Virginia, amended its sanitary ordinance in 1973 to "... require installation of all future absorption systems... in two separate sections with separate distribution boxes and a flow diversion valve or some satisfactory method for utilizing half of the total system for a period of time, then switching to the other for a similar period."[70] Other research has led a number of people to conclude that regular maintenance of septic tanks, regardless of design or operation mode, is the *sine qua non* of improved septic tank performance.[71] Several septic tank management systems (e.g., in California,[72] Switzerland and Sweden[73]) already exist. Suggestions for public and/or private management of septic systems have been made to the State of Virginia.[74] In addition, general ecological and sociological advantages of individual units have been stressed by some: beneficial nutrient return to soil and vegetation rather than possibly detrimental return to streams and lakes; replenishment of groundwater and maintenance of the hydrologic regime; and suitability of the decentralized approach for that segment of the population which prefers low density living.[75]

One factor which is important in comparing centralized to decentralized waste treatment systems is cost. Such a comparison is rarely done as a matter of course in present engineering practice. However, as it becomes recognized that individual waste treatment in some circumstances can be technologically and environmentally equal to centralized sewer service, a cost comparison will become an important criterion in choosing between the two alternatives for any particular area. Several studies have indicated that individual treatment may be less expensive. A 1971 study done for Norwich, Vermont showed an annual cost savings of $120 to $314 per household,[77] while an analysis of a California development showed a savings of approximately $1,000 per unit in initial costs and $1,000 per unit in maintenance costs.[78] Another estimate for low-density residential development shows the cost of the average on-site system to be $1,600 and the individual share of the centralized system $2,100.[79] A Mitre Corporation study predicts a potential savings of $3 billion in the United States if certain policy decisions are made in support of improving and advancing on-site treatment practices.[80] An analysis done by Downing in 1969 of urban and rural sewer service for an area in Wisconsin found that septic tanks are cost competitive with centralized treatment at not uncommon residential densities when located sufficiently distant from the treatment plant.[81] Generally, the potential for money savings seems to exist when the circumstances of a particular service area are appropriate.

Application to Service Area

The alternative of individual waste treatment was examined in detail for the Falling Creek Service Area. A general methodology for any area consists of two steps. First, since septic tanks would be realistic alternatives to centralized service only in areas where septic tanks are suitable, delineation of these areas must be done using both natural and man-caused criteria. Second, a cost comparison should then be made between centralized service to all areas, and a mix of centralized service to the unsuitable areas and septic tank use in all suitable areas. The assumption made is that proper design, installation and maintenance of septic tanks would result in equivalent technical and environmental performance compared to centralized service.

In the case of Chesterfield, a recent survey supports this assumption. Conditions responsible for septic tank permit application rejections and/or malfunctioning units were estimated as: 32 percent soils, 15 percent design, 5 percent faulty installation, 10 percent overload, 16 percent maintenance, and 22 percent age.[86] Assuming that proper management would prevent future use of unsuitable soils, and would employ correct design, installation, loading and maintenance procedures, the only uncorrected condition - age - would be reduced considerably. The results would thus likely be equivalent performance.

The primary criterion in developed regions for delineating areas suitable for long-term septic tank use is the adequacy of the drainfield area for expansion. This area must be adequate in quantitative terms (e.g., lot boundaries, proximity to wells and drainage swales) and qualitative terms (e.g., proper soil, geologic and topographic conditions). However, existing County records are not detailed enough to judge such adequacy; a lot-by-lot survey would be necessary.[82]

In defining the suitability of undeveloped land for long-term septic tank use, a map classifying soils into suitability categories by series or type is only the first step. The process of land development - primarily subdivision and road alignment - will in most cases reduce the amount of usable suitable land.[83] Without knowing future lot boundaries and road alignments for the Service Area, any attempt to delineate future suitable areas is unrealistic. Therefore, a map compositing suitable areas for both developed and undeveloped land is impossible to construct without much speculation and additional work.

The cost comparison requires a septic tank life span survey, as was conducted by Fairfax County,[84] in order to ascertain the average septic tank life. However, County records are not complete enough, especially for older septic tanks, to produce valid results. Even if the records were complete, the fact that they are based on owner complaints rather than periodic inspections of all units in the Service Area would seriously underestimate the problem. An accurate life span curve is thus impossible to contruct. However, an estimate provided by the County of a 15-year average life span can be used with Downing's sewer cost study to obtain a rough cost comparison between septic tanks and centralized sewer service. Table IV–21 is adopted from Downing's study.[85] Equilibrium year is defined as the minimum number of years that septic tanks must perform properly for their annualized costs, including maintenance and replacement, to be competitive with sewer service. It is seen from this table that septic tanks are more competitive for low residential densities and relatively larger distances from the treatment plant.

Application of the figures in Table IV–22 to the Falling Creek Service Area must be done cautiously because of differences in location, relative price level, interest rates, and soil conditions.

TABLE IV-21

Equilibrium Year for Comparing Septic Tanks and Sewer Service, By Residential Density and Distance to Treatment Plant

Residential Density (Persons/acre)	Estimate of Sewer Cost	Distance from Subdivision to Treatment Plant (Miles)					
		5	10	15	20	25	30
0.4	Low	31	26	21	19	18	16
	High	11	8	6	5	5	2
1	Low	35	35	32	27	23	21
	High	15	9	8	7	6	4
4	Low	x	x	35	35	34	29
	High	31	21	14	13	11	9
16	Low	x	x	x	35	35	34
	High	x	35	32	25	19	17

Source: Paul B. Downing, "Extention of Sewer Service at the Urban-Rural Fringe", in *Land Economics* (Vol. 45, Feb. 1969).

Notes: 1. "x" indicates that septic tanks can never be expected to be cost-competitive with centralized sewer service for that combination of residential density and distance from treatment plant.

2. In the "Estimate of Sewer Cost" column, "Low" represents the situation where interceptor sewers have been constructed to the subdivision in question as well as to adjacent areas; here the subdivision pays only its proportional share of the construction cost. "High" represents the situation where the interceptor sewers serve only the subdivision, hence it must pay the full construction cost.

With these limitations in mind, it is instructive to look at the Service Area using the "equilibrium year" concept. It appears that for the prevailing life span of 15 years, all portions of the Service Area except the western reaches farther than 20 miles from the plant are probably more economically served by sewers than septic tanks.

TABLE IV-22
Equilibrium Year of Septic Tank Life Span, by Sewer Cost and Distance to Treatment Plant

Distance from Plant (Miles)	Equilibrium Year (years) Lower Sewer Cost	High Sewer Cost
5	X	X
10	X	23
15	35+	17
20	35	15

Notes: 1. Six persons per gross acre is assumed.
2. "X", "Low", and "High" Sewer Cost are defined as in Table IV-21.

A 1973 study of sewer service costs in several single family residential suburbs of Milwaukee, Wisconsin - perhaps a closer approximation to Service Area conditions than Downing's - showed a cost of roughly $1,500 per acre for densities similar to those in the Service Area (e.g., 11 persons per net acre, or approximately 6 persons per gross acre at the prevailing land use mix in the Service Area).[87] Converting 6 persons per gross acre to roughly 2 single family houses per gross acre, the cost of centralized service becomes $750 per house. Comparing this to the prevailing septic tank cost $1,050, it appears that centralized service would be cheaper. In sum, in the absence of a cost comparison specific to the Service Area, and a more definite estimate of on-lot treatment systems' average life span, sewer service for the great majority of the Service Area is economically justified.

Two points are related to this subject. One, the 667 rejected lots of a total 6,428 recorded as of October, 1974 estimates the number of lots denied a permit to build a home, due to soils not suitable for septic tanks or the absence of sewer service. This 10 percent ratio of rejected to recorded lots reaches as high as 50 percent for individual subdivisions. This represents substantial interference with the land development process and individual property rights. Occasional disputes do result between the County and landowners, but have never gone to court.[88] One means of reducing the number of rejected lots is to revise the traditional soil limitations criteria for on-site disposal. This has been done on an experimental basis by Bouma at the University of Wisconsin, who found that "New technology, based on a detailed analysis of liquid movement and associated purification, can be used to overcome severe and very severe limitations and to reduce slight and moderate limitations."[89] The increased area suitable for development on a non-sewered basis for three Wisconsin counties, as well as the land use and policy implications, are discussed in another report.[90] Application of this concept to Chesterfield would depend on evaluation by relevant authorities, such as the State Department of Health, Chesterfield Health Department, and the Soil Conservation Service.

A second point deals with the possibility of variable lot size zoning in order to allow adequate space for good septic tank performance under all circumstances. The legal implications of such zoning, as well as possible interference with subdividing and road alignment, present some problems. However, such zoning has been recommended to all counties by the State Department of Health since 1974. Chesterfield County is beginning to implement this procedure by requiring adequate area within all lots for expansion of the drainfield if the original drainfield fails. This policy should ease the pressure for sewer service by gradually reducing the number of lots with malfunctioning drainfields and no room for expansion.

b. Other On-Lot Treatment Systems

Two other on-lot system alternatives have been considered: self-contained systems and aerobic units.[91] There are two classes of self-contained systems, distinguished by mode of operation: composting and incineration. The advantage of both is that water is not used, eliminating the discharge of pollutants to any surface or ground water; household water use is reduced by approximately 25 percent. Also, since soil suitability is not a limiting factor, development served by self-contained systems has more freedom of location and opportunity for higher density service than if served by septic tanks. Thus, for example, residential development need not encroach as much on farmland because of the mutual need for suitable soils, as now happens where septic tanks are used. The possibility, present with septic tanks, of a forced conversion to sewers when the system fails with inadequate room for drainfield expansion, does not occur with self contained systems. The composting system, in addition, produces a humus with good fertilizer value, consumes little or no energy and requires little maintenance. One available system even accepts kitchen garbage. The cost of the compositing systems ranges from $500 to $1,500, depending on the manufacturer.

One major drawback of both kinds of self-contained systems is their inability to handle the remaining liquid household wastes such as bath, kitchen and laundry water. Separate facilities, at additional cost, must be installed to handle this grey water. There are no combinations of self-contained systems and grey water handling facilities in Chesterfield County today. In fact, both County and State regulations discourage use of such systems. Additional drawbacks of the incinerator toilet are its consumption of gas and electricity and its potential for air pollution. In summary, regulations, the relative newness of the systems, and the lack of long-term performance data and evaluation of envirmonmental effects have limited use of these systems, reducing their feasibility as an on-lot treatment and disposal alternative at the present time.

Aerobic units provide better waste treatment than septic tanks, resulting in better quality effluent percolating into the drainfield. Consequently, there is less chance of ground or surface water contamination, with the likelihood of longer drainfield life. However, especially under the variable loading conditions that frequently occur in the individual household, the aerobic unit may provide uneven performance. Without proper and regular maintenance, the quality of the effluent can thus be worse than that from septic tanks. County practice requires the same drainfield sizing for aerobic units as for septic tanks in case of such uneven performance. Hence the potential benefit of reduced land costs per dwelling (due to a smaller minimum lot size requirement) are not obtained; the disadvantage of higher capital and maintenance costs still exists. At the present time, no aerobic units exist in the Service Area, and due to present County practice, they do not appear to be a feasible alternative to septic tanks.

2. Package Plants

Chesterfield County as discouraged the construction of package plants in the Service Area because of the possibility that the surfaae discharges would result in pollution and eutrophication of the Falling Creek Reservoir. In addition, many subdivisions are not near a stream suitable for such a discharge. Poor maintenance is another common problem associated with small plants. Only one package plant, at Midlothian High School, exists in the Service Area. In summary, the feasibility of a number of small package plants to serve disposal needs is rather limited in Chesterfield County.

C. NO ACTION

This alternative is a continuation of present policies with regard to septic tanks, and no expansion and upgrading of the

Falling Creek STP. Present policies would result in non-alternating drainfield operation for septic tanks, less than adequate inspection and maintenance, and an increasing number of lots prohibited from development as the amount of land suitable (by natural and man-caused criteria) for development continues to decrease. Increasing numbers of reported and unreported malfunctions could be expected with possible contamination of ground and surface waters. Multi-family or higher-density residential development would probably not be allowed unless their flows could be accommodated by the present STP, or a package plant could be installed and properly maintained and operated. Thus, from the standpoints of accommodating medium and high density residential and commercial development, and protecting the waters of Chesterfield County, it is rather obvious that an expansion of the Falling Creek STP should be undertaken.

D. COST COMPARISON OF SELECTED PLANT EXPANSION INCREMENTS

It appears that the needs of the Service Area can best be met with continued and expanded treatment at the Falling Creek STP. There will, however, probably be parts of the Service Area where on-lot treatment can provide proper treatment at less cost than centralized collection and treatment.

This section is a cost analysis of the several expansion increments identified in Section III.B. The Federal Water Pollution Control Act Amendments of 1972 requires that EPA construction grants be made only for projects that are cost-effective in meeting their treatment objectives. EPA's concern in the present case is that it may not be cost-effective to provide treatment capacity initially which will not be used for several years.[92] Since the need for treatment capacity depends on the growth assumptions being made, costs for each of the expansion increments are analyzed for both the high and low growth rates discussed above.

The alternative expansions are:

1) three increments of 2 MGD (2+2+2);
2) one of 2 MGD, then one of 4 MGD (2+4);
3) two increments of 3 MGD (3+3);
4) one of 4 MGD, then one of 2 MGD (4+2); and
5) one expansion of 6 MGD (proposed alternative).

Table IV–23 lists the capital and O&M costs of each alternative, for both high and low growth rates. Costs for each are shown in order of total costs in Table IV–24.

It should be understood that this cost comparison differs from a standard cost-effectiveness analysis as defined by EPA regulations (40 CFR, Part 35, Appendix A). The latter analysis compares the costs of different treatment processes in meeting an established effluent goal within a standard planning period of 20 years with a given growth rate. The present case compares the costs of selected expansion increments of the same treatment process within a planning period of 10.5 years or 34 years, depending on the growth estimate.

Since only those estimated costs incurred during the same planning period may be validly compared, comparing costs for the same alternative for the two different growth estimates (and hence different planning periods) is not valid. The relevant comparison is among the five alternatives for the same growth estimate (or planning period).

The figures in Tables IV–23 and IV–24 show trends which one would expect: with the high growth estimate, capital costs decrease as the size of the initial construction increases from 2 to 6 MGD; O & M costs do not vary substantially in this range. In comparing alternatives 6, 4+2, and 3+3, total costs differ by less than five percent. With the low growth estimate, the greatly extended period during which the 12 MGD is reached has two results: differences in capital costs are virtually eliminated due to the present worth discounting procedure; and O & M costs are a more significant part of total costs. Thus, two factors - relative equality of capital costs and lower O & M costs for smaller expansion increments - combine to make the total costs lower for the smaller expansion increments.

The net effect of assuming the lower growth rate reverses the total cost rankings: on a cost basis, any alternative is preferable to the proposed MGD expansion. The 3+3 alternative is least costly, approximately 8 percent less than the County's 6 MGD proposal.

If present trends continue, costs for sewage facility construction would rise faster than the general price level. In such a case, the results of using constant dollars for future capital and operation and maintenance costs, as was done above, is questionable. Assuming that STP construction and O & M costs rise three percent faster than the general price level (based on the 1967-1974 EPA construction cost index, which rose two to three percent faster than other costs during that period), the cost comparison in Table IV–25 results.

TABLE IV-23.
Capital and O&M Costs for Selected Expansion Increments, High and Low Growth Rates

Expansion Sequence	Present Worth Using High Growth Estimate		Present Worth Using Low Growth Estimate ($$10^6$)	
	Capital	O&M	Capital	O&M
2+2+2	$17,295	$5,972	$13,686	$10,931
2+4	16,290	6,218	13,699	11,269
3+3	15,258	6,202	13,030	11,466
4+2	14,888	6,319	13,066	11,877
6	13,590	6,881	13,590	13,078

Notes: (1) Costs provided by design consultant.
(2) Cost analysis conforms with precedures in *Guidance for Facilities Plan* (EPA, January 1974); salvage value not included.
(3) The Water Resources Council's current discount rate of 5 7/8 percent is used to convert future costs to present value.
(4)High and low growth rates are developed in Section III.B.

TABLE IV-24.
Total Costs for Selected Expansion Increments, High and Low Growth Rates

Cost	Using High Growth Estimate Alternative (MGD)	Present Worth ($10^6)	Using Low Growth Estimate Alternative (MGD)	Present Worth ($10^6)
Least	6	$20,471	3+3	$24,496
	4+2	21,207	2+2+2	24,617
	3+3	21,459	4+2	24,943
	2+4	22,509	2+4	24,968
Most	2+2+2	23,267	6	26,668

TABLE IV-25.
Total Costs for Selected Expansion Increments, High and Low Growth Rates,
With 3 Percent Relative Inflation Rate

Cost	Using High Growth Estimate Alternative (MGD)	Present Worth ($10^6)	Using Low Growth Estimate Alternative (MGD)	Present Worth ($10^6)
Least	6	$21,647	3+3	$31,922
	4+2	23,055	4+2	32,128
	3+3	23,342	2+4	32,729
	2+4	23,707	2+2+2	32,802
Most	2+2+2	25,442	6	33,066

For the high growth estimate, the relative ranking of the alternatives remains the same as in Table IV–24. The cost difference between 6 MGD and either of the next two alternatives is approximately seven percent of total costs, compared to five percent in the previous analysis. For the low growth estimate, the least and most costly alternatives are the same, although the intermediate three have changed positions. The cost savings of the 3+3 alternative over the 6 MGD alternative is approximately three percent of construction costs, compared to eight percent in the previous analysis.

CHAPTER IV - FOOTNOTES

57. Energy and chemical requirements are an increasing important consideration in determining the long-term desirability of alternatives, and enter the analysis in the cost-effectiveness and environmental areas.

58. Pumping is often required for transfer of flows between minor drainage areas, between major drainage divides (e.g., the Bailey Bridge pump station will convey flows between the upper Swift Creek and Falling Creek basins), and to allow for sewer construction closer to the ground surface.

59. See Table 42 of the Environmental Assessment. These figures were taken from the 1971 Comprehensive Countywide Sanitary Sewer Study.

60. See Section IV.B. for a discussion of the potential for sewerage service by less centralized (e.g., lagoons, package plants) or on-lot systems.

61. Secondary treatment is defined in 40 CFR 133.102.

62. An NPDES discharge permit is issued which explicitly identifies each effluent limitation.

63. Rather than describing here the physical, chemical, and biological processes involved in each of these treatment processes, the reader's attention is invited to pages 160-174 of the Environmental Assessment. An excellent reference work for all aspects of wastewater collection and treatment is *Wastewater Engineering*, Metcalf & Eddy, Inc., McGraw-Hill, 1972. Section III.A. above provides some detail on the proposed processes.

64. As with wastewater treatment processes, descriptions of these processes can be found in any text on wastewater treatment processes.

65. Characteristics of the waste sludge from the proposed 12 MGD facility are that: waste activated sludge will be combined with primary sludge and sent to a sludge thickener. Thickened sludge is expected to have a solids content of 6 percent and a specific gravity of 1.1. The total dry weight of solids removed will be approximately 26,000 lb/day, and 70 percent of these solids will be volatile. A facility of less than 12 MGD would produce proportionately less sludge (assuming treatment processes are the same). The results of the analysis would not change significantly. Nitrogen in the thickened sludge was assumed to be approximately 4 percent of the total solids. It was further assumed that heavy metals such as zinc, copper, nickel, cadmium and lead were present in concentration ranges typically found in domestic sewage sludge and that unusually high concentrations were not present.

66. Other crops utilize different amounts of nitrogen. For example, if coastal Bermuda grass is grown nitrogen uptake as high as 600 lbs/ac/yr reduces the land requirement by a factor of four. The cost of the distribution system would be lower, although the other capital costs in Table IV-26 would remain the same.

67. Such a system is being considered for Standardsville, Virginia. This area of Green County (Standardsville, Quinque and Corner Store) will contribute flows of less than 0.5 MGD in the design year.

68. A septic tank is water-tight, covered receptacle that receives sewage from a building sewer, separates solids from the liquid, digested organic matter and stores digested solids, and allows the clarified liquid to discharge for final disposal.

69. Winneberger, J. T., and McGauhey, P. H., *A Study of Methods of Preventing Failure of Septic-Tank Percolation Fields*, Fourth Annual Report (College of Engineering and School of Public Health, University of California Berkeley, October 31, 1965).

70. Clayton, John W., "An Analysis of Septic Tank Survival Data From 1952 to 1972 in Fairfax County, Virginia," in *Journal of Environmental Health*, Vol. 36, No. 6, p. 566.

71. Goldstein, Steven N., and Moberg, Walter J. Jr., *Wastewater Treatment Systems For Rural Communities* (Commission on Rural Water, Washington, D. C. 1973), page 82.

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Winneberger, J. T., and Klock, J. W., *Current and Recommended Practices for Subsurface Waste Water Disposal Systems in Arizona* (College of Engineering Sciences, Arizona State University, July, 1973).

72. Winneberger, op. cit. (in *Journal of Environmental Health).*

73. Goldstein, Wenk, Fowler and Poh, op. cit., p. 79.

74. Johnson, op. cit., pp. 28-34.

75. Bernhart, Alfred P., Treatment and Disposal of Waste Water from Homes by Soil Infiltration and Evapotranspiration (University of Toronto Press, Toronto, 1973), pp. 9-10.

76. Referenced in: Goldstein, Steven N., "Community Sewerage Systems vs. On-Site Sewage Treatment Systems," in *On-Site Waste Management, Vol. I*, Hancor, Inc., Findlay, Ohio, p. 2.

77. Murphy, Raymond F., "Comparison of Economics of Normal Sewage Collection and Disposal vs. Ground Disposal," in *On-Site Waste Management, Vol. IV*, Hancor, Inc. Findlay, Ohio.

78. Bernhart, op. cit., p. 10.

79. Goldstein, Wenk, Fowler and Poh, op. cit. Goldstein, op. cit.

80. Downing, Paul B., "Extension of Sewer Service at the Urban-Rural Fringe," in *Land Economics* (Vol. 45, Feb. 1969).

81. Virginia Department of Health, State Technical Services, *1974 Survey of the Magnitude of The Septic Tank Problem in The State of Virginia*, December 19, 1974.

82. See Stewart, op. cit., p. 95. The closest available data to such a survey in Chesterfield consists of the "Remarks" section of the County document, "Data on Falling Creek S.T.P. Service Area, Public Health Aspects," Oct. 30, 1974.

83. Virginia State Technical Services, Virginia Polytechnic Institute and State University, *Tech Tran Report*, "Household Waste Water Treatment Techniques," May 29, 1974, p. 6.

84. Clayton, op. cit.

85. Downing, op. cit., p. 110.

86. According to the article, the actual situation - clustering of denser areas with intervening sparser areas - will raise slightly the minimum cost-competitive septic tank life, due to decreased sewer collection costs.

87. Anderson, Marshall L., "Community Improvements and Services Costs," in *Journal of the Urban Planning and Development Division*, ASCE, Vol. 99, No. UPI, March 1973.

88. Conversation with Mac Spencer, Chesterfield Health Department.

89. Bouma, J., "New Concepts in Soil Survey Interpretations for On-Site Disposal of Septic Tank Effluent," in *Soil Science Society of America Proceedings*, Vol. 38, No. 6, November-December, 1974, p. 941.

See also: Beatty, M. T. and Bouma, J., "Application of Soil Surveys to Selection of Sites for On-Site Disposal of Liquid Household Wastes," in *Geoderma*, 10, 1973, pp. 113-122.

90. Amato, Peter W., and Goehring, Harrison D., *Land Use and Policy Implications in a Three County Wisconsin Area* (University of Wisconsin-Extension Small Scale Waste Management Project, April 1, 1974).

91. For further technical information, see Goldstein and Moberg, pages 133-137 and pages 166-201.

92. The amount of reserve capacity for a proposed treatment plant must be determined by EPA on a case-by-case basis. Section 204 (a)(5) of the FWPCA requires "that the size and capacity. . .relate directly to the need to be served by such works, including sufficient reserve capacity. The amount of reserve capacity provided shall be. . .on the basis of a comparison of the cost of constructing such reserves. . .and the anticipated cost of providing expanded capacity at a date when such capacity will be required." This legislative requirement is the basis for the analysis in this section of the EIS.

V. CONCLUSIONS CONCERNING THE MAJOR ISSUES

This Environmental Impact Statement was prepared to improve EPA's understanding of the two major issues surrounding the proposed upgrading and expansion of the Falling Creek STP: the appropriate amount of expansion, if any, of the facility at this time, and the effect of this expansion on water quality in the Service Area. No additional salient issues were uncovered during the course of this study.

A. PLANT CAPACITY

One's choice of growth estimate, orientation to the wastewater planning process, and evaluation of the potential effectiveness of environmental protection policies and regulations in Chesterfield County could lead to one of several conclusions concerning the proper expansion increment of the Falling Creek STP. This section discusses the various reasons involved in making this decision.

Reasons Favoring the Proposed 6 MGD Addition:

1. The high estimate of wastewater flows has a 10.5-year planning period for the 6 MGD addition (Table II-19, III.B. of text). For a relatively high growth rate, this is a reasonable period. A 6 MGD addition would be the logical choice.
2. There is a possibility that an average annual growth rate greater than 5.8 percent may exist for some periods in the future. This possibility is based on the fact that in recent years the County has experienced a 9 percent annual rate. However, such a rate is in part due to a recent exodus of population from Richmond which cannot be expected to continue indefinitely.

Reasons Favoring an Addition of Less than 6 MGD:

1. The low estimate of wastewater flows shows a 34 year planning period for the 6 MGD addition (Table III-19, III.B. of text). This is generally considered a rather long planning period. The 19 year period for the low estimate for the 3 + 3 alternative is much closer to the standard 20 year planning period.
2. The low estimate of flows generally favors less than a 6 MGD addition. This estimate relies on the Virginia Department of State Planning and Community Affairs' population projections for the years 1980-1990. It also heeds the advice of the CEQ publication, *Interceptor Sewers and Suburban Sprawl*, that a realistic estimate of per capita wastewater flow based on water use should be used in designing plant capacities, rather than a standard estimate such as 100 gpcd.
3. Using the low growth estimate might lead to a low-capacity plant with possible overflow problems. Using the high growth estimate might lead to a high-capacity plant with excess capacity. Although the first of these two possibilities would appear worse than the second, the chance that the first will occur is very slight with timely planning of plant expansion increments (see Figure III-5). A high-capacity plant will have initial excess capacity, however, which may induce growth. Especially in the case of Chesterfield County, where the interceptor lines have already been laid and the County states that it "is not in a position to deny a reasonable request for residential zoning," excess capacity could accelerate the rate of land development in the Service Area. Therefore, the probability as well as the consequences of a too-high or too-low capacity plant expansion must be evaluated.
4. If the high estimate of flows prevails, a less-than-6 MGD addition would have a number of significant advantages over a 6 MGD addition. The shorter planning periods anticipated, especially the initial 5.7 year period for the 3+3 alternative (see Table III-19, III.B. of text), will provide the opportunity for a "mid-course" evaluation of several County projects and policies before additional sewage capacity is installed. One project is the County's plan for connecting specified existing developments into the sewer system during the years 1975-1980. Implementation of the plan will largely determine the degree of compliance with EPA's mandate to concentrate on serving existing development. County policies which are crucial determinants of the secondary impacts of STP expansion and whose implementation could benefit from a mid-course evaluation are: the updating of the 1995 General Plan; the revision of County soil erosion control standards to conform with State standards; and the development of a management plan for the Swift Creek Reservoir. Finally, the initial 5.7 year planning period for the 3+3 alternative would not require design for the next expansion increment until late 1981. At that time preliminary 1980 United States census data may narrow the difference between County and State population projections, thus reducing disagreement on the design size of the next increment.
5. As all previous construction has been in 3 MGD increments, the County's engineering consultants have indicated that the easiest increment to design and construct—smaller than 6 MGD—is the 3+3 alternative.

Reasons Favoring Neither/Both Levels of Additional Capacity:

1. The cost comparison (IV.D. of text) shows that all expansion increments, except the 2+2+2 alternative using the high growth estimate, differ in cost by less than 10 percent. Although, based solely on cost, the high growth estimate favors a 6 MGD increment and the low growth estimate a 3+3 increment, the differences are so small that cost cannot be considered a significant determinant of the appropriate plant capacity addition.
2. Likewise, certain environmental considerations cannot be prime determinants of the amount of expansion, for several reasons:
   a. The differences in direct environmental impact of the various expansion increments of the STP *per se* (not the interceptor and collector sewers, which EPA is not funding) is small.
   b. Although increased total secondary environmental effects occur with larger expansion increments, there is no reason to believe that per capita impacts are greater. The determinants of per capita impact are the rules and procedures at all levels of authority governing the land development process, and they are applied regardless of the expansion increment funded by EPA. Given equal per capita impact, and assuming constant governing rules and regulations, the increased impact of, for example, 6 as opposed to 3 MGD, would be due primarily to the increased number of people serviced, and the increased time period over which the impacts can occur. As in the cost comparison, the relevant environmental comparison is between alternatives of equal capacity: 6 vs. 3+3 vs. 2+2+2, and so forth; not 6 vs. 3 or 6 vs. 2. In this analysis differences in secondary environmental effects are small if they exist at all.

Capacity Decision: EPA has decided that the Falling Creek STP should be expanded to 9 MGD at this time.

B. SWIFT CREEK RESERVOIR

In response to existing eutrophic conditions in the Reservoir, the County has recently introduced the chemical addition of $CuSO_4$ to retard the growth of foul taste and odor-producing algae.

Future development of the watershed will occur in response to the high growth rate exhibited in Chesterfield County. To protect the Reservoir as a water supply, it will be necessary to provide stringent erosion and sedimentation controls for all development in the watershed. State Erosion and Sedimentation Controls exist and will be supplemented in the near future by the promulgation of County Control Laws and Areawide 208 development plans. However, as expressed in the VPI Report, the sensitivity of this area dictates that a comprehensive watershed management program must be adopted to minimize the adverse effects of watershed development on the Reservoir.

Chesterfield County has contracted EcolSciences, Inc. to prepare a management program for the Reservoir based on a one-year monitoring study. Due to be released in draft form this fall, the program should provide a cost-effective combination of in-lake and intransit controls to best provide for the Reservoir's preservation. Although not legally bound to accept the conclusions of this management program, it is hoped that the County will adopt this, or a similar, program.

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APPENDIX A

TABLE A-1
Levels of Sulfur Oxides and Suspended Particulates, Chesterfield County, 1972 and 1973

	Sulfur Oxides		Suspended Particulates	
Primary Standard[1]	Average 24 hr. Concentration= 0.14 ppm		Annual geometric mean = 75 ug/m³	
Secondary Standard[1]	Same as Primary Standard		Annual geometric mean= 60 ug/m³	
	Sample Date	Value[2] (ppm)	Sample Date	Value[2] (monthly geometric mean)
	1972		1972	
	April	0.020	March	69 ug/m³
	May	0.013	April	51
	June	0.002	May	54
	July	0.001	June	35
	Aug.	0.001	July	35
	Sept.	0.001	Aug.	69
	Oct.	0.004	Sept.	40
	Nov.	0.003	Oct.	14
	Dec.	0.006	Nov.	49
			Dec.	58
	1973		1973	
	Jan.	0.010	Jan.	47
	Feb.	0.006	Feb.	50
	March	0.007	March	53
	April	0.001	April	73
	May	0.001	May	73
	June	0.000	June	82
	July	0.000	July	64
	Aug.	0.002	Aug.	48
	Sept.	0.003	Sept.	79

Annual Geometric Mean is 48 ug/m³

[1]National Ambient Air Quality Standards (40 CFR 50; 36 FR 22384, November 25, 1971): EPA Regulations adopted by Virginia Air Pollution Control Board
[2]Data collected at Bensley Fire Department

TABLE A-2
Existing and Allowed Emissions of Particulates and SO_x, Chesterfield County

	Particulates (tons/yr.)	SO_x (tons/yr.)
Recorded Point Sources[1]	1,644	115,156
Area Emissions[2]	834	653
TOTAL	2,478	115,809
Allowed Emissions[3]	9,242	185,440

[1]Source: NEDS
[2]Source: Virginia APCB estimates of residential fuel, solid waste and transportation emissions for 1975
[3]Source: The State Implementation Plan, under the Clean Air Act Prescribes total allowable emissions of SO_x and particulates for each Air Quality Control Region. Data in this table applies only to the Chesterfield County portion of the State Capital AQCR.

TABLE A-3
AADT and Corresponding Peak Hour CO Concentrations in Service Area, 1975

Highway and Segment	AADT[1]	Peak Hour Vehicles per Hour[2]	Emission Factor[3]	Peak Hour CO Concentration (ppm)[4]
Rt. 1 - 301 Fr. Rt. 150 to Bellwood	31,615	3161.5	0.8	7.03
Rt. 10 Fr. Rt. 145 to Rt. 150	7,860	786.0	0.8	5.36
Rt. 60 Fr. WCL Richmond to Rt. 147	17,085	1708.5	0.8	5.96
Rt. 147 Fr. Rt. 678 to Rt. 711	7,975	797.5	0.8	5.37
Rt. 150 Fr. Rt. 60 to Rt. 686	23,640	2364.0	0.8	6.42
Rt. 360 Fr. WSCL Richmond to Rt. 604	16,115	1611.5	0.8	5.89
Rt. I-95 Fr. Falling Creek Interchange to Maury St.	45,645	4564.5	0.8	8.25

National Ambient Air Quality Standard for One Hour CO Concentration, Primary and Secondary: 35.00 ppm.
[1]*Virginia DOT, 1973.*
[2]Highway Capacity Manual, Highway Research Board, 1965.
[3]Kirchner and Armstrong, EPA 450/2-73-003.
[4]Derived from using Milligan's empirical (e) equations, as contained in a study submitted to EPA by Andrew J. Milligan, September 5, 1972.

TABLE A-4
Levels of Ozone and NO_2, Chesterfield County, 1974

	Ozone	NO_2
Primary Standard[1]	Maximum 1 hour Average Concentration=0.08 ppm	Annual Arithmetic mean = 0.05 ppm
Secondary Standard[1]	Same as Primary	Same as Primary
Sampling Date, 1974	Value (ppm)[2]	* Value (ppm)
Sept. 25	0.094	0.016
Sept. 26	0.095	0.014
Sept. 27	0.120	0.009
Sept. 28	0.068	0.028
Sept. 29	0.110	0.000
Sept. 30	0.100	0.000
Oct. 1	0.110	0.033
Oct. 2	0.106	0.023
Oct. 3	0.086	0.021
Oct. 4	0.109	0.019
Oct. 5	0.123	0.007
Oct. 6	0.131	0.025
Oct. 7	0.149	0.021
Oct. 8	0.101	0.035
Oct. 9	0.131	0.027
Oct. 10	0.148	0.010
Oct. 11	0.148	0.060
Oct. 12	0.140	0.011
Oct. 13	0.133	0.018
Oct. 14	0.129	0.024
Oct. 15	0.094	0.000

[1]National Ambient Air Quality Standards (40 CFR 50; 36 FR 22384 November 25, 1971): EPA Regulations, adopted by Virginia Air Pollution Control Board
[2]Data collected at Pocahontas State Park Special Facility
*NOTE: There are not enough data to derive a valid annual arithmetic mean concentration. Hence the daily values are not averaged.

TABLE A-5
Total Hydrocarbon Emissions in Chesterfield County, 1975

Emission Source	VMT[1]	CDM[2]	hm[2]	Speed Factor[2]	Emission Factor[2]	Emissions Tons/year[3]
Light Duty Vehicles	1,054,240	4.4	1.8	.75	5.1	2,159
Heavy Duty Vehicles	89,559	16.2	5.4	.75	17.45	628
Mobile Source Sub Total	1,143,799					2,787
Stationary Sources[4]						12,629
TOTAL						15,416

[1]Virginia DOT, 1973 (vehicle-miles of travel)
[2]Kirchner and Armstrong, EPA-450/2-73-003 (Exhaust emissions)
[3]Derived by multiplying VMT × Emission Factor (Evaporative emissions)
[4]National Emission Data System, 1974

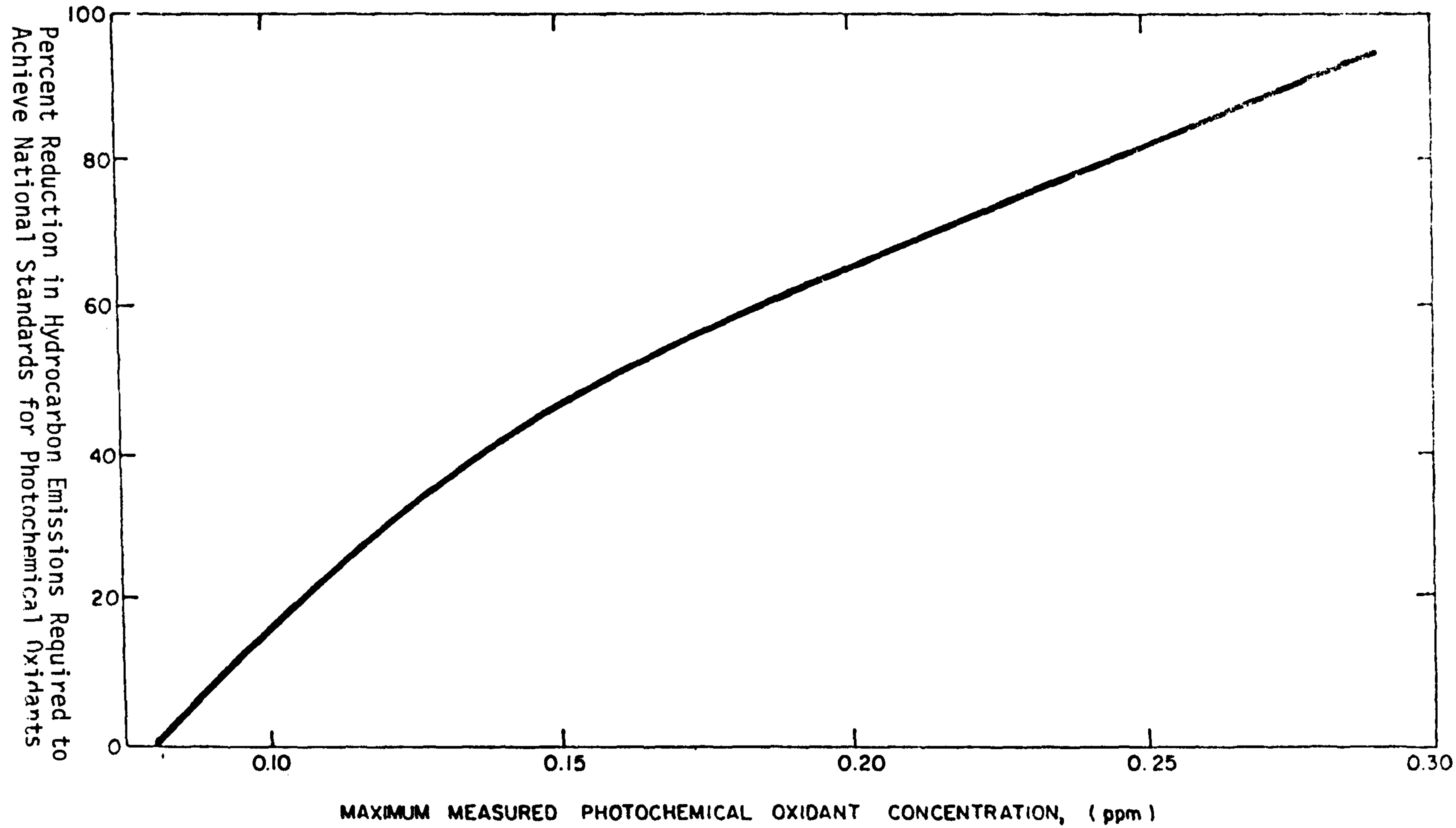
TABLE A-6
Present and Projected Peak One Hour CO Concentrations in Service Area

Highway and Segment	Year	AADT[1]	Peak Hour Vehicles Per Hour[2]	Emission Factor Grams/VMT[3]	Peak Hour CO Concentration (PPM)[4]
Rt. 1 & 301	1975	31,615	3161.5	.8	7.03
Fr. Rt. 150	1985	38,886	3888.6	.3	7.68
To Bellwood	2000	53,746	5374.6	.118	9.12
Rt. 10	1975	7,860	786.0	.8	5.36
Fr. Rt. 145	1985	9,667	966.7	.3	5.50
To Rt. 150	2000	13,362	1336.2	.118	5.76
Rt. 60	1975	17,085	1708.5	.8	5.96
Fr. WCL Richmond,	1985	21,014	2101.4	.3	6.27
To Rt. 147	2000	29,044	2904.4	.118	6.88
Rt. 147	1975	7,975	797.5	.8	5.37
Fr. Rt. 678	1985	9,809	980.9	.3	5.52
To Rt. 711	2000	13,558	1355.8	.118	5.77
Rt. 150	1975	23,640	2364.0	.8	6.42
Fr. Rt. 60	1985	29,077	2907.7	.3	6.87
To Rt. 686	2000	41,088	4108.8	.118	7.82
Rt. 360	1975	16,115	1611.5	.8	5.89
Fr. SWCL	1985	19,821	1982.1	.3	6.18
Richmond, To Rt. 604	2000	27,395	2739.5	.118	6.76
Rt. I-95	1975	45,645	4564.5	.8	8.25
Fr. F.C.	1985	56,143	5614.3	.3	9.36
Interchange to	2000	77,596	7759.6	.118	11.97
Maury St.					

National Ambient Air Quality Standard, Primary and Secondary: One-Hour Concentration 35.00 ppm

[1]Virginia DOT, 1973 and EPA Projections based on population increase.
[2]Highway Capacity Manual, Highway Research Board, 1965.
[3]Kirchner and Armstrong, EPA-450/2-73-003.
[4]Derived through use of Milligan's empirical (e) equations, as contained in a study submitted to EPA by Andrew J. Milligan, September 5, 1972.

Figure A-1 Relationship of hydrocarbon reduction to oxidant concentration.



APPENDIX B

TABLE B-1
Water Quality of Swift Creek, Falling Creek, and James River at Selected Locations

FALLING CREEK

Appliable Water Qaulity Standards	III A	III A PWS	III A PWS	III A
Location	Rt. 1	Reservoir	Rt. 10	Rt. 360
Mileage*	0.85	3.67	5.78	13.0
Temp.(°F)	60.7	63.3	64.8	61.4
D.O. mg/1	9.2	9.2	9.7	8.4
BOD mg/1	2.3			2.6
pH	7.0	7.1	7.2	6.7
NO_2, NO_3, NH_3, (as N) mg/1	.323	.316	.262	.223
Total PO_4 (as P) mg/1	.094	.106	.106	.099
As ug/1	4.4	1.1	1.1	4.4
Cd ug/1	8.9	1.0	1.0	8.9
Fe ug/1	470			1979
Pb ug/1	11.4	10.0	15.0	10.7
Mn ug/1	107			127
Hg ug/1	3.9	0.50	0.50	0.63
Total Coliforms /100ml	2706			5575
Fecal Coliforms /100ml	676	300	212	274

SWIFT CREEK

Applicable Water Quality Standards	III B PWS	III A	III B	III B	III B	III B	III B	III A PWS	III A PWS
Location	Rt. 1	Rt. 655	Lake Dam	Lake	Lake Head-waters	Rt. 653	Rt. 360	Rt. 604	Rt. 606
Mileage*	4.92	19.2	21.2	23.2	23.5	25.3	30.7	34.1	38.0
Temp.(°F)	62.8	60.9	79.2	78.4	76.6	59.6	62.9	63.8	57.9
D.O. mg/1	9.0	8.8	8.0	7.6	7.7	9.1	8.8	9.0	9.3
BOD mg/1	2.9			1.0			2.4		
pH	6.9	6.8	7.0	7.0	6.7	6.9	7.0	6.9	7.0
NO_2, NO_3, NH_3 (as N)mg/1	.267	.149	.128	.159	.119	.186	.173	.174	.188
Total PO_4 (as P)	.096	.099	.099	.099	.099	.120	.092	.099	.099
As ug/1	5.0	5.0	3.0	4.0	4.0	5.0	5.8	5.0	5.0
Cd ug/1	10.0	10.0	7.8	7.8	7.8	10.0	10.0	10.0	10.0
Fe ug/1	823						503		
Pb ug/1	10.0	12.5	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Mn ug/1	133						360		
Hg ug/1	0.50	0.50	0.50	0.50	1.75	0.50	0.56	0.50	0.50
Total Coliforms /100ml	3596		100		1600		3566		
Fecal Coliforms /100ml	722	136	115	181	646	268	129	158	145

JAMES RIVER[1]

Mileage	94.8	96.8	98.3	100.9	103.2	104.7	106.2	108.0	109.6
Temp.(°F)	78	77	76	74	76	69	75	74	62
D.O. mg/1	6.8	6.5	6.0	4.8	6.4	5.8	7.0	8.4	9.7
BOD mg/1	2.2	2.5	2.9	4.8	9.7	3.0	4.0	2.9	2.3
pH	7.3	7.3	7.1	7.0	7.4	7.3	7.4	7.7	7.7
NO_2, NO_3, NH_3 (as N)mg/1	.714	.715	.852		.791		.738	.603	.545
Total PO_4 (as P)	.113	.117	.157		.133		.177	.111	.095

*Mileage are in distance from the mouth of the stream.

TABLE B-1 (Continued)
Water Quality of Swift Creek, Falling Creek, and James River at Selected Locations

JAMES RIVER[1]									
Applicable Water Quality Standards	III B PWS	III A	III B	III B	III B	III B	III B	III A PWS	III A PWS
Location	Rt. 1	Rt. 655	Lake Dam	Lake	Rt. Head-waters	Rt. 653	Rt. 360	Rt. 604	Rt. 606
As ug/1	5.0	5.0	5.0		5.0		5.0	5.0	5.0
Cd ug/1	10.0	10.0	10.0		10.0		10.0	10.0	10.0
Fe ug/1									783
Pb ug/1	10.0	12.0	10.0		10.0		10.0	12.0	11.8
Mn ug/1	70.0	80.0	80.0		50.0		30.0	10.0	33.3
Hg ug/1	0.0966	0.50	0.50		0.69		1.39	0.51	0.70
Total Coliforms /100m1	7891	20524	65686	421200	236462	578600	915108	209519	29803
Fecal Coliforms /100m1	2946	4215	5895		5012		4961	725	3563

The applicable Water Quality Standard for all samples is II B

Source: Virginia State Water Control Board
Figures in this table are based on samples taken between the spring of 1970 and the autumn of 1974.

Table B-2
Virginia Public Water Supply Standards[1]

Constituent	Concentration
Physical	
Color (color units)	75
Inorganic Chemicals	mg/l
Alkalinity	30-500
Arsenic	0.05
Barium	1.0
Boron	1.0
Cadmium	0.01
Chloride	250
Chromium, hexavalent	0.05
Copper	1.0
Fluoride	1.7
Iron (filterable)	0.3
Lead	0.05
Manganese (filterable)	0.3
Nitrates plus nitrites	10 (as N)
Selenium	0.01
Silver	0.05
Sulfate	250
Total dissolved solids (filterable residue)	500
Uranyl ion	5
Organic Chemicals	mg/l
Carbon Chloroform extract (CCE)	0.15

Constituent	Concentration
Cyanide	0.20
Methylene blue active subtances	
Pesticides:	
Aldrin	0.017
Chlordane	0.003
DDT	0.042
Dieldrin	0.017
Endrin	0.001
Heptachlor	0.018
Heptachlor epoxide	0.018
Lindane	0.056
Methoxychlor	0.035
Organic phosphates plus Carbamates	0.1
Toxaphene	0.005
Herbicides:	
2,4-D plus 2,4,5-T, plus 2,4,5-TP	0.1
Phenols	0.001
Radioactivity:	pc/l
Gross beta	1,000
Radium-226	3
Strontium-90	10

General standards, based on climate, geology and water usage, are also applicable to waters within the State.

[1]from "Water Quality Standards Summary for Interstate Waters of the Commonwealth of Virginia", 1971.

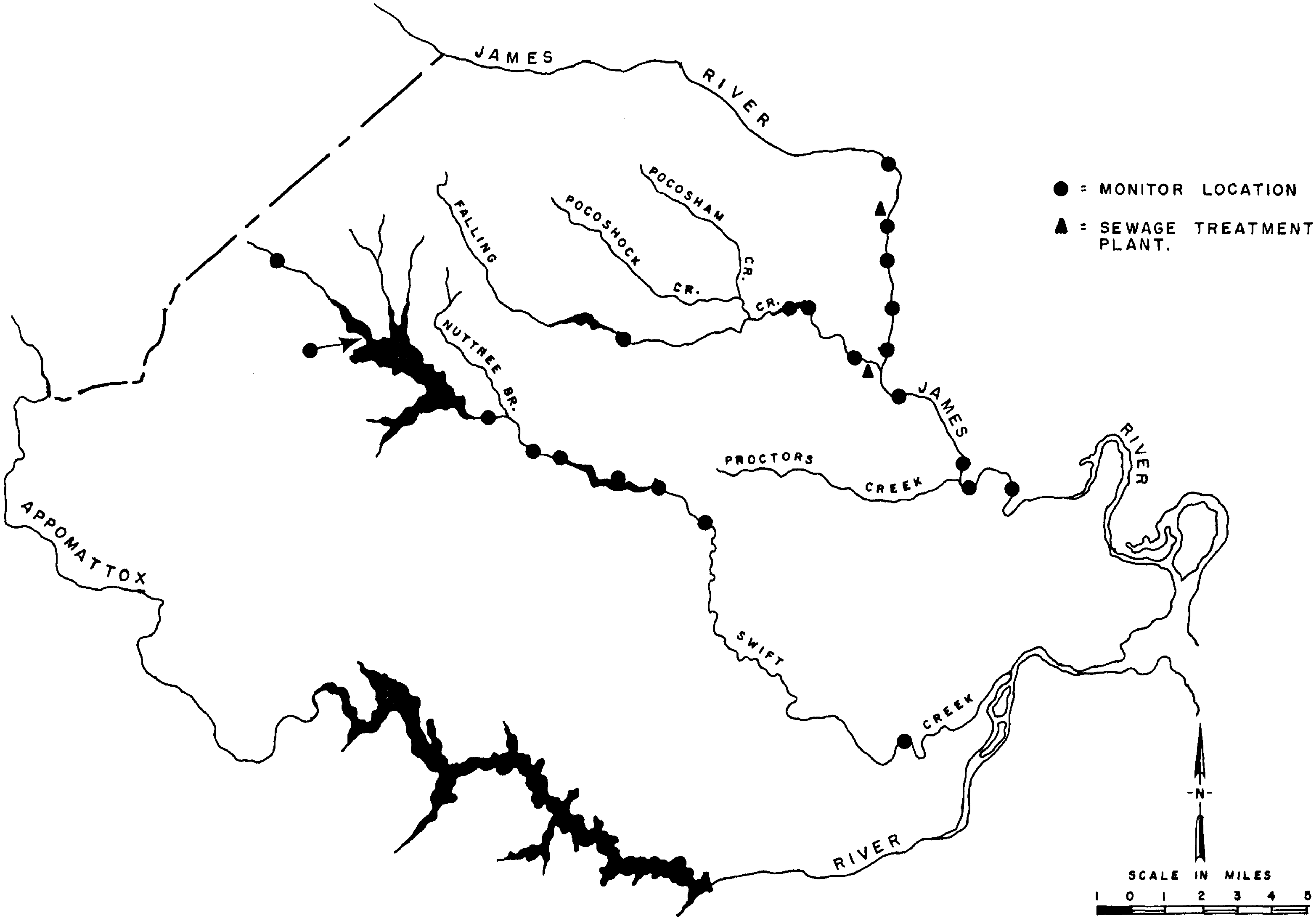


FIGURE B-1

SWCB STREAM QUALITY MONITORING LOCATIONS

A. Primary Classification of Waters Within the State

MAJOR CLASS	GEOGRAPHICAL AREA DESCRIPTION WATER	D.O. mg/l Min.	Daily Av.	pH	Temp. °F Rise Above Natural	Max.
I	Open Ocean (Seaside of the Land Mass	5.0	—	6.0-8.5	4.0(Sept-May) 1.5(June-Aug)	— —
II	Estuarine (Tidal Water - Coastal Zone to Fall Line	4.0	5.0	6.0-8.5	4.0(Sept-May) 1.5(June-Aug)	— —
III	Free Flowing Streams (Coastal Zone & Piedmont Zone to the Crest of the Mountains	4.0	5.0	6.0-8.5	5	90
IV	Mountainous Zone	4.0	5.0	6.0-8.5	5	87
V	Put & Take Trout Waters	5.0	6.0	6.0-8.5	—	70
VI	Natural Trout Waters	6.0	7.0	6.0-8.5	—	70

B. Subclasses to Complement Major Water Class Designitions

1. *Subclass A*
Uses - Waters generally satisfactory for use as public or municipal water supply, secondary contact recreation, propagation of fish and aquatic life, and other beneficial uses.

Criteria - Coliform Organisms - Fecal coliforms (multiple-tube fermentation of MF count) not to exceed a log mean of 1000/100 ml. Not to equal or exceed 2000/100 ml. in more than 10% of samples.

Monthly average value not more than 5000/100 ml. (MPN or MF count). Not more than 5000 MPN/100 ml. in more than 20% of samples in any month. Not more than 20,000/100 ml. in more than 5% of such samples.*

2. *Subclass B*
Uses - Waters generally satisfactory for use as public or municipal water supply, primary contact recreation, (prolonged intimate contact; considerable risk of ingestion), propagation of fish and other aquatic life, and other beneficial uses.

Criteria - Coliform Organisms - Fecal coliforms (multiple-tube fermentation of MF count) within a 30 day period not to exceed a log mean of 200/100 ml. Not more than 10% of samples within a 30-day period will exceed 400/100 ml.

Monthly average not more than 2400/100 ml. (MPN or MF count). Not more than 24/100 ml. in more than 20% of samples in any month. Not applicable during, nor immediately following periods of rainfall.*

* With the exception of the coliform standard for shellfish waters, the enforceable standards will be those pertaining to fecal coliform organisms. The MPN concentrations are retained as administrative guides for use by water treatment plant operators.

APPENDIX C

A descriptive account of annual events in water supply lakes and reservoirs (An except from "Water Supply Lakes and Raw Water Storage Reservoirs", Ridley, J. E., 71 W4/USA/3100, September-October, 1971.)

The natural sequence of physical-chemical and biological events in water-supply lakes and reservoirs affects quality control at treatment plants where the first objective is to ensure economic production of a safe, potable product. The term "safe" is here defined as free from toxic chemicals and from pathogenic bacteria and viruses; "potable" implies the absence of objectionable smell or taste, and minimal coloration and turbidity.

These standards are at greater risk when eutrophic waters are the supply sources, even when water treatment technology is at a high level, because there is always a possibility of failure to cope with extreme situations.

At the same time there is an urgent need to augment existing high-quality surface and ground water sources with low-quality surface waters. Thus, the major supply source to high-population areas is, in the future, more likely to be an enriched impoundment requiring elaborate systems of filtration and disinfection to ensure adequate quantities of a safe, potable water.

The economics of raw water storage favour the valley-dam type of construction, where the seasonal inflow and outflow may be extremely variable. In any particular terrain there will be an optimum economic depth of water at the dam, determined solely by geological and engineering decisions. In lowland valleys the minimum depth is likely to be about 30 feet, while in steep and narrow valleys the depth at the dam may exceed 100 feet. Surface areas will range from a few hundred acres to several square miles, and as the impoundment will probably fulfill water supply and recreational needs in the area, the seasonal patterns require consideration before investing in the vapious types of in-reservoir control systems.

(i) SPRING

After the winter ice cover melts, any solar heating of the surface layers is disrupted by vernal winds and there will be downwards transfer of heat. The water column will be isothermal and will be colonised by algae as water temperature increases. At this time of year, the most successful algae are likely to be diatoms which are tolerant to relatively low levels of light and water temperature. Continued development of the algal population to bloom proportions depends upon many factors; it may continue until specific nutrients are depleted, or it may die as a result of reduced turbulence in the water column because the larger algal cells are then unable to maintain their position in the photic zone unless morphologically or physiologically adapted to flotation. The developing blooms may be attacked by viruses or by fungal parasites, or the algae themselves may exert a "self-shading" effect as cell numbers increase and eventually restrict penetration of light into the water column.

(ii) EARLY SUMMER

With increased rates of solar heating, and decreasing winds, thermal-density gradients develop and the lake gradually becomes stratified, firstly to a two-layered system (epilimnion and thermocline) and ultimately to the three-layered situation (epilimnion, thermocline and hypolimnion). The density differences in the various layers are then sufficient to restrict free vertical circulation through the full depth of the water column, thus preventing "ventilation" of the mud surface by downward movement of highly oxygenated water from the surface layers. Wind forces may then be incapable of creating enough turbulent movement in the lake to fully circulate the dissolved oxygen available in the topmost layers, where surface aeration and algal activities are producing surplus oxygen.

This physical change in the structure of the water column begins to favour those species of algae which are tolerant to relatively quiescent conditions, but requiring somewhat higher levels of light and water temperature than the spring crop of diatoms. This group includes numerous species of green algae.

At the same time, there will be an increase in the numbers and types of grazing invertebrates, again with column zonation depending upon specific feeding habits. At this time, therefore, the grazing zooplankton may have a markedly selective effect on the success, or failure, of specific types of algae to assume bloom proportions.

(iii) MIDSUMMER

Thermal layering will be at maximum, and in subtropical areas the topmost layers may be 25 to 30°C while the bottom layers remain at about 15°C. Column stagnation then accelerates the rate of deposition of dead algal cells, providing that they have a density in excess of the surrounding water, and they may decompose during settlement or when reaching the bottom of the lake. As the rate of decomposition of deposited organic matter increases, the dissolved oxygen concentrations immediately above the mud surface begin to fall, and when at a concentration of about 2 mg/1, i.e. about 20% of the saturation value, there is a release of absorbed and complexed nutrients from the deposits.

At this time, nitrate-N is reduced to NH_4-N, complexed phosphates released as ortho and meta-P, Fe^{+++} and MN^{++} reduced to Fe^{++} and Mn^{++}, sulphates reduced to H_2S, proteins to polypeptides and aminoacids, complexed silicates released etc., etc. The rate of nutrient release and accumulation in the bottom layers increases rapidly as the dissolved oxygen continues to fall to 10% saturation, then to zero, and ultimately to extreme anaerobic conditions where H_2S concentrations may build up in excess of 10 mg/1.

The bottom layers of the lake could then be described as a nutrient concentrate, requiring only oxygenation to eliminate substances such as H_2S and Mn^{++} which would be toxic to algae. If, therefore, a partial mixing of the water column occurs, possibly during a midsummer storm, some proportion of these nutrient-rich layers will be transported to the well-oxygenated upper layers of the lake and be immediately available to the algae.

If, on the other hand, the density stagnation of the water column remains undisturbed, algae in the photic zone will flourish until they have stripped specific nutrients or until the bloom becomes self-limiting by reducing the penetration of light. In either event, the deposited cells add a further quantity of decomposing material for bacterial degradation at the mud-water interface, with consequent increase in nutrient concentration in the bottom water.

Phytoplankton associations of midsummer are likely to be dominated by the blue-greens, although mixtures of Chlorophyta, Cryptophyta, and Chrysophyta commonly occur. The blue-greens tend to concentrate near the surface and may flourish even after stripping all sources of dissolved nitrogen because some species have a physiological capability for utilizing atmospheric nitrogen.

At this time of the year, the topmost layers of the lake may contain vast concentration of algae, of the order of 200,000 cells/ml, while the bottom layers may be foul-smelling and contain massive concentrations of nutrients. Thus, the volume of readily usable water for a water supply treatment works may be less than 50% of the total volume hold in storage and at the same time the lake may be aesthetically unacceptable if blue-green algal scums are present.

(iv.) LATE SUMMER THROUGH FALL

The rate of solar heating of the surface layers decreases rapidly, and autumn winds increase in strength and frequency. This combination of heat-loss and wind-induced turbulence gradually breaks down the density gradients established during summer. If the vertical mixing process transports nutrient-rich strata from the lake bottom at a time when light penetration and water temperature in the upper layers are still favourable, there will be a fall bloom of algae. The relatively low light and temperature tend to favour particular diatoms, as in the spring, although some of the summer algae will remain as minor constituents.

During late fall, continuing loss of heat to atmosphere and increasing winds sufficiently disrupt the density gradients to rapidly produce an isothermal column, and full circulation, in shallow lakes. In deeper lakes, this "fall overturn" will be delayed until early winter. However, the overall effect is to fertilize the water column with high concentrations of nutrients which have accumulated in the bottom layers during summer stratification. At this time, water temperature and light are less favourable to development of algae, and the lake remains throughout the winter as a nutrient-loaded ecosystem requiring only the light and heat of the following spring to reactivate the biological cycle. The concentration of nutrients in the water column at the onset of winter is, therefore, an important factor in determining the potential crops of algae in the following spring.

(v) WINTER

Dissolved oxygen in the water column will be equalized during the fall overturn, to a concentration determined by the oxidation requirements of reducing substances transported from the bottom strata. Aerobic decay of bottom deposits continues through the winter, although at a much reduced rate as water temperature decreases.

Immediately after ice cover, there will be a continuing loss of dissolved oxygen from the water column, due to absence of wind-induced aeration at the surface and also to the minimal activities of over-wintering algae which are merely at survival level. The invertebrate and vertebrate components of the ecosystem continue to consume oxygen, although at a much reduced rate, and the dissolved oxygen concentration may fall to a level below the tolerance of some species of fish.

APPENDIX D

1. The Modeling Process

The water quality problems facing the two County reservoirs are inherent to all artificial impoundments. The free-flowing stream can transport sediment loads and assimilate nutrients over the entire course of the stream due to the swift velocity and high dilution of nutrient concentrations. When man dams these naturally cleansing streams, the velocity loss causes a deposition of sediment and inorganic matter. This accumulation of nutrients promotes growths of diatoms, green and blue-green algaes. The great quantities of both plant and animal organic matter leads to a gradual filling in of the reservoir. The waters consequently become generally warmer. Rooted aquatic plants take over increasingly more space, their dead remains accelerating the filling of the reservoir. Eventually this process transforms the eutrophic lake into a marsh and finally into extinction. This process is called eutrophication.

A significant issue of the proposed action is the effect of induced development on the quality and future usefulness of the two County water supply reservoirs. In order to assess these effects, base information and present water quality must be estimated.

The classical approach in determining the quality of a reservoir is to quantify all nutrient sources and sinks on a yearly basis. This is followed by a determination of which nutrients, in what quantities, are optimal (and maximum) for support of a healthy hydrologic system. This quantification is specific to each reservoir, based on many factors, including: regional geology, size and depth of the lake basin, flushing rate, slopes and area of the contributing watershed, latitude of the lake, and man's activities in the watershed.

Eutrophication is the result of a gradual accumulation of nutrients. Nutrients are organic plant and animal material, and trace elements and vitamins. The greatest influence on the degree of eutrophy is the availability of two inorganic elements: phosphorus and nitrogen. The sources and sinks (gains and losses) of these nutrients are listed in Table D-1. A review of the sources indicates the difficulties involved not only in quantifying the contributions by source, but also in delineating the boundaries of contributing sources.

Contributions to the reservoir from groundwater, precipitation and dry fallout (airborne sources), and the in situ sources (within the lake) cannot be accurately estimated. The only legitimately quantifiable contribution, as well as the most abundant, is from surface water contributions from the drainage area. Because of these quantification difficulties, it is probable that no studies have measured all the sources and sinks for any single lake. However, an alternative to actual measurement is the development of a simulation model of nutrient transport based on estimated nutrient loads from various land uses in the drainage area (Lee, et al, 1966). Nutrient studies focus on nitrogen and phosphorus as the best indicators of eutrophy. Table D-2 shows the results of many studies regarding the relationship between nutrient amncentrations in receiving waters and the land uses draining into them. Only forest and urban land uses are shown because of their predominance in the Swift Creek drainage area.

TABLE D-1
Sources and Sinks of Nutrients in Reservoirs

1. Sources
   Surface
   - Agricultural runoff and drainage
   - Animal waste runoff
   - Marsh Drainage
   - Forest Runoff
   - Urban storm water runoff
   - Domestic and Industrial waste effluents

   Airborne
   - Precipitation
   - Aerosols and dust
   - Leaves and miscellaneous debris

   Underground
   - Natural soil contributions
   - Subsurface agricultural and urban drainage
   - Septic tank discharges

   In Situ
   - Nitrogen fixation
   - Sediment leaching

2. Sinks
   - Effluent Loss
   - Fish & Weed harvest
   - Volatilization (of NH_3)
   - Denitrification
   - Sorption of NH_3 onto sediments
   - Groundwater recharge
   - Insect emergence
   - Evaporation
   - Sediment deposition of detritus

Source: Brezonik, 1973

TABLE D-2
Nitrogen and Phosphorus Concentration from Various Nutrient Sources

Land Use	Nitrogen kg/ha-yr	Phosphorus kg/ha-yr	Reference
Forest	1.3-5.0	0.084-0.18	Cooper, 1969
	1.5-3.4	0.83-0.86	Sylvester, 1961
	1.6-2.2	0.18-0.32	Viro, 1953
	1.3-5.1	0.01-0.86	Uttormark, 1974 (8 references)
Igneous basin		0.047	Vollenweider, 1974
sedimentary basin		0.117	Vollenweider, 1974
Urban	8.8	1.1	Brezonik, 1973 (4 references)
	2.1-8.8	0.5-2.9	Uttormark, 1974 (8 references)
	6.84	5.27	Tafuri, 1974
sedimentary basin		1.1-16.6	Vollenweider, 1974

The next step in modeling is to choose the concentration of nitrogen and phosphorus and calculate the loading rates to the reservoir. This is done by dividing the annual nutrient contributions by the surface area of the impoundment. Based on this loading rate, a direct comparison with published levels and dangerous nutrient levels indicates the probability of eutrophication of the reservoir. Using Brezonik's values (listed in Table D-3), a nitrogen loading rate below 1.9 g/m will not cause water quality problems associated with overfertilization. A value over 3.4 g/m indicates excessive nitrogen contributions, which, together with a correspondingly high phosphorus contribution, often leads to eutrophic conditions. A reservoir with nitrogen and phosphorus levels below these levels is nutrient-poor, or oligotrophic. Values between these limits may lead to eutrophic conditions, indicating that a reservoir's condition is not completely dependent on these loading rates. These intermediate, or mesotrophic, nutrient levels, are found in most impoundments.

TABLE D-3
Brezonik's and Vollenweider's Critical Nutrient Loading Rates (g/m₂)

Brezonik's Nutrient Loading Rates			
		N	P
Permissible		1.9	0.28
Dangerous		3.4	0.49
Vollenweider's Nutrient Loading Rates			
	Mean depth (m)	N	P
Permissible	up to 5	1.0	0.07
	10	1.5	0.10
	50	4.0	0.25
Dangerous	up to 5	2.0	0.13
	10	3.0	0.20
	50	8.0	0.50

Vollenweider (1974) has refined Brezonik's model by including mean depth of the reservoir as an additional independent variable. This is based on the fact that the critical nutrient loading rates are greater for lakes of greater mean depth.

Vollenweider's loading rates are more conservative than Brezonik's. This difference of standards, reflecting the state of the art of the lake modeling process, is greatest for phosphorus loading rates in shallow lakes.

Vollenweider further refined his model by including the hydraulic flushing rate. This parameter, explained in Section II.A.5., accounts for the availability of the nutrient loading to biological processes while it is present in the lake. Figure D-1 relates the loading rate of phosphorus to the mean depth divided by the flushing rate. This model is probably the best available method for estimating a lake's degree of eutrophy. It has been used to predict nutrient budgets for several lakes in southern Ontario (Michalski, et al, 1973). Included is a number of phosphorus budget parameters reported in the literature by Dillon and Vollenweider (1974).

2. Falling Creek Reservoir Model

As Table D-2 indicates there is such great variance in reported nitrogen and phosphorus levels that only a general loading rate can be determined for the modeling process. Actual samples taken from tributaries and the Reservoir itself are of much greater significance in approximating the actual physical conditions of the impoundment.

There are presently two data sources for the Falling Creek Reservoir from which a predictive model can be derived (Table D-4).

TABLE D-4
Estimated Nutrient Loadings to the Falling Creek Reservoir ($g/m^2/yr$)

Data Source	N	P	Point on Figure D-1
Va. SWCB	30.74	10.99	FC1
Raw Water Intake	46.97	11.04	FC2

The first, a State Water Control Board monitoring program (used in Table B-1), has samples from February, 1970 to August, 1974. The second was taken at the raw water intake of the Falling Creek Water Filtration Plant, in February, 1975. The nutrient loadings to the reservoir derived from these data are listed in Table D-4. When compared to the 5 meter depth figures in Table D-3, it is apparent that present nutrient loadings produce highly eutrophic conditions. Further, when plotted on Vollenweider's graph (Figure D-1), the degree of eutrophy appears critical. The beneficially fast flushing rate (7.8 days) emphasizes the critical nutrient loading levels. As the flushing rate decreases (i.e., more settling of nutrients in the reservoir), the locations on the graph shift to more eutrophic conditions.

Reports from the County agree with the conclusions of this model. Treatment with Copper Sulfate ($CuSO_4$) has been a seasonal activity in Falling Creek Reservoir since its construction. In the spring of 1974, an aeration system was installed to eliminate odor and taste problems related to the stagnant anaerobic conditions prevalent throughout the summer. These and other treatment alternatives are disucssed Appendix J.

3. Swift Creek Reservoir Model

Using the same modeling approach, three data sources for Swift Creek Reservoir were obtained. The State Water Control Board has collected data for both the Falling and Swift Creek systems. Data from the Swift Creek Water Filtration Plant obtained in February, 1974 has also been compiled. Due to the specific concerns about development near the Reservoir, Chesterfield County has engaged EcolSciences, Inc. to collect and analyze water quality data for the tributaries of the Reservoir. The actual monitoring program is discussed in Appendix G.

TABLE D-5
Estimated Nutrient Loadings to the Swift Creek Reservoir (g/m₂/yr)

Data Source	N	P	Point on Figure D-1
Va. SWCB	1.57	0.94	SC1
Raw Water Intake	2.04	0.94	SC1
Ecol Sciences	1.96	0.59	SC2

The figures in Table D-5, when compared to the critical nutrient levels in Table D-3, indicate excessive phosphorus loadings to the Reservoir. Nitrogen levels, consistently lower in all samples than the predicted quantities of Table D-2, reflect only slight mesotrophy. Figure D-1 substantiates the marginal quality of the impoundment. Again, the flast flushing rate (113 days) prevents a more severe loading rate problem. Although there is some variance in the data, there is general agreement between the data from both reservoirs.

4. Projected Reservoir Trophic State for Swift Creek Reservoir

The same modeling process can be used to predict changes in water quality resulting from reduced pollution contributions, improved sewage treatment or increased development in the watershed.[1]

Presently under construction on 1,600 acres adjacent to Swift Creek Reservoir is a planned development called Brandermill.

Surface runoff from this area (considered to be urban) contains considerably higher nutrient concentrations than that from forested areas prevalent in the Swift Creek basin. Therefore, to predict conditions in the Reservoir after Brandermill is complete,an estimate (by measurement or assumed values) must be made of the increased nutrient loadings. Without the advantage of actual measurements from the developing area, values chosen for nitrogen and phosphorus are 6.8 Kg/ha and 5.3 Kg/ha, respectively.[2] Incorporating these values for the 1,600-acre development with the previous data established for reservoir loading rates, a new position in Figure D-1 indicates the deterioration of water quality which can be expected from the development.[3] The result is a significant shift to more eutrophic conditions.

These model results provide the best estimate of nutrient loadings available at this time. There are several variables which, when better defined, will provide a better estimate:

a. the effectiveness of on-site erosion and sediment controls;

b. the significance of the proximity of the development to the Reservoir (although Brandermill occupies only four percent of the Reservoir's drainage area); and

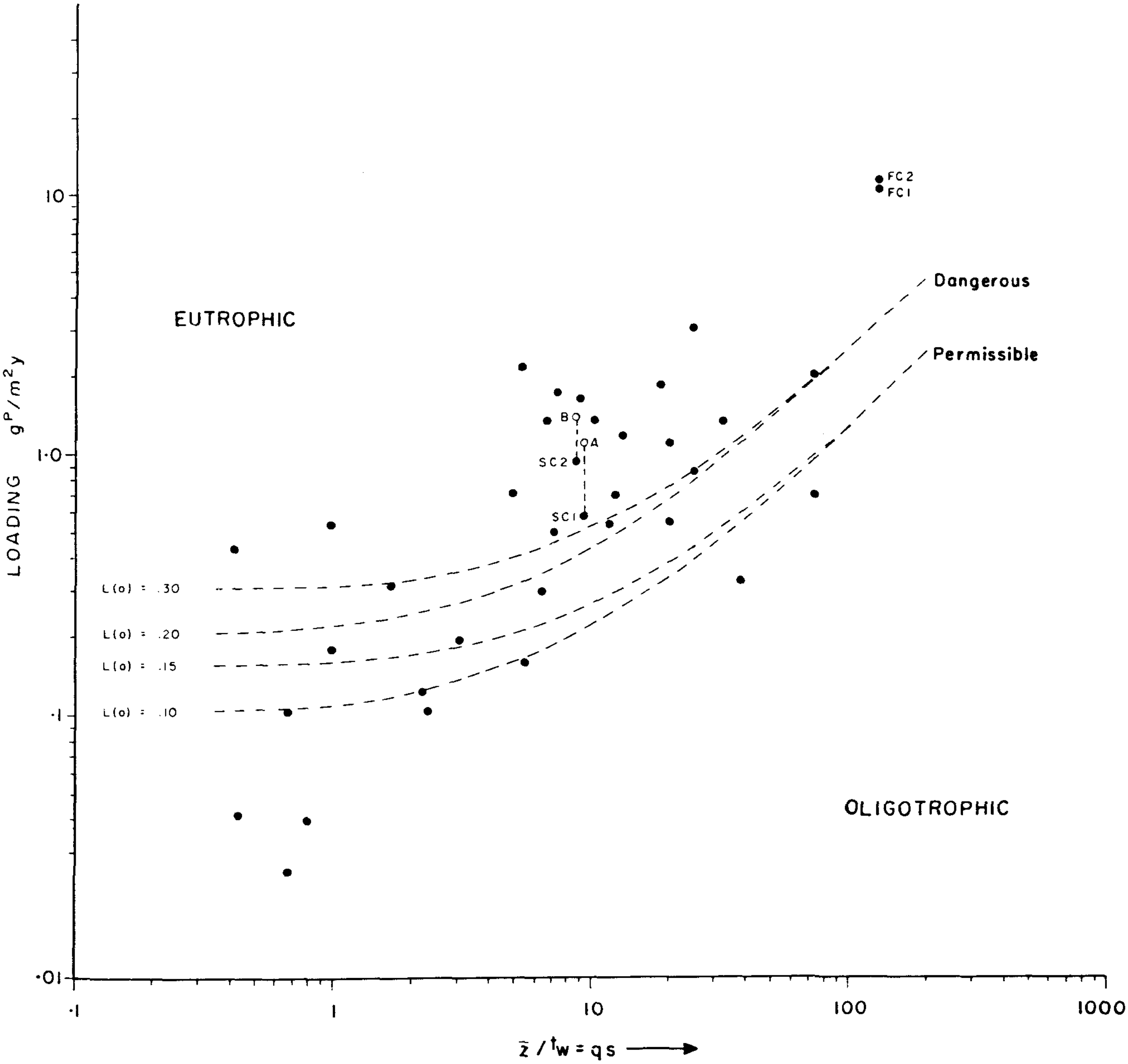
c. the general validity of Vollenweider's critical nutrient levels and the estimated nutrient contributions from the Brandermill development.

APPENDIX D FOOTNOTES

1. Investigations have been conducted by Michalski, Johnson and Veal (1973) predicting the trophic change insurred by increased population and reduced sewage contributions.

2. Tafuri, A. R., *Characterization and Treatment of Urban Land Runoff,* December, 1974. The values were selected since they were representative of a typically urbanized area occurring in the Piedmont region of the Southeastern United States (Durham, N. C.).

3. As indicated in Figure D-1;
A = SC1 plus the contribution from 1600 acres of development;
B = SC2 plus the contribution from 1600 acres of development.



VOLLENWEIDER'S TOTAL PHOSPHORUS LOADING vs.
MEAN DEPTH ÷ WATER RESIDENCE TIME ($\bar{z}/{}^t w$) RELATIONSHIP

FIGURE D-1

APPENDIX E

COMMONWEALTH of VIRGINIA

STATE WATER CONTROL BOARD
2111 North Hamilton Street

Eugene T. Jensen
Executive Secretary

Post Office Box 11143
Richmond, Virginia 2323
(804) 770-1411

Please Reply To: Piedmont Regional Office
4010 West Broad Street
P. O. Box 6616
Richmond, Virginia 23230
(804) 770-5401

February 10, 1975

Mr. J. A. Limerick, Jr.
R. Stuart Royer & Associates
1514 Willow Lawn Drive
Richmond, Virginia 23226

Subject: Response to W. L. Carter's December 13, 1974 letter to E. T. Jensen - Old Town Creek and Colonial Heights interceptors

Dear Mr. Limerick:

In response to W. L. Carter's December 13, 1974 letter (Attachment I) to E. T. Jensen, I feel the following comments are necessary to fully evaluate the problem.

The data base which Engineering-Science, Inc. used in the preparation of Volume VII-4 (Part B), "Existing Hydrologic and Climatological Data Base (Groundwater Hydrology)," in the James River Comprehensive Water Quality Management Study (3-C Report) was based primarily on reports by Cederstrom (1945) and the Virginia Division of Water Resources (1970). When these bulletins were published, recharge of the principal aquifers was considered to occur by direct infiltration along the Fall Zone where the deeper coastal plain sediments crop out.

More recently, results of a State Water Control Board - U.S. Geological Survey aquifer system model of the coastal plain of southeastern Virginia has shown that vertical leakage through confining layers is the major mechanism for recharge to the Potomac aquifer (see Attachment II, pages 7, 8, and 9). Vertical recharge occurs at a minimum rate of 30,000 gallons per day per square mile (see Attachment III, pages 2 and 3). The results of a pump test conducted in January, 1975 on a well in eastern Henrico County indicated that vertical recharge in that part of the coastal plain may be as much as six to ten million gallons per day per square mile.

In the Hopewell area many large ground-water users have converted to the use of surface water since 1970. The cone of depression at Hopewell, therefore, is not expected to expand; the future availability of ground water at Hopewell should not be a major problem.

The westward movement of the salt-water-fresh-water interface in southeastern Virginia has been a concern for a number of years. Several deep wells show high chloride concentrations (see Attachment II, page 20). The U.S. Geological Survey has defined the interface (see Attachment II, page 21); however, the staff of the State Water Control Board does not feel that there exists enough data points to predict the movement of the salt front. In the near future the Board's Bureau of Surveillance and Field Studies plans to construct several new deep wells to monitor the movement of salt waters.

At the January 24, 1975 meeting of the State Water Control Board, southeastern Virginia (as described in Attachment II) was declared a Critical Groundwater Area. Under this program the area now will be managed to prevent the depletion of ground-water supplies and the deterioration of ground-water quality.

I hope that these remarks will assist you in your answer to EPA.

Sincerely,

David H. Walz

David H. Walz
Regional Geologist

Enclosures: I - letter dated December 13, 1974, W. L. Carter to E. T. Jensen

II - Planning Bulletin 261-A, "Groundwater of Southeastern Virginia

III - letter dated September 27, 1973, J. J. Cibulka to E. G. Councill, III

cc: J. J. Cibulka

L. H. Corkran

dtb

APPENDIX F

TABLE F-1
Population Projections,
Chesterfield County Portion of Service Area

Base Population, January, 1975: 50,726
County Growth Rate: 5.8 percent annually
DSPCA Growth Rate: 1980-1984 - 2.7 percent
1985-1989 - 2.6 percent
1990-1994 - 2.1 percent
1995-2000 - 2.0 percent

End of Year	County	"DSPCA"[1]
1975	53,668	53,668
1976	56,780	56,780
1977	60,074	60,074
1978	63,558	63,558
1979	67,244	67,244
1980	71,145	69,059
1981	75,271	70,924
1982	79,637	72,839
1983	84,256	74,805
1984	89,142	76,825
1985	94,313	78,823
1986	99,783	80,872
1987	105,570	82,975
1988	111,693	85,132
1989	118,172	87,345
1990	125,026	89,180
1991	132,277	91,052
1992	139,949	92,965
1993	148,066	94,917
1994	156,654	96,910
1995	165,740	98,848
1996	175,353	100,825
1997	185,524	102,841
1998	196,284	104,898
1999	207,669	106,996

Notes: 1. Since the 1975-1979 rate of 5.8 percent used here is not DSPCA's, figures in this column reflect EPA's combined use or rates.

TABLE F-2
Subdivisions to be Served by Public Sewers,
1975 - 1980, and the Number of Housing Units in Each

Key Ref. No.	Grid No.	Subdivision	Number of Houses
193	27	Stonehenge	167
203	16	Sunny Dell Acres	18
152	27	Hylton Park	63
221	27	Kinrey	11
185	27	Pocoshock Heights	34
143	27	Forest Acres	84
202	39	Spring Hill	48
219	28	Gatewood	30
209	38	Wagstaff Circle	32
126	39	Bexley	50
159	39	Lake George Hamlet	16
121	50	Bedford	28
163	50	Lyndale	20
217	50	Longwood Acres	137
140	50	Falling Creek Acres	18
141	50	Falling Creek Farms	103
173	40	North Lake Hills	47
124	40	Belmont Hills	18
164	40	Marlboro	30
137	29	Elkhardt Park	28
192	29	Southaven	82
220	29	Schloss Manor	14
213	29	Manchester Heights	14
195	39	Surreywood	74
216	67	Rayon Park	80
150	52	Henning Heights	38
187	52	Rock Spring Farms	117
199	52	Trampling Farms	63
212	52	Gravel Brook Farms	41
154	51	Jessup Place	11
	51	Dale Meadows	8
	51	Fernwood	6
123	51	Belmont Acres	96
227	41	Wilkerson Terrace	75
132	38	Chestnut Hills	106
116	38	Arrowhead	47
157	27	Lake Crystal Farms	109
120	38	Beechwood Farms	11
158	49	Lake Genito	60
138	64	Estridge	53
149	64	Hallie	10
146	41	Garland Heights	144
119	52	Beechwood	42
117	17	Avon Park	10
218	16	Black Heath	24
200	16	Windsor Forest	42
129	28	Brookfield	135
139	42	Falling Creek Court	20
228	40	McKesson Place	8
145	66	Fuqua Farms	114
229	67	Bellwood Addition	55
230	53	Bensley Village	30
226	16	Midlothian Area	75
189	8	Salisbury	328
224	29	Amber Heights	22
161	51	Land-O-Pines	44
175	51	Old Coach Hills	33
153	51	Jessup Farms	21
	28	Ruthers Road	20
111	17	Dunns Trailer Park	42
151	8	Hillanne	8
112	28	Cedar Grove	23
225	39	Pocoshock Hills	43
188	38	Runnymeade	8
165	49	Mayfair Estates	78
172	76	Mockingbird Hills	8
197	62	Swift Creek Farms	20
		Unrecorded lots in Grids 8, 16, 17, 26, 28, 29, 38, 39, 40, 41, 48, 49, 50, 51, 52, 53, 63, 64, 67	150
		Sub-Total	3644
		Houses which have applied for sewer but have not connected	511
		Houses with sewer service laterals to the property line but have not applied	252
		Houses to be connected in the City of Richmond from extensions now planned or under construction	318
		TOTAL	4725

APPENDIX G

PROVISIONS OF THE SWIFT CREEK RESERVOIR MONITORING AND MANAGEMENT PROGRAMS

Although the State Water Control Board and Chesterfield County are conducting independent studies, the most reliable and relevant data will be obtained from the program being administered by EcolSciences, Inc. for the County.[1]

Table G-1 lists the constituents being monitored by each program. Also included is the depth and locations of the sample location.

Discussion of EcolSciences, Inc. Monitoring and Management Program at Swift Creek Reservoir

As part of its monitoring and management program for the Swift Creek Reservoir, EcolSciences is developing a loading model of the lake. EcolSciences is not developing a dynamic model of the reservoir at this time because:

1) the required data base for a dynamic model is not currently available but is being generated by Chesterfield County and the State Water Control Board;
2) the proposed loading model will be more useful to the County than a dynamic lake model in assessing proposed development within the drainage basin of the reservoir;
3) the proposed loading model will be an integral part of any dynamic lake model; and
4) the cost of developing a dynamic model for Swift Creek Reservoir is currently excessive with respect to anticipated benefits to the County.

At a meeting of parties interested in the fate of Swift Creek Reservoir (Chesterfield County, EcolSciences, Sea Pines Company, and the State Water Control Board), EcolSciences announced its intention, as the County's consultant, to monitor water quality in the tributaries to the reservoir, and to develop a loading model basin upon land use in the lake's drainage basin. This strategy was approved by all parties, and is integrated into a monitoring program involving the other three parties.

The tributary monitoring program has been designed to provide base line loading data for phosphorus, nitrogen, suspended sediment, coliform bacteria, and heavy metals. These data will be used to:

1) develop a loading model based upon current land use in the Swift Creek Basin; and
2) form the basis of projections of future loadings based upon changes in land use within the basin.

Loading data developed during this phase of the study will be analyzed in reference to recent discussions of loading rate and trophic conditions in lakes (Vollenweider, 1971, Brezonik, 1972; Putnam, Brezonik and Shannon, 1972; Uttormark, Chapin and Green, 1974; Dillon, 1975).

[1]Water quality data from the County is limited because it lacks information on nitrogen and phosphorus concentrations. The SWCB data has lacked sensitivity and also has little utility. EcolSciences has requested that the SWCB increase the sensitivity of its analyses to permit some interpretation of its results. Mr. Pete Trexler of the SWCB has indicated that the SWCB cannot comply completely to this request because of increased costs. EcolSciences currently views the SWCB data as having marginal value. The increased sensitivity of the phosphorus analyses will not significantly improve the value of the data.

TABLE G-1
Constituents Being Monitored at Swift Creek Reservoir

Constituent	State Water Control Board[1]	Chesterfield County[2]	EcolSciences, Inc. (Tributaries)[3]
Dissolved Oxygen	X	X	X
pH	X	X	X
Temperature	X	x	x
Turbidity	X	X	X
Fecal Coliforms	X	X	X
Total Coliforms			X
Alkalinity	X	X	
Total Solids	X		
Volatile Solids	X		
Fixed Solids	X		
Total Suspended Solids	X		X
Volatile Suspended Solids	X		
Fixed Suspended Solids	X		
Total Kjedhal Nitrogen	X		
Ammonia (as N)	X		X
Nitrate (as N)	X		X
Nitrate (as N)	X		X
Total Phosphorous	X		X
Ortho Phosphorous	X		X
Standard Plate Count		X	
Color		X	
Secci Disk		X	
Lead			X
Mercury			X

NOTES:
1. All SWCB parameters are measured at mid-depth on a monthly basis. One sample, nearest the dam, is also measured at the surface and bottom. Sample locations are indicated on Figure G-1.
2. All County parameters are measured at mid-depth on a monthly basis. Sample locations are indicated on Figure G-1.
3. All EcolSciences, Inc. parameters are measured below the surface of eight tributary streams on a monthly basis. Sample locations are indicated on Figure G-1.

The loading rates and trophic condition of the lake will be projected to 1995 based upon Chesterfield County's land-use plan for that year. In addition, loading rates based upon the completion of various phases of Brandermill will be incorporated into the model. Loadings from developed apeas will be based upon coefficients provided by the Real Estate Research Corporation (1974) and other appropriate sources.

The model will predict the variation of nutrient concentrations in the reservoir resulting from alterations of land use within its drainage basin. The predictive capability of the proposed model is dependent upon two factors:

1) The validity of published data on nonpoint source pollution for developed areas; and
2) the validity of published discussions of loading rates and the resulting trophic conditions in Lakes.

Theoretically, the model will be sensitive to any land use change in the drainage basin, regardless of the area involved. However, the two factors limiting the predictive capability of the model will also dampen its sensitivity. This aspect of the model is currently being assessed by EcolSciences.

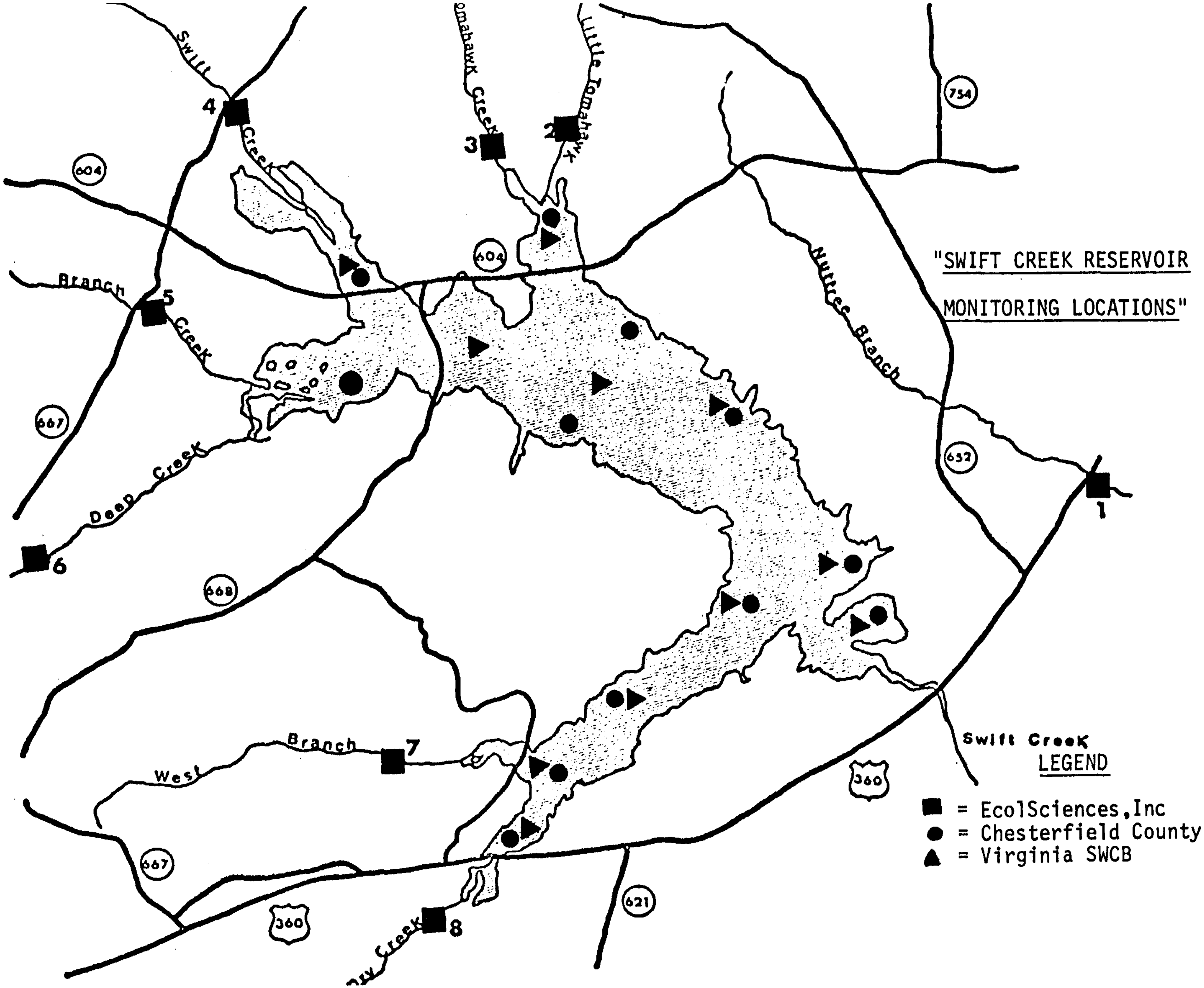
Lake management programs are directed toward either the prevention of pollutant inflow or are therapeutic treatments to improve water quality and relieve the symptoms of eutrophication. The first approach is the more desirable and is available to Chesterfield County. Because the drainage basin of the Swift Creek Reservoir is rural, the County can control development in that area to protect the water supply.

A critical step in assessing the fate of the reservoir is the development of the loading model. This model permits EcolSciences to assess the effects of current and projected land use in the basin upon water quality in the reservoir. The model can incorporate all of the land use patterns available to the County. In this case, EcolSciences can present to the County a series of projections based upon field observations, recent theoretical advances, and management options. The County must make the final determination of feasibility based upon the future use of the lake as a water supply and the costs of maintenance and management.

EcolSciences currently maintains the position that the diversion of silt and stormwater runoff from developed areas immediately surrounding the reservoir is a critical portion of any management program. Based upon four months of water quality data from the tributaries to Swift Creek Reservoir, surface runoff into the lake contains low concentrations of total phosphorus and orthophosphate. Surface runoff from urban areas contains considerably higher phosphorus loads than that from forested areas similar to the Swift Creek basin (Uttormark, Chapin and Green, 1974). This is apparently due to the high phosphorus retention capacity exhibited by forest soils. Runoff from urban areas also contains large quantities of pesticides and petroleum residues which would be detrimental to a water supply reservoir. In addition, the direct channelization of runoff leads to heavy sediment transport during periods of heavy rainfall. This contributes directly to the siltation of the reservoir, and indirectly to nutrient buildup through the addition of compounds associated with the sediment particles. All of these problems would be exaggerated during construction. Diversion of urban runoff would also facilitate in-lake management techniques by reducing the total load of polluting substances.

The second phase of the program involves the development of an in-lake management strategy. The total strategy is composed of a series of management techniques combined to efficiently control macrophyte infestations and phytoplankton blooms. EcolSciences will approach the problem by evaluating the potential for algal and/or macrophyte production in the reservoir, and offer a series of alternative treatment techniques based on each specific problem. Each evaluation will include an estimation of the costs, effectiveness and impacts of each alternative management technique. The resulting management matrix will allow a flexibility in decision-making that is necessary for good management. The matrix will provide guidance for day-to-day management decisions, while detailed background data on the various techniques will be available in the body of the report. This approach has been used in management plans developed by EcolSciences personnel for other reservoirs.

The determination of feasibility is, again, the responsibility of two parties, EcolSciences and Chesterfield County. EcolSciences will, in its review of lake management techniques, arrive at several conclusions and present recommendations to the County. Chesterfield County will make the final decision concerning the feasibility of any management technique or program. In its determination, the County will consider the future of the lake as a water supply, the costs of the management program, and the future of all water supplies under its jurisdiction.


"SWIFT CREEK RESERVOIR
MONITORING LOCATIONS"
Swift Creek
omahawk Creek
Little Tomahawk
Nuttee Branch
Branch Creek
Deep Creek
West Branch
Creek
Swift Creek
1
2
3
4
5
6
7
8
604
604
754
667
668
632
667
360
360
621
LEGEND
= EcolSciences,Inc
= Chesterfield County
= Virginia SWCB

-FIGURE G-1

APPENDIX H

ENVIRONMENTAL RELATIONSHIPS OF THE BRANDERMILL PLANNED UNIT DEVELOPMENT TO SWIFT CREEK RESERVOIR AND ASSOCIATED WATERSHED

A TECHNICAL REVIEW

James E. Hackett, Division of Environmental and Urban Systems
Joseph L. Intermaggio, Division of Environmental and Urban Systems
Kenneth L. Dickson, Center for Environmental Studies
David W. Smith, Division of Forestry and Wildlife Resources

Virginia Polytechnic Institute and State University
Blacksburg, Virginia
April 16, 1974

Introduction

Investigative studies were conducted at the request of the Chesterfield County Board of Supervisors to assess the relationships of the proposed plan of development of Brandermill, a planned unit development adjacent to Swift Creek Reservoir, to the environmental integrity of the reservoir and the associated watershed. The findings of the investigations contained in this report are intended as an objective technical review of available data and information to assist the County Board of Supervisors in forthcoming zoning decisions concerning the proposed development property. The conclusions of the study are conditioned by the nature and quality of the existing information base.

The period allotted to these review and assessment efforts was four weeks between March 19 and April 16, 1974. The study team consisted of four faculty members of VPI & SU from the environmental sciences and urban and regional planning areas as follows: Dr. James E. Hackett, Professor, Division of Environmental and Urban Systems; Joseph L. Intermaggio, Professor, Division of Environmental and Urban Systems; Dr. Kenneth L. Dickson, Associate Professor, Center for Environmental Studies; Dr. David W. Smith, Assistant Professor, Division of Forestry and Wildlife Resources.

The report summarizes the results and conclusions of this effort as drawn from technical and planning reports regarding the proposed development and the watershed, and from discussions and conferences with county officials, representatives of county and regional planning agencies, consulting firms, Brandermill Development, Sea Pines Company and a spokesman for concerned citizens. The report consists of five major sections each of which reflects a different perspective of the issue. These perspectives are as follows: Watershed Considerations, Reservoir Potentials, Reservoir Conditions, Brandermill Planned Unit Development, and Community Responsibilities.

Watershed Considerations

Substantial population growth is anticipated in the western part of Chesterfield County for the future. As a consequence of this growth, Swift Creek Reservoir Watershed will face increasing pressure for urban development. Improved transportation along proposed Route 288 and Powhite Parkway, accessibility of sewer facilities through the auspices of the Sewerage Improvement Program and the development of Brandermill as a suburban growth center will tend to further stimulate urbanization in the watershed. Even without the development of Brandermill, suburban growth can be expected in the watershed due to the general increase in population and the provision of transportation and sewerage facilities. Therefore the following conclusions are relevant:

I. According to recent soils mapping and land use suitability analyses, the Swift Creek Watershed is largely within the area of greatest soils limitation to urban land use within the County. If uncontrolled urban or suburban growth is permitted within the watershed, or if either rural or urban land use management is inadequate, degradation of Swift Creek Reservoir as a source of water supply or as an environmental and recreational amenity will be significantly accelerated.

II. Three general alternatives appear to be available with respect to the future of Swift Creek Reservoir Watershed in County development: (1) As a protected open space serving as a buffer to expanding suburban development; (2) as as area of highly managed developmental growth where land use is adjusted to the protection requirements of the reservoir and the watershed, (3) as an area of developmental sprawl with patterns and characteristics of land use similar to those currently experienced elsewhere in the county.

The alternative of maintaining Swift Creek Reservoir Watershed as an open space buffer to urban and suburban development would have the least environmental impact on Swift Creek Reservoir. It would, however, involve substantial commitments, financial as well as social, on the part of the citizens of the county to secure that use through public ownership and control and to insure the environmental integrity of the area through technically sound land use control and management.

If intensively managed developmental growth is selected as the alternative, stringent minimum standards with regard to water quality and discharge, sediment yield, and land use type and density should be defined and applied as the basis for development planning, regulatory controls, physical management programs, and the development and subsequent maintenance of sites. These standards should be established with regard to the discrete physical characteristics of the watershed.

Typical urban and suburban growth, not specifically sensitive to the environmental factors of the watershed and not compatibly adjusted to these characteristics, would have the greatest adverse impact on the reservoir and on the watershed in general. Although an intermix of alternatives one and two can be accomodated within the watershed without necessarily adverse consequences, alternative three, if allowed in relation with either of the other alternatives, would result in degradational impacts.

III. There is a need for Chesterfield County to make a basic policy decision with regard to the eventual use or extent of developmental growth in the Swift Creek Reservoir Watershed. Regardless of the policy decisions that are made, a comprehensive management system based on the critical environmental constraints of the area is mandatory to maintain the environmental integrity of the area.

Reservoir Potentials

I. Water quality of Swift Creek Reservoir at present is well within the minimum standards for use as a source of domestic water supply and is a valuable environmental amenity to the county. However, the future role of the reservoir as a source of public water supply for the county is unclear. This is largely due to the lack of an official water resource and water supply management plan based on a detailed assessment of projected needs and programming of storage, supply and distribution facilities that are formulated in terms of regional programs of water resource utilization. The need is pressing for a comprehensive water resources management plan for the county as a basis for decisions regarding the ultimate use of Swift Creek Reservoir and developmental growth within the watershed.

II. Community values with regard to the reservoir as an amenity are subject to change with developmental growth and shifts in resource management programs. Future uses of the reservoir could reflect changing requirements with regard to recreational and environmental amenity needs and the desires of the community. In any event it is advantageous to preserve existing levels of quality of the reservoir and its environs to maximize flexibility in choices for future use.

III. Although water supply and visual and recreational amenities of Swift Creek Reservoir are primary concerns, the reservoir also serves other valuable functions which could be seriously impaired by poorly managed land use in the watershed. These include the protective roles of the reservoir with regard to downstream areas in terms of flood water storage, sediment control and water quality control.

Reservoir Conditions

I. Swift Creek Reservoir currently has acceptable water quality to serve as a water supply for Chesterfield County. From a water supply viewpoint, major problems are those associated with the high levels of manganese and iron which require special water treatment technology to overcome. However, current practices by the Swift Creek Water Plant cope adequately with this problem. Limited chemical data from the Virginia State Department of Health on the raw water at the intake to the water treatment plant indicate that:

(1) The level of lead has been increasing in the last three years and is approaching the recommended maximum of 0.05 mg/1. Additional data are needed to define this condition.

(2) The data available on pesticides from the Virginia State Department of Health for the raw water intake are not sufficiently sensitive to determine if the water meets the criteria proposed by the Environmental Protection Agency for drinking water and aquatic life (*Proposed Criteria for Water Quality* Volume I, U.S. Environmental and Protection Agency, October 1973).

II. Available water quality data on Swift Creek Reservoir indicate that sufficient nutrients (nitrogen, carbon and phosphorous) are available to support algal blooms which could result in nuisance conditions (taste and odors, algal mats, etc.). However, the occurrences in these conditions in the reservoir has been infrequent, probably because of the relatively low levels of dissolved inorganics.

III. Water quality in the reservoir currently does not limit recreational use. However, the use of the reservoir as a source of public water supply serves as a constraint to the type of recreational use that should be allowed.

IV. Changes in the storage capacity of the reservoir since its construction are not known. There is a need for the establishment of a data base to determine the rate of siltation of the reservoir basin. Such data are valuable in predicting the long term viability of the reservoir as a water supply and would be needed in the design of a reservoir management program. This could be accomplished through the establishment of a chemical, physical and biological monitoring program on the reservoir and feeder streams. Such a program should be designed to determine a sediment and chemical budget for the reservoir.

The causeways in the upper part of the reservoir should be evaluated in relationship to their functional role as siltation buffers (i.e., traps) for the main body of the reservoir. Input-output data would be required for this evaluation.

V. Swift Creek Reservoir will undergo the natural phenonema of eutrophication and will change in its physical, chemical and biological characteristics. However, the rate at which this aging process proceeds is highly dependent upon the type and level of activity in the watershed. The current data base is inadequate to predict the life of Swift Creek Reservoir as an acceptable source of water supply and as an environmental amenity under present social standards. However, available soil, topography and vegetation data indicate that there is a high potential for an accelerated rate of eutrophication dependent upon land use activity and management of the watershed.

VI. In order to maintain the present use of the reservoir, it is recommended that all inputs to the reservoir be required to comply with the criteria identified by the Environmental Protection Agency in *Proposed Criteria for Water Quality*, Volume I, October 1973. These proposed criteria are based on the latest scientific knowledge on the identifiable effects of pollutants on human health, fish and aquatic life, plant life, wildlife, shorelines and recreation. Suspended solids, pesticides, lead, oil and surfactants are the pollutants identified as of specific importance in urban development.

Brandermill Development

Brandermill, a planned unit development complex of the Sea Pines Company, represents the more advanced concepts of community development design—allowing for greater flexibility in land use arrangement and density distributions than standard or conventional subdivision developments. This flexibility in design permits accommodation of the structural arrangement of the development to the physical characteristics and environmental management requirements of the site. To do this requires that an adequate base of environmental information exists and that it is appropriately related to the development design elements. A review of the environmental information base acquired with respect to the Brandermill site indicates that the basic data studies generated generally exceed those which are normally obtained for subdivision development.

Sea Pines Company appears committed to produce a quality community with high environmental standards. The company has a realistic understanding of the value of the reservoir as an environmental amenity and an economic asset to the development, and recognizes that these values would be significantly impaired by a degradation in the water quality or visual qualities of the reservoir. In the area of soil data and interpretation, however, information acquired by technical consultants responsible for environmental studies was inadequately prepared and, as a result, misrepresentative and misleading information on soil conditions was provided to the development firm. Consequently, existing development plans and site management programs do not conform in all respects to the known physical constraints of the area. Appropriate consideration of these factors in development planning, design and management is essential if consequences adverse to the development site and surrounding area are to be forestalled.

The following conclusions and recommendations are made with regard to the needs for environmental protection, the quality of the environmental information base, use of environmental information in development planning and design, adequacy of existing environmental control standards and needs for construction phasing for the development.

I. The quality of the information base prepared for the Brandermill Development Plan was adequate with the exceptions of soils information and reservoir siltation data.

The soils information in the Swift Creek Community Environmental Assessment Report does not adequately reflect soil conditions typical of the development site. Hydrologic, slope, topographic, vegetation and bank erosion characteristics have been inventoried and are representative of the development area. They are generally adequate for development planning, design and management. Water quality data is inadequate to evaluate the rate of eutrophication of the reservoir. It is only applicable to current development planning, design and management, and does not address the life span of the reservoir as an environmental amenity related to the development.

II. Existing plans and environmental management programs for the Brandermill Development have been prepared without adequate cognizance of the prevailing soil conditions and of the significance of soil characteristics in general for site specific planning and design. This constitutes a major deficiency with regard to the design and development of effective management programs to minimize impacts on Swift Creek Reservoir, associated drainage ways, and the development site itself.

The major portion of soils in the Swift Creek Reservoir Watershed are derived from mudstone, shale, sandstone and conglomerate of the Triassic geologic era. Typically, these soils have medium to coarse textured surface horizons that normally do not exceed 14 inches in depth. However, this varies considerably throughout the area depending on previous erosion losses. The subsoil horizons are generally fine textured, of low permeability and have a high swell potential.

Data in the James River Comprehensive Water Quality Management Study compiled for the Commonwealth of Virginia Water Control Board - October 1972 indicates that the potential sediment yield from the areas in the Brandermill development are more than double the generalized values reported in Table IV-I in the report on Environmental Assessment prepared for Brandermill. The James River Comprehensive Water Quality Management Study (hereafter referred to as the James River Study) indicates that under fallow conditions an estimated 151 tons/acre/year can be expected. Exposed-soil areas such as construction sites have been shown by studies of the U.S. Department of Interior to exceed the sediment yield produced on cultivated agricultural land or open spaces. Therefore, the generalized sediment yields reported in the Brandermill report underestimate the potential sediment yield based on site-specific data.

Within the James River Basin, the Swift Creek Basin has approximately twice the potential of other tributory basins within Chesterfield County for suspended solid or bed load yields at its mouth. This indicates the high potential for excessive siltation and poor water quality. This estimate is based on soil erosion potential data for each of the watersheds, using U.S. Soil Conservation Service methodology.

The James River Study determined that only 0-25% of the land in the Swift Creek Reservoir Watershed is suitable for the following development-related land uses.

1. Septic tanks
2. Sanitary landfills
3. Roads, streets and parking lots
4. Buildings - three stories or less with basements
5. Parks and picnic areas
6. Campsites.

An analysis of soil survey information (*Soils of Chesterfield County, Virginia*, 1970) for the portions of the Brandermill lands on the eastern side of Swift Creek Reservoir indicate there are substantial limitations to development stemming from adverse soil conditions. At least 60% of the St. Ledger and Old Hundred Landing areas of the Brandermill development are classified as poor or fair-to-poor for homesites. In excess of 75% is classified as poor or fair-to-poor for basements, foundations and roadways. The reasons for the low suitability classification are related to the high clay content and associated seasonal perched watertable in more than two-thirds of the soils. The high clay content of the subsurface horizon produces a high potential for moderate to severe erosion when ground cover or surface soil is removed.

To compound and further complicate the problem, more than 75% of the soils are naturally low in fertility, have low organic matter content and do not respond well to fertilization.

It is therefore imperative that design and construction criteria for development specificallv deal with these site limitations. Site specific data and analyses are necessary to determine the exact location and percentage of suitable areas for development and associated uses.

III. For Swift Creek Reservoir to remain as a source of potable water and an environmental amenity for the citizens of Chesterfield County, positive controls must be instituted to protect the reservoir from the adverse environmental changes that accompany urbanization.

The impact of Brandermill development on Swift Creek Reservoir, both short and long term, is directly related to the management program implemented by the developer. Of primary concern are the monitoring and control of sediments, nutrients, pesticides, oil, debris, trash and other urban contaminants. To maintain the integrity of the reservoir a natural buffer zone of sufficient depth is essential along the shoreline and drainage-ways for purposes of maintaining a visual screen, to control bank erosion, and to functionally ameliorate the impact or urban contaminants. Existing design standards should be reviewed and expressed in terms of minimum distances for excavation and construction activity and for visual screening.

IV. Nuttree Branch is particularly sensitive to the impact of suburban development and it will require specially designed management programs to protect the quality characteristics of the stream both within the Brandermill development area and in downstream reaches. These management programs should incorporate individual building site safeguards as well as drainage system controls. Because of the widespread presence of a highly permeable surface soil layer, road construction, roof areas, paved parking areas and other impervious surfaces will effectively modify the natural storm-water runoff characteristics of the site. The effects could be increased periodicity of overbank flows, lower low flow or extended periods of no flow, higher peak discharges and greater velocity of flow. Experience in urbanized areas has shown that this can result in increased bank erosion downstream from developed areas. The more significant factors to be considered in the development program and site use are: the preservation of the integrity of the permeable surface soil, minimization of impermeable surface areas, minimal use of storm or sewer ditch drains and maximum retention of storm water at an individual site.

Nuttree Branch is part of a fragile ecosystem, and adverse modification of stream flow and water quality conditions would serious affect its present amenity. In addition to storm water runoff control, sediment control and control of urban contaminants, a natural buffer zone would be required to protect the stream from human activity. Sewer lines and other potential sources of pollution and contamination should not be located immediately adjacent to the stream bed but should be positioned with respect to the protective requirements of the stream.

V. The Brandermill development plan does not reflect a critical review, updating and integration of the available environmental data. Brandermill's conceptual framework of design recognizes the needs for storm water runoff control and sediment discharge control. However, the application of management controls and response to environmental constraints at the site development scale are less clear. Stockpiling, subsequent replacement and immediate revegetation of surface soil are of utmost importance to a compatible land use program. Unless this procedure is diligently followed, growth of vegetation, storm water runoff control and sediment control will present difficult problems.

Brandermill's general development plan apparently includes such management activities as runoff storage, sediment detention, use of natural swales for runoff, reduction of impervious surfaces, lake buffer zone, phasing of construction activities, and general construction controls. The allocation and implementation of these environmental management activities should be determined by an analysis of site conditions, and associated structural limitations and potentials for runoff control should be determinants not only for the management plan but for site development as well. Standards and guidelines of the type and in the detail needed are contained in the "Guidelines For Site Planning" developed for the Woodlands (Texas) New Community.

VI. Specific quantifiable control standards must be developed in order to implement an enforceable environmental management program.

Suggested criteria for design of control standards regarding storm water discharge, fertilizers and pesticides follow:

1. Storm water runoff should contribute no increase in off-site discharge during design strom (design storm is based on local hydrological data).
2. Total suspended solids to the aquatic systems should not exceed 80 mg/l.

3. Urban contaminants to aquatic systems (oils, pesticides, lead, etc.) should meet the standards established by the State Water Control Board and the Environmental Protection Agency at all points of discharge.

4. The use of fertilizers and pesticides should be kept to a minimum and used only on a site specific basis where a substantiated need exists. Quantifiable standards for discharge are not currently available but need to be established in concert with state regulatory agencies.

VII. Phasing of site development would assist in establishing a quantitative base for management design and provide for protection of the receiving systems during the course of construction. Beginning with the initial development, a program for phasing of construction should be developed that will provide adequate opportunities for redress and control of construction impact on the receiving system (lake or stream). Of particular concern would be the earliest construction activity which should be located at a point sufficiently removed from the receiving systems so that supplemental management controls can be incorporated in the event of inadequate protection. In addition, a quantitative monitoring program to provide the data base and feedback system to control design in subsequent development phases must be incorporated as a continuing operational development.

If the Brandermill project is approved with appropriate safeguards, cooperation between the county and the developer is essential to capitalize on the experience gained in managing Brandermill's development in connection with future development in the Swift Creek Reservoir Watershed and the county.

Community Responsibilities

The proper development of Swift Creek Watershed and the use and viability of Swift Creek Reservoir should be defined by public policy, taking into account all citizens of the county. These interests should be safeguarded and insured through cooperative interaction among the citizens, landowners, government officials and development interests using such advisory groups as needed.

Brandermill must be assured that future developments in the watershed will not contribute to the accelerated degradation of the lake as a consequence of poor land use and management. The county must assume the responsibility to control developmental practices in such a manner that the investments in environmental protection made by Brandermill or other development interests are safeguarded.

APPENDIX I

BRANDERMILL EROSION AND SEDIMENTATION CONTROL

This guide is part of an evolving program of erosion and sedimentation control for Brandermill. It is broken down into three basic parts:

(1) Land Planning
(2) Design and Construction Measures
(3) Continuing Controls

This program will be continually updated and refined in coordination with further development of the overall planning, design and construction process. More specific and definitive procedures for individual sites will be prepared in conjunction with the detailed plans for each site.

LAND PLANNING

1. Open Space System

An extensive open space system will be maintained throughout the property.

The naturally vegetated areas and carefully maintained fairways in this system will help control erosion in a number of ways:

(a) reduce runoff velocity
(b) promote infiltration
(c) disperse overland flow over a wide area

In addition, vegetated areas, especially grass, filter out most of the nutrients and dissolved elements in the runoff.

2. Natural Buffer around the Lake

A buffer of natural vegetation will serve as the final line of defense before runoff enters the lake.

100% of all tracts are set back at least 50 feet.
78% of the shoreline has a tract setback of over 100 feet.
49% of the shoreline has a tract setback of over 200 feet.
31% of the shoreline has a tract setback of over 300 feet.

This natural buffer reduces the rate of stormwater runoff and removes suspended and dissolved solids just prior to the water entering the lake.

3. Natural Drainage Swales

Natural swales form an integral part of the open space system.

Because they serve as areas of concentration and collection for stormwater runoff within a specific topographic section, these swales will be maintained in a natural state for purposes of erosion control.

Diversion channels will open into these swales rather than directly into the lake or streams in order to take advantage of the natural filtering process of the vegetation.

4. Steep Slopes and Areas with the greatest Erosion Potential

These areas will remain undisturbed wherever possible. They have been identified and mapped based on an analysis of the soils, slopes and vegetation of the property.

An excellent example of this policy is the narrow peninsula near the southern end of the reservoir. The entire 15 acres of the peninsula, designated Sunday Park, will remain unspoiled except for nature trails and passive recreation largely because it has some of the steepest slopes and most erodible soils on the property.

5. Location of Roads

Most major roads will be on ridges or fitted to the topography in order to minimize cuts and fills and minimize runoff velocities.

6. Bike Trails

The bike trails running along portions of the lake will be designed to reduce the rate of overland flow and therefore reduce sheet erosion immediately along the lake's edge.

DESIGN AND CONSTRUCTION MEASURES

1. Land Grading

The plans for each lot will show the location, slope, cut, fill and finish elevation of the surfaces to be graded as well as the practices for safe disposal of runoff water, slope stabiliation and erosion control.

Provision will be made to safely conduct surface water to waterways and diversions to prevent surface runoff from damaging cut faces and fill slopes. Water disposal systems and debris basins will be installed wherever possible before vegetative cover is removed for building construction.

2. Sediment Basins

Prior to construction, permanent sediment basins will be established across waterways and at the base of natural swales in order to temporarily detain runoff so that the sediment drops out and is retained in the basin. The water will be gradually released to the reservoir.

storage capacity: the minimum capacity of each basin will be not less than 0.50 acre-inches for each disturbed acre in the drainage area.

maintenance: the Company will maintain permanent easements in order to permit periodic maintenance of the basins. The basins will be cleaned out when the storage is reduced to one-half of the original volume.

outlet: the water from the basins will be released over a wide vegetated area in order to reduce flow velocity and filter the water before it enters the lake. In order to protect against scour and gully erosion at the base of the dam, proper measures such as using crushed rock at the outlet will be taken.

3. Drainage Channels

A. Vegetated waterways

Natural or constructed channels will be established on gentle and moderate slopes for safe disposal of runoff.

purpose: Naturally vegetated or grassed waterways will be used on sites where added capacity and/or vegetative protection is required to control erosion resulting from concentrated runoff.

Vegetation, especially grasses, filter the runoff and remove a significant amount of dissolved nutrients and trace elements.

The vegetation in these waterways reduces runoff velocities and encourages infiltration.

limitations: Vegetated waterways are limited to gentle and moderate slopes where non-erosion velocities can be maintained.

B. Structurally Stabilized Waterways

On steep slopes, where channel velocities exceed safe velocities for vegetated waterways, structural stabilization will be employed.

In some channels it will be sufficient to construct the channel bed out of crushed rock. This will reduce channel velocities and promote infiltration. Other channels may require linings of either asphalt or concrete to avoid bank erosion.

Structurally stabilized channels will empty into vegetated waterways. Outlets will be designed to prevent gully erosion.

4. Diversions

A diversion consists of a graded channel with a supporting ridge on the lower side constructed across a sloping land surface.

purpose: Diversions intercept and divert surface runoff before it gains sufficient volume and velocity to cause erosion. The water is collected and conveyed laterally along the diversion at slow velocity and discharged into a protected area.

location: Diversions will be located across slopes above the critical area where the concentration of water presents an erosion hazard.

outlets: Outlets will be stabilized prior to the construction of diversions and will be designed to convey runoff without causing damaging erosion.

maintenance: The cross-sectional shape of permanent diversions will be such that it can be maintained with modern equipment.

At sites where adequate protection for sediment-producing areas above the diversion is not possible, provision will be made to periodically remove the sediment from the channel.

5. Vegetative Practices

A. Temporary Cover for Construction Sites

Temporary cover crops will be used to protect sites from erosion when the time of year is unfavorable for seeding and establishing permanent cover. Grasses that are adapted to the locality and season during which protection is needed will be used.

B. Permanent Cover

Natural vegetation will be maintained to the maximum extent possible. On disturbed sites, permanent cover will be established as soon as possible following the completion of construction activity.

The selection of the proper seed for permanent cover will be based on adaption of the grass to the soils and climate, its suitability for a specific use, its longevity or ability to self-reseed, ease of establishment, maintenance requirements and esthetic value.

On steep slopes and other inaccessible areas, plants and grasses will be used that require little or no maintenance.

C. Mulching

Mulch will be used to help establish grasses on steep slopes and other areas where it is difficult to establish plants.

By reducing runoff, mulch allows more water to infiltrate the soil. It also holds seed, lime and fertilizer in place, conserves moisture and reduces surface compaction of soil during heavy rain.

D. Jute Netting

Jute netting is a coarse, open-mesh, web-like material that will be used as a mechanical aid to protect the soil from erosion during the critical period of vegetative establishment.

Jute netting will be used in place of mulch on steep slopes where ordinary seeding methods fail or it will be used to anchor straw mulch.

Jute thatching will also be used to repair and protect waterways and diversions until a permanent grass cover is established.

E. Sodding

Sodding will be used in areas requiring immediate, permanent protection and where the concentration of runoff is such that other methods of stabilization will not be effective.

Sodding will be particularly useful in waterways and diversions when the season is not suitable for seeding and a complete vegetative cover is needed immediately.

6. Phasing of Construction Activity

Tracts will be developed in small, workable units so that each site will be in a disturbed condition for a minimum amount of time. No large tracts will be disturbed and left unprotected for extended periods while awaiting further construction activity.

APPENDIX J

(Adapted from "Measures for the Restoration and Enhancement of Quality of Freshwater Lakes", EPA 400/9-73, 005)

At present, lake restoration measures are not well developed and have been carried out primarily in experimental studies in small lake projects. Even after specific successes, general applicability to other lake problems are uncertain. Only after detailed analysis and testing can a management program for a particular reservoir be developed.

There are two approaches to the rehabilitation of lakes: restricting the input of undesirable materials and/or providing in-lake treatment for the removal or inactivation of undesirable materials.

Only one input-restriction method applicable to the Chesterfield County reservoirs exists. This is sedimentation and erosion controls from the contributing watershed. The implementation of protective control measures for land use management can be most effective for preventing erosion from construction, farming, road building and forestry activities.

Sedimentation basins and filter dams are prominent defenses against the gradual filling of the reservoir. Sediment control measures not only reduce the rate at which the basin fills in, but also restricts the input of nutrients absorbed to sediment particles (See Section II.B. concerning County sedimentation and erosion ordinances).

Appropriate in-lake restorative methods include dredging, nutrient inactivation, covering of sediments, artificial destratification and hypolimnion aeration and drawdown.

Lake Dredging

Dredging is the physical removal of lake bottom sediments and potential nutrient supplies while biological and chemical results from such experimental studies have been encouraging, the relatively high costs prohibit this as an alternative for very large lakes. In the past, many small lakes have been improved using this method, although dredging is a restorative rather than preventative method.

Nutrient Inactivation

This method involves the addition of a material to help coagulate suspended matter and settle out these nutrients into some unavailable form. Alum, copper sulfate, sodium aluminate, fly ash and others have been used as flocculating agents. Some pilot studies have proven successful, but large scale applicability remains uncertain.

Covering of Sediments

Deposition of inorganic particulates or heavy plastic material has been used to prevent sediment-lake exchange of nutrients in small lakes. Although sediment covering removes a potential growth stimulus and retards rooted growth, problems of construction and maintenance inhibit this as a reliable alternative.

Destratification and Hypolimnetic Aeration

Anaerobic conditions, produced by thermal stratification, can be relieved by pumping dissolved oxygen or surface (oxygen-rich) water into the hypolimnion. To date, this option has proved highly beneficial in reducing odors and tastes from reduced bottom sediments, reducing the degree of algal blooms, and maintaining a high dissolved oxygen level throughout the reservoir.

Drawdown

Lake drawdown can be used to control rooted vegetative growth and permit oxygen into formerly anoxic sediments. When drawdown is extreme, an increase in lake volume is possible through consolidation of sediments. As is the case for the other mitigative measures, results are inconclusive while studies continue.

APPENDIX K

*Lake Protection and State Management Statutes**

Authorization for State or Local Unit to:	State Agency Statutory, Cite, Session Law	Percentage of States with Authorization
Regulate pollution dischange into lakes.	Water Control Board Code of Va. § 62.1-44.5 § 62.1-44.18 § 62.1-44.33 § 62.1-194 et.seq. § 62.1-3.1	100
Regulate placement and fill in lakes	Marine Resources Commission Code of Virginia 62.1-3	96
Regulate dredging or mineral extraction.	Marine Resources Commission Code of Va. § 62.1-3 et.seq. § 62.1-390 et.seq. § 62.1-1	94
Regulate the use of chemicals for weed or algae treatment.	None	86
Regulate the construction of dams or barrages.	State Corporation Commission Code of Va. § 62.1-80 et.seq. § 62.1-104 et.seq. § 62.1 Ch. 7	98
Establish water levels for impounded waters.	None	70
Construct dams or barrages	Commission of Game and Inland Fisheries - Va. Code (§ 29-11) Title 29, Ch. 2	84
Stock fish and maintain fish habitat, etc.	Commission of Game and Inland Fisheries Va. Code Title 29, Ch. 2	96
Stabilize banks in areas of erosion.	None	66
Treat lakes for algae and weed control.	None	80
Dredge or otherwise reclaim or rehabilitate lakes.	None	56

*Adapted from "Survey: Lake Protection and Rehabilitation Legislation in the United States", Kusler, 1972

APPENDIX L

This appendix describes the five alternative systems for sludge processing and disposal that were identified in Section IV.A.3. In addition, cost and energy consumption are discussed, as well as the environmental impact of each alternative.

Alternative I - Anaerobic digestion, chemical conditioning, vacuum filtration, landfill (base case). The existing sludge treatment system would be expanded to serve the full 12 MGD plant. Two primary digestors and one secondary digestor, similar to the existing units, would be added along with additional units for chemical conditioning and vacuum filtration. Supernatant treatment would also be included to avoid overloading the main aeration tanks with sludge treatment wastes.

In the digestors, anaerobic bacteria consume about 50 percent of the volatile solids present in the sludge. Methane and carbon dioxide gas are produced in this process. The digested sludge would be chemically conditioned to prepare it for vacuum filtration. The vacuum filters remove much of the remaining water to produce a cake-like sludge with a solids content of 20 to 30 percent. The total dry weight of sludge for disposal would be 17,000 pounds per day.

Assuming that the sludge is removed to a landfill and piled 10 feet deep, 15 acres of land would be sufficient to dispose of sludge for 30 years. It was further assumed that this land could be found within 10 road miles of the treatment plant.

A major cost advantage of this alternative is that nearly half of the required treatment units are already operating on the site. Costs are, therefore, the lowest of all alternatives, with annualized costs* of $430,000 per year. The successful operation of this system has been proven by the existing plant.

The major energy inputs include electrical energy for mixing the digestors and operating the chemical conditioning equipment and vacuum filters; heating energy to maintain the digestors at a practical operating temperature; and diesel fuel to haul the sludge to the landfill. However, the methane gas produced by the anaerobic digestion process has a substantial recoverable energy value, which can serve other plant needs such as heating. Overall, when properly operated, the process can achieve a net energy production equivalent to 3,800 barrels of oil per year.

Alternative II - Anaerobic digestion, chemical conditioning, vacuum filtration, dry land disposal. The in-plant processes of this alternative are identical to those of Alternative I. However, the dewatered sludge would be spread over cropland and used as a fertilizer, rather than placed in a landfull.

The rate at which sludge can be applied to land depends upon the soil characteristics, the ability of particular crops to utilize nutrients, and the concentration of nutrients and heavy metals in the sludge. Local conditions, rather than general guidelines, determine the proper application rate for a particular location. Before sludge could be spread on cropland in Chesterfield County, a pilot study would be necessary to determine the safe application rate, guidelines for runoff control, and potential crop benefits.

An application rate is required in order to make even a preliminary estimate of the land needed. For a range of 20 to 65 (dry) tons per acre over the life of the plant (assume 30 years), approximately 1,400 to 4,500 acres, respectively, would be required for sludge spreading.

Hauling costs would be higher than the base case (Alternative I) because most agricultural land is in the western end of the County. It was assumed that farmers would allow sludge spreading on their land and that purchasing land would not be necessary. Annual costs would be $29,000 above the base case, and are clearly sensitive to the market value of the sludge.

Consumption of extra fuel in transportation reduces the overall energy production equivalent to 3,600 barrels of oil per year.

Alternative III - Anaerobic digestion, liquid land disposal. This alternative would eliminate the chemical conditioning and vacuum filtration steps of Alternative I and spread the sludge in liquid form upon cropland. Approximately 31,000 gallons per day of sludge with a solids content of 6 percent and a specific gravity of 1.1 will be withdrawn from the digestors.

This alternative saves the cost of conditioning and dewatering sludge, but the large volume of liquid sludge greatly increases hauling costs. Annual costs are $215,000 above the base case, making this the most costly of all alternatives. Hauling energy nearly offsets the energy produced in digestion, for a net energy gain equal to only 1,300 barrels of oil per year.

Alternative IV - Heat treatment, vacuum filtration, incineration, landfill. Sludge digestion would be eliminated and sludge directly from the thickeners would be heat treated and vacuum filtered. The dewatered sludge would be incinerated in a multiple hearth incinerator, which incorporates air preheating, gas scrubbing, and recycle of heat to the heat treatment units. Approximately 8,600 pounds per day (dry weight) of ash would remain after incineration and then sent to a landfill. Less than two acres of land would be required to dispose of ash for 30 years.

Heat treatment was selected for sludge conditioning because the incineration process needs sludge with approximately 30 percent solids content. It was not certain that chemical conditioning of undigested sludge could achieve such dewatering on a vacuum filter.

Besides requiring new heat treatment units for the entire plant capacity, this alternative would also require larger vacuum filters for the greater volume of undigested sludge. Costs of treating supernatant would also be higher. The existing digestion tanks would have little salvage value. Total annual costs are $150,000 above the base case.

It was assumed that heat treatment and vacuum filtration can dewater the sludge sufficiently for it to incinerate autogenously without further fuel input. Electrical energy input would be required to operate the vacuum filter equipment and the motors of the multi-hearth furnace; diesel fuel would be required for hauling ash to the landfill. The net energy input to the process is equivalent to 700 barrels of oil per year.

Alternative V - Chemical conditioning, vacuum filtration, composting, dry land disposal. The existing chemical conditioning and vacuum filtration equipment would be expanded to dewater sludge directly from the thickeners. The dewatered sludge would be mixed with an additional 20 percent carbon carrier (such as sawdust) and composted in windrows. The stabilized sludge would be spread on cropland.

The limitations on land disposal of composted sludge are essentially the same as for Alternative II, except that the carbon carrier increases the volume of composed sludge. Using the same loading criteria as Alternative II, 4,400 acres of land would be required over a 30-year period.

The chemical conditioning and vacuum filtration equipment will have to be large enough for the extra volume of undigested sludge. The solids content of the dewatered sludge is not as critical as for incineration, but must be nearly 20 percent for convenient handling of the sludge.

The source of the carbon carrier has not been determined; unless it can be provided by a waste source, such as municipal refuse, purchase costs would be incurred. As for Alternative II, it was assumed sludge would be given to the farmers and that land would not have to be purchased. Annual costs are estimated at $106,000 above the base case.

*Includes capital and operation costs of anaerobic, supernatant treatment chemical conditioning, vacuum filtration, hauling and land filling, excluding the cost of land. Capital costs were amortized at 7 percent for 20 years. The *Engineering News Record* construction cost index was 2,200.

Energy is required for operating equipment, maintaining windrows and hauling compost for disposal. The composting process does not generate usable energy. The net energy input is equivalent to 1,400 barrels of oil per year.

Environmental Impacts

Alternative I - Anaerobic digestion, chemical conditioning, vacuum filtration, landfill.

Land use - Disposal of sludge to a landfill will remove 15 acres of land from productive use. In addition, the value of neighboring land may be reduced because of noise, potential odor and visual impact. The amount of land required, however, is small in comparison to the size of the County, and careful selection of a site can minimize impacts. After several years of stabilization the landfill could be reclaimed for recreational or other purposes where soil settling would be tolerated.

Public Health - A properly managed landfill will not pose a hazard to public health. Chemical conditioning of the sludge can destroy most pathogens.

Water Quality - Surface runoff from a landfill can contain excessive suspended solids unless good erosion control practices are followed. Water percolating through a landfill can leach heavy metals and BOD into surface waters and groundwater. Again, site selection and management are important.

Air Quality - Burning of digestor gas to recover its heat value will emit less than ten pounds per day of sulfur dioxide at various locations throughout the plant. Concentrations of sulfur dioxide at the site boundary will be well below state standards. Proper operation and maintenance of the sludge digestors and other mechanical equipment will prevent odors at the plant. At the landfill, odors can be prevented by promptly covering the fill material. Dust suppression techniques, such as wetting, can control dust.

Aesthetics - The landfill site will have an aesthetically unpleasant appearance. Proper selection of the site can minimize this impact.

Traffic - During the normal workday, truck traffic will average about five trips per day.

Alternative II - Anaerobic digestion, chemical conditioning, vacuum filtration, dry land disposal.

Land Use - This alternative will require using approximately 4,400 acres of cropland. In 1971, Chesterfield County contained 71,000 acres of farmland, but only 9,300 acres were actually used for cropland. Furthermore, the development of the County will continue to reduce the amount of available farmland. Land disposal of sludge will, therefore, have a significant impact on the County's agriculture. Application of sludge to existing farmland would require acceptance by many of the County's farmers. Unless agricultural benefits are clearly demonstrated, the size of this "market" for sludge may not be sufficient to meet all disposal needs on a continuous basis. The economic success of starting new cropland for sludge utilization would depend upon the marketability of the crops produced.

Public Health - The chemical conditioning process can destroy pathogens in the sludge. Lime, chlorine or other chemicals can be used. Assuming that a pilot study determines a proper application rate for sludge utilization, and that this rate is followed, concentrating heavy metals in the human food chain will not be a hazard. However, since a large number of farmers would be involved with sludge spreading, potential for misuse (i.e., over-application) by individuals does present some element of risk.

Water Quality - If proper guidelines for sludge application are developed and followed, pollution of surface water and groundwater by runoff and percolation will be minimal. Improperly applied to land, however, sludge disposal runoff and percolation could contain excessive concentrations of BOD, nitrates, heavy metals and other pollutants. Since most sludge disposal will take place in the western end of the County, upstream of the water supply, this potential pollution problem would require surveillance.

Air Quality - Burning of digestor gas has the same impacts as Alternative I. The sludge spread on the land will have only a minimal odor, since it will be stabilized and chemically conditioned. The odor will be considerably less than that of manure spreading.

Aesthetics - The sludge spreading sites will have the same aesthetic impact as other croplands.

Traffic - During the normal working day, truck traffic will average about five trips per day. The destinations of these trucks would be scattered throughout the western part of the County.

Alternative III - Anaerobic digestion, liquid land disposal.

Land Use - The land use impacts of this alternative are essentially the same as for Alternative II.

Public Health - This alternative does not offer the opportunity to destroy pathogens in the chemical conditioning process, although anaerobic digestion will accomplish sufficient pathogen removal to preclude a severe public health hazard. Direct runoff from a liquid sludge disposal site could cause pathogens to enter surface waters. This is particularly significant since most liquid sludge disposal sites would be upstream of the public water supply. Wells near disposal sites could become contaminated. This effect can be avoided by choosing disposal sites so that any percolation from the sludge entering the groundwater is purified as it travels through the soil. An element of risk would, therefore, exist from improper application of liquid sludge.

Root crops or crops intended for human consumption in the raw form should not be sprayed with liquid sludge. The effects of heavy metals is essentially the same as for Alternate II.

Water Quality - The water quality impacts of this alternative are the same as for Alternative II, i.e., proper application can avoid problems.

Air Quality - The air quality impacts of this alternative are the same as for Alternative II. If the liquid sludge is sprayed on the land, aerosols can be contained by a buffer zone around the site.

Aesthetics - Liquid sludge, because of its resemblance to sewage, may be more unpleasant, aesthetically, than dry sludge.

Traffic - During the normal working day, truck traffic will average about 50 trips per day, or about one truck every ten minutes. The destinations of these trucks would be scattered throughout the western portion of the County.

Alternative IV - Heat treatment, vacuum filtration, incineration, landfill.

Land Use - Land use impacts of this alternative are the same as for Alternative I, except that only two acres of land would be required.

Public Health - The incineration process will destroy all pathogens in the sludge. Emissions from the incinerator stack will comply with primary air quality standards (see Air Quality).

Water Quality - Surface runoff from a landfill can contain excessive suspended solids unless good erosion control practices are followed. Water percolating through a landfill can leach heavy metals into surface waters and groundwater.

Air Quality - The incinerator will be designed to comply with the emission limits of 40 CFR, Part 61, which would permit, in this case, particulate emissions to 88 mg/sec. There is no emission standard for sulfur dioxide, but available data for other incinerators indicates a maximum emission of about 16 ppm, with 2 to 3 ppm a more common average.

To estimate maximum ground level concentrations under typical weather conditions, the following assumptions were made:

Stack height	50 ft (15.2m)
Stack diameter	0.4m
Exit velocity	25mps
Exit temperature	120°F

Stability class	C	
Wind speed	3.5mps (average at Richmond Airport)	

The maximum concentrations would occur at a distance of 200 meters from the stack. The maximum particulate concentration would be 9 ug/m^3 and the maximum sulfur dioxide concentration would be 0.005 ppm by volume. These values are lower than national ambient air quality standards.

Heavy metals, except for mercury, are not known to volatize in the incinerator, but are believed to remain with the ash. Removal of particulates from the stack gases, therefore, can be expected to remove most heavy metals. Even if heavy metal concentrations in the sludge were as high as 5,000 mg/l, less than 0.1 lb/day would be emitted with the stack gases. Mercury can be decomposed in an incinerator to volatile mercuric oxide or metallic mercury. However, the amount of mercury contained in the sludge is expected to be small, and total emissions will probably be less than 0.1 lb/day, well below the standard for sludge incinerators.

Aesthetics - The landfill site will be barren, with an aesthetically unpleasant appearance. Proper selection of the site can minimize this impact. Visible emissions from the incinerator will have less than 20 percent opacity and will be only a minor impact.

Traffic - Truck traffic will average less than one trip per working day.

Alternative V - Chemical conditioning, vacuum filtration, composting, dry land disposal.

Land Use - The land use impacts of this alternative are the same as for Alternative II. Several additional acres, located near the treatment plant, would be needed for the windrowing.

Public Health - The public health impacts of this alternative are the same as for Alternative II.

Water Quality - The water quality impacts of this alternative are the same as for Alternative II.

Air Quality - Composting is an aerobic process and, assuming proper operation, odors will be minimal during both composting and land spreading.

Aesthetics - The composted sludge spreading sites will have the same aesthetic impact as other croplands.

Traffic - During the normal working day, truck traffic will average about six trips per day.

Comparison of Alternatives

The costs and energy differences between the alternatives are shown in Table IV-19, which also presents a summary of the major advantages and disadvantages of each alternative.

Alternative III, involving liquid land disposal, can be eliminated by comparing it to dry land disposal as in Alternative II. The higher costs and potential health hazard of liquid land disposal are not offset by its advantages.

The two dry land disposal Alternatives (II and V) compare closely. However, anaerobic digestion, Alternative II, costs less, produces energy and does not require a carbon carrier, as does composting. Operating difficulties, the only comparable disadvantage of anaerobic digestion, have not been a major problem at the existing plant. Alternative II can therefore be considered preferable to Alternative V.

The uncertainty of a sufficient and continuous "market" for dewatered sludge among local farmers was discussed above. Given this uncertainty, land spreading, as in Alternative II, is not recommended at this time as the primary means for disposing of sludge in Chesterfield County.

Of the remaining alternatives, incineration (Alternative IV) has a higher cost than anaerobic digestion (Alternative I). Incineration would produce a small amount of air pollution but would not significantly degrade air quality or cause ambient air quality standards to be exceeded. Incineration is a more reliable operation than anaerobic digestion, but this advantage is small since the digestors at the existing plant have been operating correctly.

Besides lower costs due to existing units, anaerobic digestion also offers the opportunity to recover energy from the sludge. This energy can supply one-third to one-half of the total energy needs of the Falling Creek Sewage Treatment Plant.

Selection of Alternative I would not preclude land spreading of sludge. Although it is doubtful land spreading could accommodate all the sludge produced, a portion of the sludge could be spread if marketing conditions permit. The advantages of Alternative I and II could thus be combined.

Recommendations

It is recommended that sludge treatment facilities at the Falling Creek Sewage Treatment Plant be designed in accordance with Alternative I - anaerobic digestion, chemical conditioning, vacuum filtration and landfill. This recommendation is based on lower costs, potential energy production and flexibility of disposal, offset by only a minor increase in comsumptive land use.

It is further recommended that consideration be given to utilizing a portion of the digested sludge for agriculture in the County.

MAPS

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