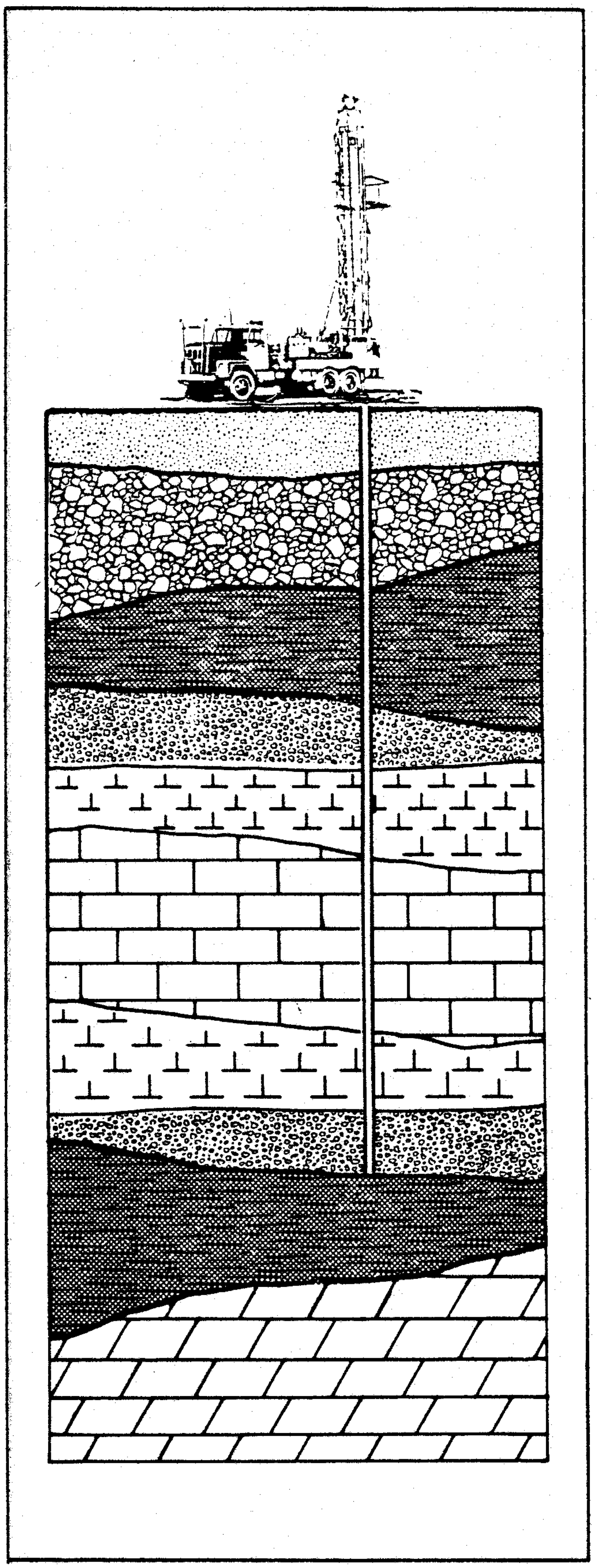


PRINCE WILLIAM COUNTY GROUNDWATER

PRESENT CONDITIONS AND PROSPECTS

by

C. D. Comer

and

NORTHERN REGIONAL OFFICE

COMMONWEALTH OF VIRGINIA

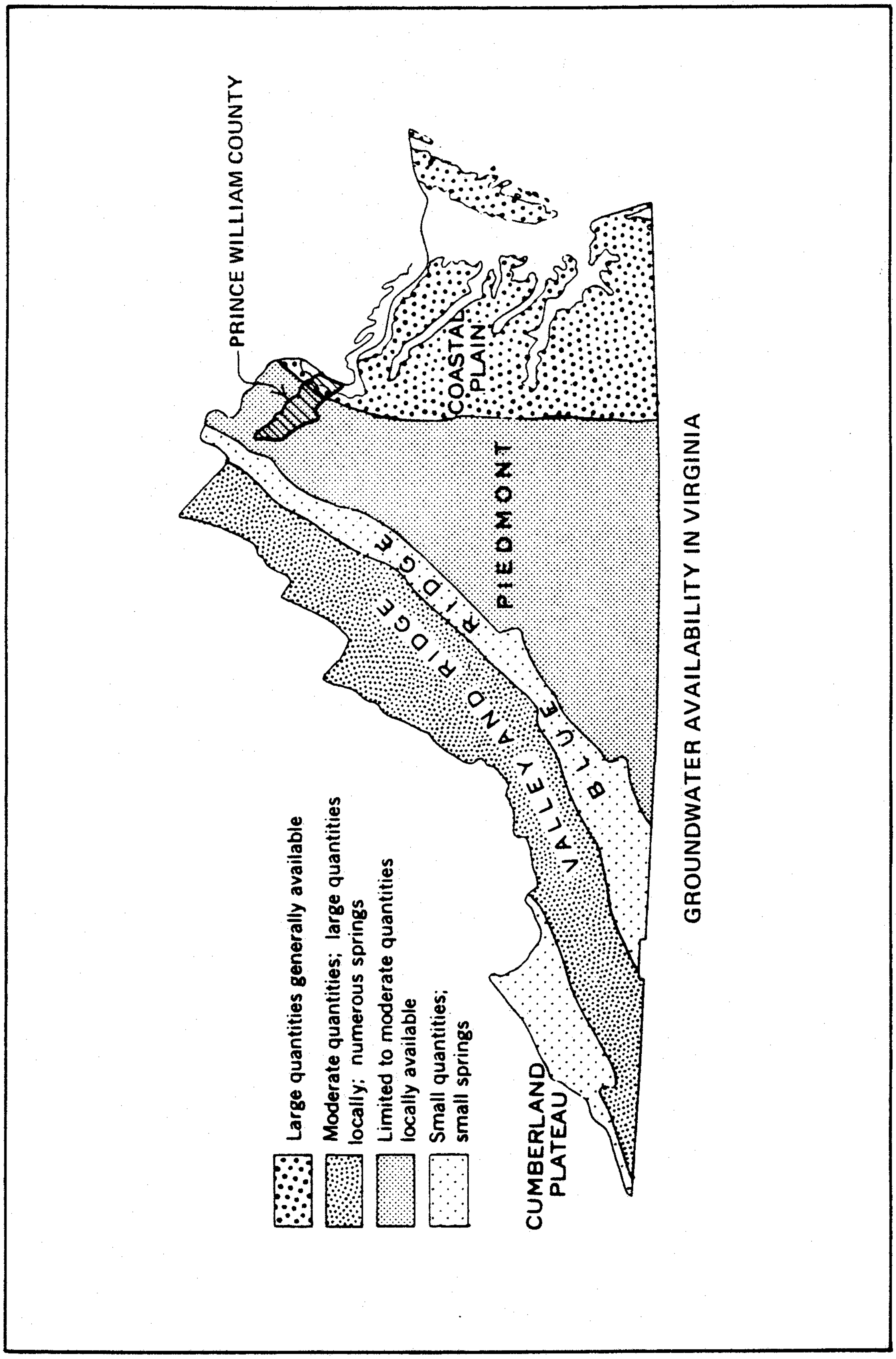
STATE WATER CONTROL BOARD

BUREAU OF WATER CONTROL MANAGEMENT

Richmond, Virginia

Planning Bulletin 303

August 1976



GROUNDWATER AVAILABILITY IN VIRGINIA

Source: Virginia State Water Control Board — BWCM

Frontispiece

E R R A T A

Prince William County Groundwater, Present Conditions and Prospects
Planning Bulletin 303

PAGE	LINE	ERROR
A-4	SWCB NO 76	"FIELD UNIT #3" should be "FIELD UNIT #6"
A-4	SWCB NO 77	"FIELD UNIT #3" should be "FIELD UNIT #26"
A-6	SWCB NO 170	Under "TOTAL HARDNESS", "12" should be "212"
A-6	SWCB NO 173	Under "SO_4", "2000.2" should be "2.2"
B-7	SWCB NO 130	Under "DEVEL FROM", "1000" should be deleted
B-8	SWCB NO 171	Under "USE", "PUB" should be "DOM"
B-8	SWCB NO 172, 173, 174, and 175	Under "STATIC LEVEL", "YIELD", "DRAW DOWN", "SPEC CAPAC", and "HRS", values indicated are incorrect and should be deleted; under "USE", "PUB" should be "DOM"
B-9	SWCB NO 198	"AQUIFER" should be "MSCH"; "YIELD" should be "0"; Under "USE", "DOM" should be "ABD"
B-9	SWCB NO 199	"AQUIFER" should be "MSCH"; under "USE", "PUB" should be "GOV"
B-9	SWCB NO 200 and 201	"AQUIFER" should be "MSCH"; under "USE", "COM" should be "PUB"
B-9	SWCB NO 208	"AQUIFER" should be "TRNS"
GLOSSARY OF TERMS	3	"strate" should be "strata"

PRINCE WILLIAM COUNTY GROUNDWATER

PRESENT CONDITIONS AND PROSPECTS

by
C. D. Comer
Northern Regional Office

VIRGINIA STATE WATER CONTROL BOARD
BUREAU OF WATER CONTROL MANAGEMENT
PLANNING BULLETIN 303
August 1976

FOREWORD

This report is part of a series intended to cover the entire State, and to provide private citizens, groundwater users, developers, investors, well drilling contractors, consultants, professionals, and government officials with as complete a picture as possible of the groundwater situation, including prospects, as it exists in each of the counties of Virginia.

On the basis of this report, prospective groundwater users and anyone else interested in the development and protection of that invaluable resource that is groundwater can call a consulting hydrogeologist to handle their specific groundwater problem, while the State Water Control Board remains at the public's service for general information and governmental action.

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ACKNOWLEDGEMENTS

Appreciation is expressed to the citizens of Prince William County who furnished information on their wells and who allowed water samples to be taken for chemical analyses. Also, officials of Manassas, Manassas Park, the greater Manassas Sanitary District, and Prince William County were most helpful in providing data on public water-supply wells. The Bureau of Sanitary Engineering in the State Department of Health is acknowledged for furnishing copies of chemical analyses on public water-supply wells. Several water well contractors who operate in the County were especially helpful in providing information on construction characteristics and productivity of wells.

PRINCE WILLIAM COUNTY GROUNDWATER

PRESENT CONDITIONS AND PROSPECTS

by

C. D. Comer

ABSTRACT

Groundwater availability is highly variable in Prince William County and depends primarily on the geologic formation in which the groundwater occurs and secondarily on the topographic position of the well site. The greatest variations in the geologic formations occur among the physiographic areas which, from West to East are: Bull Run Mountain, the Triassic Lowlands, the Piedmont Uplands, and the Coastal Plain.

Aquifers are geologic formations that are capable of containing and transmitting groundwater to wells. The quartzite rock on Bull Run Mountain is a very poor aquifer. The red shale, siltstone, and sandstone rocks of the Triassic region are the most widespread and productive aquifers in the County, while the diabase rock of the Triassic region is the poorest aquifer. The granite and schist rocks of the Piedmont yield low to moderate quantities of groundwater, and wells drilled in valleys, draws, and ravines yield more water than wells on ridges or hilltops. The unconsolidated Coastal Plain deposits in the extreme eastern portion of the County are good aquifers, but these sediments are too thin in some places to be highly productive.

The natural quality of the groundwater varies with the aquifer. The water from the Piedmont schist and granite is soft to moderately hard, contains low to moderate amounts of dissolved mineral matter, often contains excessive iron, and is acid to slightly alkaline and may be corrosive. The quartzite rock on Bull Run Mountain yields water that is very soft, low in dissolved minerals, and is acidic and corrosive. Groundwater from the Triassic sedimentary rocks is hard to very hard, very high in dissolved minerals, alkaline (noncorrosive), sometimes contains objectionable amounts of iron, and often contains excessive sulfate. The Triassic diabase groundwater is similar to that of the sedimentary rocks, but is lower in sulfate content. Water from the Coastal Plain sediments is soft to moderately hard, relatively low in dissolved mineral matter, acidic to slightly alkaline, and commonly contains excessive iron.

Groundwater pollution is a potential long-range problem, especially where there are high concentrations of septic tanks. The Triassic sedimentary rocks are probably more vulnerable than any other aquifer system in the County to septic-tank contamination. Gasoline leaks in buried storage tanks are another significant source of groundwater contamination.

Present groundwater development is significant, by means of numerous wells in the Manassas area for public water supplies and in several subdivisions and governmental institutions throughout the County. Most domestic water supplies in rural areas of the County depend exclusively on groundwater.

The area with the best potential for large-scale groundwater development is a 27 square-mile tract south of Manassas to the Fauquier County line and west of Cedar Run. This area is in Triassic sedimentary rocks and could possibly yield 10.6 million gallons per day. A second area in the Triassic sedimentary rocks could be developed west of Catharpin but a reliable estimate of the potential yield cannot be made. The southeastern portion of the Coastal Plain along the Potomac River from the Stafford County line to Powells Creek also likely contains a significant amount of groundwater readily available for development.

CHAPTER I

INTRODUCTION

Background

Prince William County is located in Northern Virginia approximately 25 miles from Washington, D. C. (Plate 1). The majority of the County is rural in nature, although urbanization has occurred at a very rapid rate since 1960. The proximity of the County to the nation's capitol is primarily responsible for this trend. The incorporated towns with their populations (1974 data) are: Manassas (13,067), Manassas Park (6,308), Dumfries (2,230), Occoquan (672), Quantico (777), and Haymarket (235).

Agriculture, chiefly livestock and poultry products, has been increasing in economic output although declining in over-all importance in the County. Manufacturing has increased greatly in output and employment with the principal industries being involved in construction materials (particularly structural steel), refrigeration and air conditioning equipment, motors and generators, electronic components, and research activities. The U. S. Marine Base at Quantico employs some of the County's residents. Also, many citizens commute to the Washington D. C. area, primarily for government-related jobs. (Much of this information was taken from the Division of State Planning and Community Affairs, 1973).

The County's population grew from 50,164 in 1960 to 151,659 in 1974, with an average annual growth rate peaking at 8.3 percent in the 1960's. This rate is presently declining (4.8 percent), and according to the Division of State Planning and Community Affairs

(1975), the decline will continue and gradually reach 2.2 percent in the years 1990-2000. The population for the years 1980, 1985, 1990, and 2000 is projected to be 180,000, 209,000, 238,000, and 296,000 respectively.

This continuing influx of people will bring additional problems, not the least of which will be the providing of an adequate supply of potable water. At the present, much of the water utilized in the County is purchased from the Fairfax County Water Authority. The financial burden of providing water is aggravated, since the price of wholesale water is escalating along with the increased demand. Thus, it behooves the County to make use of its existing groundwater resources where available to alleviate this burden.

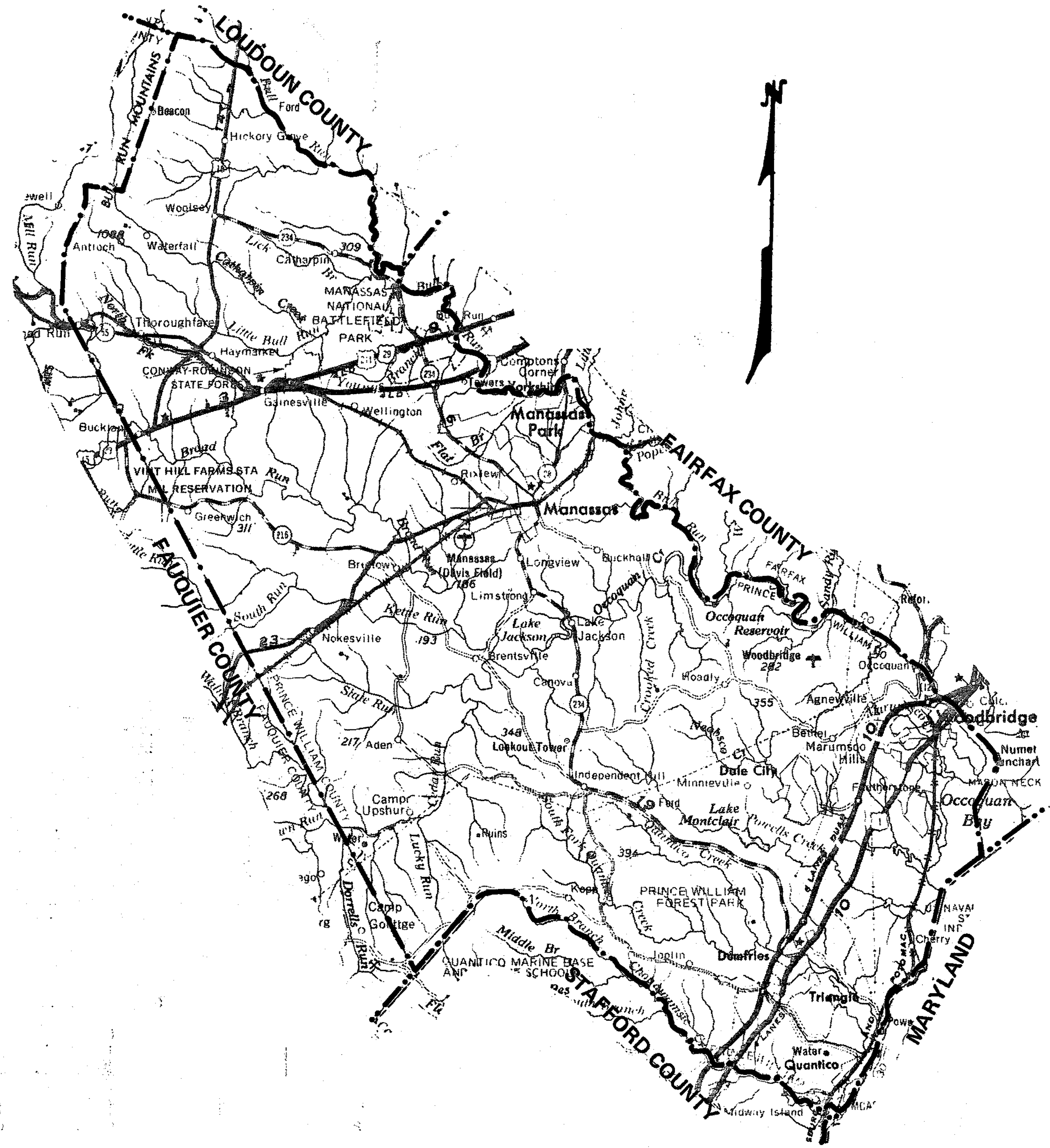
Groundwater development usually is less expensive than surface water development because of the large capital outlay required in building a surface impoundment and in purchasing land to be flooded. It is also more flexible, since wells can be drilled incrementally as demand increases.

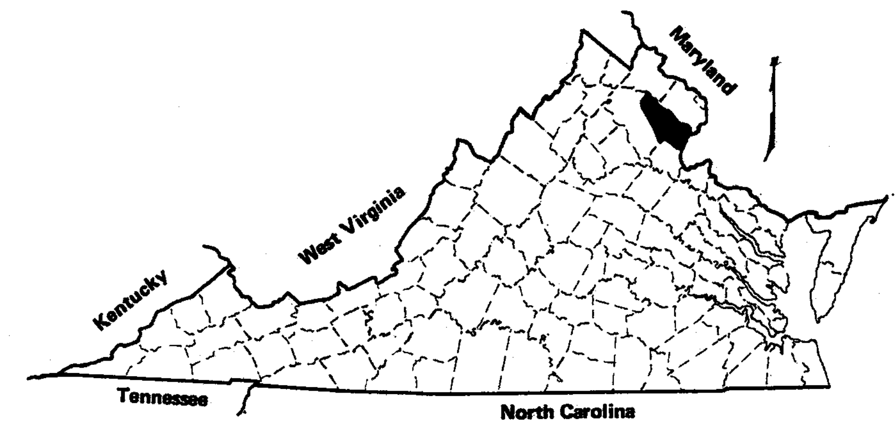
Purpose and Scope

The purpose of this report is to consolidate available information on groundwater in Prince William County, and to provide County officials and citizens with a concise publication that relates this information to existing groundwater conditions and to potential for groundwater development.

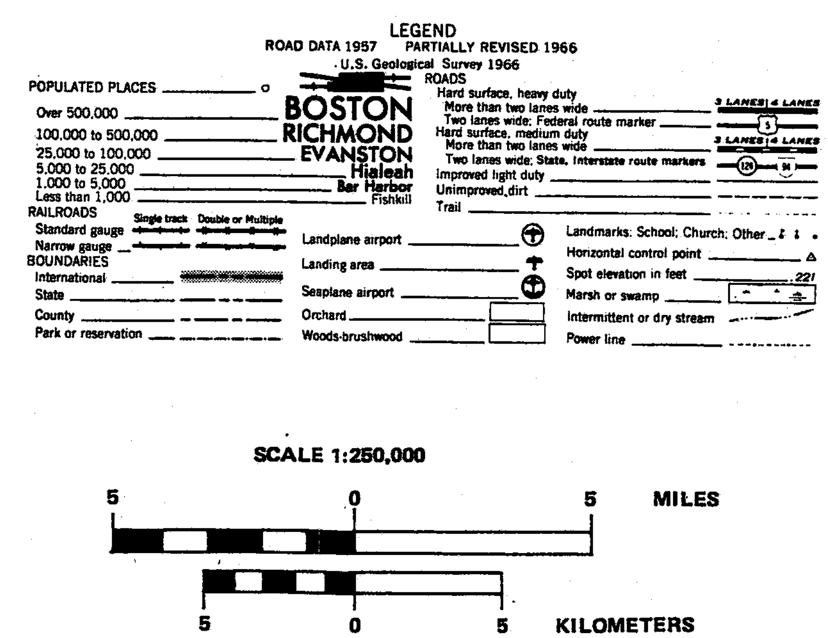
The planning and development of any area is dependent on a potable water supply. The importance of groundwater resources is magnified in areas where a sufficient quantity of surface water is

LOCATION MAP OF PRINCE WILLIAM COUNTY





COUNTY AREA: 347 Square Miles
COUNTY POPULATION: 151,659 (1974)



SOURCE: Virginia State Water Control Board — NRO

PLATE NO. 1

unavailable or where surface water is of an undesirable quality. This report attempts to identify areas where significant quantities of undeveloped groundwater are believed to exist. Also, the chemical quality of the groundwater is covered in as much detail as present data will allow, and certain groundwater problems are enumerated.

Methods of Investigation

The occurrence, availability, and quality of groundwater are governed by geology, which is very diverse in Prince William County. Therefore, the geologic framework of the County was investigated from available reports and unpublished data. Information on the productivity of water wells was examined and consolidated with the geologic data to establish the correlation between geology and well yields. The influence of topography on well yields was also considered as was the depths and construction characteristics of the wells. Chemical quality samples were collected at selected sites to establish the effect of geology on groundwater quality. These data were supplemented with chemical analyses from public water-supply wells provided by the State Department of Health. Other sources of information on the hydrogeology of the County include data from water-level observation wells, water-level measurements from private and public wells, pumpage records, and pumping test and other information provided by well drillers.

All water well information and records of water quality analyses used in this report are in the files of the State Water Control Board central office in Richmond and the Northern Regional Office in Alexandria. These data have been computerized for storage and retrieval and were used to compile Appendices A and B.

Previous Investigations

The earliest reports concerned with groundwater in Prince William County were published by Clapp (1911), Sanford (1912), and Cady (1933 and 1938). Additional groundwater information, although generalized, is contained in publications by Walp (1960), Johnston (1960) and the Virginia Division of Water Resources (1969), which is now part of the State Water Control Board.

Publications pertinent to the geology of the County include studies by Lonsdale (1927), Roberts (1928), Brown (1954), Southwick et al (1971), Mixon et al (1972), and Lee (1976). The only geologic map covering the entire County is the State geologic map prepared by the Division of Mineral Resources (1963). This map is at a scale of 1: 500,000 and therefore is not of sufficient detail for anything other than generalized groundwater investigations. The report by Mixon et al (1972) contains a detailed geologic map at a scale of 1:24,000 of the Quantico 7.5 minute quadrangle, but a detailed geologic map is not available for any other quadrangle in the County.

Detailed soils maps at a scale of 1 inch = 400 feet are available through the Bureau of Soil Science and Erosion Control in the County Public Works Department. These soil maps can be related to the underlying geologic formations by referring to Kaster and Porter (undated) and Pettry et al (1970).

Water Well Numbering System

The water wells studied for this report are identified by the State Water Control Board's Bureau of Water Control Management well numbers. Each well number consists of two parts, such as 175-55. The first number, 175, denotes the County in which the well is located; in this case Prince William. The second number, 55, is a sequential number that refers to a specific well in Prince William County.

CHAPTER II

PHYSICAL SETTING

Physiography

Prince William County lies primarily within the Piedmont Province of Northern Virginia. The extreme eastern portion of the County (roughly, the area east of Interstate Highway 95) lies within the Coastal Plain Province. The County's land area is 347 square miles and its water area is approximately seven square miles. The morphology of the County contrasts sharply between the salt marshes and tidal flats along the Potomac River and the prominent ridge of Bull Run Mountain. The intervening area consists of rolling hills and lowlands.

The crest of Bull Run Mountain forms the northwestern boundary of the County and the Potomac River forms the southeastern boundary (Plate 2). The highest point on Bull Run Mountain is 1,311 feet above sea level. The elevation drops to approximately 500 feet at the base of Bull Run Mountain.

The area southeast of Bull Run Mountain for approximately 17 miles is known as the Triassic lowlands, which is a sub-province of the Piedmont. The Triassic is characterized by flat to gently rolling topography with several prominent northeast-southwest trending ridges of 50 to 75 feet in relief. The Triassic lowlands drops in elevation gradually to about 200 feet on its eastern boundary.

East of the Triassic the Piedmont uplands extends for approximately 10 miles to the Fall Line, which forms the boundary between the

Piedmont and the Coastal Plain. The Piedmont and Coastal Plain in Prince William County have been dissected by stream erosion so that the relief in both areas is greater than in the Triassic lowlands.

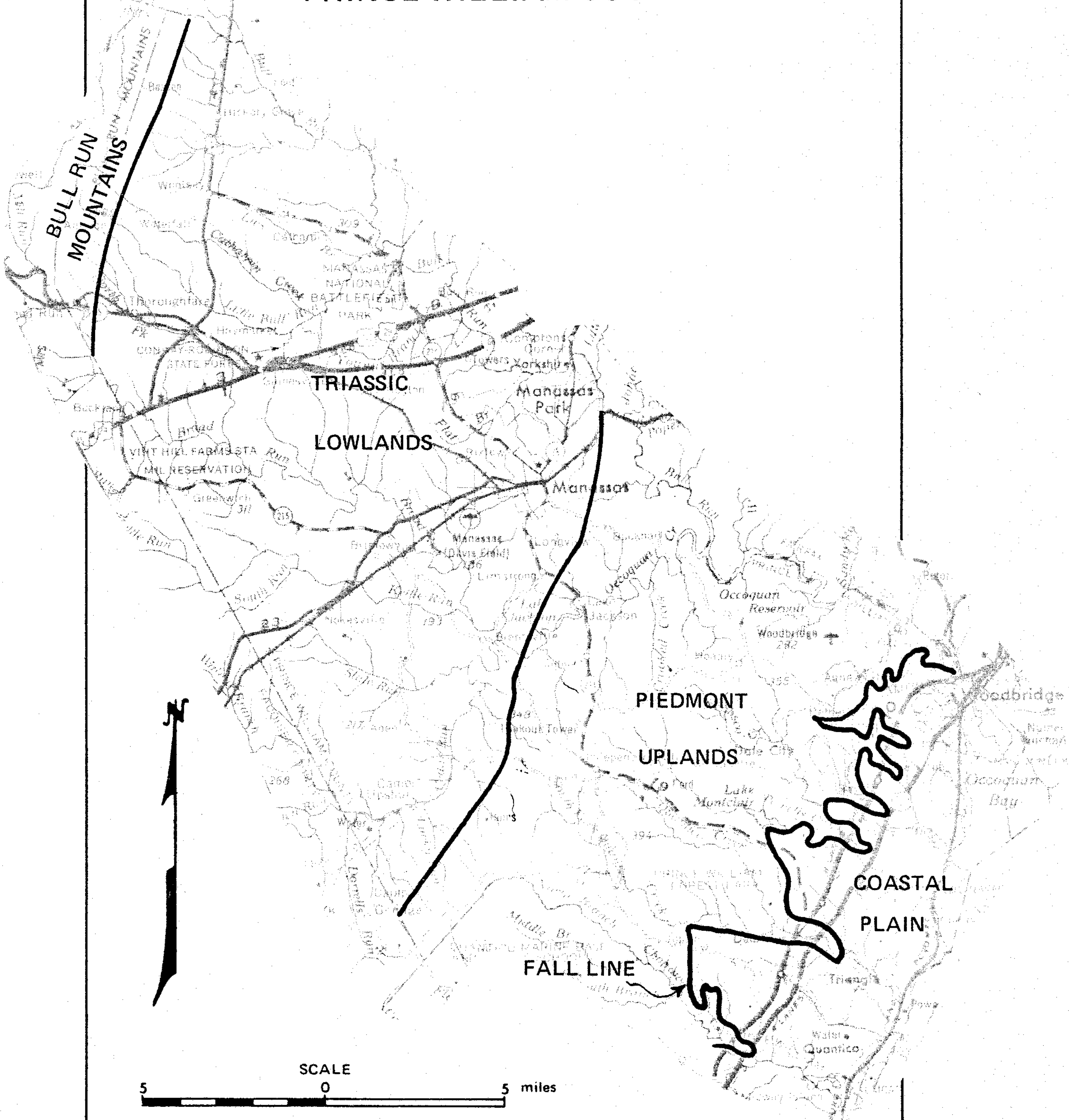
Hydrology

The County lies within the Potomac River Basin and is drained mostly by the Occoquan Watershed. Occoquan Creek is formed by the confluence of Bull Run, Broad Run, Cedar Run, and several smaller streams. Occoquan Creek is a tributary of the Potomac and enters that river at the northeastern boundary of the County. Several smaller tributaries of the Potomac drain the remainder of the County south of Occoquan Creek. The larger of these are Neabsco, Powells, Little, Quantico, and Chopawamsic creeks.

The Occoquan Watershed is impounded by two concrete dams near the town of Occoquan. The larger of the dams creates a reservoir of 9.8 billion gallons which furnishes the potable water supply for the Fairfax County Water Authority. Some of this water is utilized in Prince William County since some of the County sanitary districts purchase their water wholesale from the Fairfax County Water Authority.

Several streamflow gaging stations are maintained throughout the County. The data from these are published annually by the U. S. Geological Survey in "Water Resources Data for Virginia". Flow data for three of these stations for the years indicated are shown in Table 1. The high values for June 1972 reflect the unusually heavy rainfall associated with tropical storm "Agnes" on June 22, 1972.

PHYSIOGRAPHY OF PRINCE WILLIAM COUNTY



SOURCE: Virginia State Water Control Board – NRO

PLATE NO. 2

TABLE 1
PRINCE WILLIAM COUNTY
AVERAGE DISCHARGE AT MAIN RIVER GAGING STATIONS
(In Cubic Feet Per Second)

Station*	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
						1971						
1	530	1,747	552	593	1086	421	31.8	71.3	28.4	352	420	345
2	293	688	243	292	424	124	15.5	39.9	53	371	222	152
3	8.42	22.8	10.3	12.1	23.2	6.68	0.99	1.75	1.17	9.8	7.19	6.6
						1972						
1	317	1,551	534	624	684	3,611	214	44.5	15.1	175	1,395	1,543
2	148	656	238	352	235	2,475	108	13.5	8.55	30.3	446	669
3	6.7	24.5	10.3	12.5	14.0	48.8	3.71	0.36	0.35	2.36	16.9	20.2
						1973						
1	740	936	552	1,460	447	163	62.1	317	94.6	92.2	44	1,052
2	278	367	196	788	212	37.4	31.1	61.4	66.1	42.2	18.3	463
3	11.9	18.2	13.2	24.0	9.04	2.84	1.35	6.17	1.39	1.94	3.61	16.0

* Station 1 - Occoquan River near Manassas, downstream from Lake Jackson along State Highway 234 (USGS No. 01656700)
Station 2 - Bull Run near Manassas, along State Highway 616 (USGS No. 0165700)
Station 3 - South Fork Quantico Creek near Independent Hill, along State Highway 616 (USGS No. 01658500)

Source: U.S. Geological Survey

Several areas in the County along the major streams are subject to flooding. Flood damage in some communities, notably the town of Occoquan, has been extensive during major storms. All identified flood-prone areas in the county with the exception of the town of Haymarket, are presently participating in the National Flood Insurance Porgram administered by the U. S. Department of Housing and Urban Development.

The quality of the surface water in the County is generally poor. The Occoquan Reservoir suffers from an over-abundance of nitrogen and phosphorus nutrients derived from sewage treatment plant discharges and storm water runoff from urban areas, agricultural land, and construction sites. These nutrients contribute to excessive growths of algae which lower the dissolved oxygen content of the water and cause taste and odor problems.

The Potomac River adjacent to Prince William County is actually an estuary, which means it is within the range of the tidal fluctuations. Therefore, the water is brackish and unusable as a water supply.

Climate

The climate of Prince William County is temperate. The average annual precipitation is 39 to 42 inches. The average temperature in July, the hottest month, is 77°F and in January, the coldest month, 35°F. The tabulation below gives the average monthly values for temperature and precipitation, from a weather-observation station at the U. S. Marine Base at Quantico. The averages represent 58 years of data for temperature and 56 years for precipitation.

AVERAGE MONTHLY TEMPERATURE (^{o}F)

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
35.4	36.8	44.86	55.8	64.7	72.8	77.5	75.3	69.1	57.8	45.7	36.6

AVERAGE MONTHLY PRECIPITATION (INCHES)

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
3.09	2.45	3.19	3.19	3.30	3.58	4.27	4.79	3.13	2.82	2.43	2.74

The rainfall is distributed fairly evenly throughout the year, but is highest in July and August and lowest from October through February. However, the groundwater is recharged from December through April since the late spring and summer precipitation is utilized by vegetation and much is lost by evaporation.

Soils and Vegetation

Soils are subdivided into three zones: surface soil, subsoil, and parent material. The parent material is composed of weathered bedrock which retains much of its original texture and structure. The parent material grades downward into fresh, hard bedrock. Regolith is a term used for the weathered material and soil zone above fresh bedrock. The thickness of the regolith is an important factor in water-well productivity in areas underlain by crystalline rock (e.g. the Piedmont), since the regolith is much more porous than the bedrock. Therefore, that portion of the regolith below the water table is a good groundwater reservoir.

The soil zone is usually a direct reflection of the underlying bedrock on which it has developed. For instance, a soil that developes over a granite bedrock will have different characteristics from one that develops over a slate bedrock. The soil does not always reflect the bedrock, since some soils were deposited in the flood plains of streams (alluvial soils) and some soils have resulted from the slumping of material from a higher elevation (colluvial soils) such as at the base of a mountain or embankment.

The internal drainage characteristics of a particular soil affect the rate in which water infiltrates through the soil and, thus, affect the rate of groundwater recharge. Soil texture largely determines internal drainage characteristics. Water drains more easily through coarse textured soils, such as sandy loam, than fine textured soils, such as clay. Also, the different zones in a particular soil often have different textures and therefore different drainage characteristics. For instance, a soil that has well-drained surface soil may have drainage restrictions in the subsoil, such as sandy loam underlain by clay.

Detailed information on the soils of Prince William County can be found in the previously mentioned works of Kaster and Porter (undated) and Pettry et al (1970). These publications relate specific soil types to underlying bedrock and were used extensively in preparing this report.

Nearly half of the County is in forest, most of which is commercial. The National Park Service holds 12,000 acres in Prince William Forest Park and 1,061 acres in Battlefield Parks. Also, most of the Quantico Marine Base is in forest. The predominant forest types are oak-hickory, Virginia pine, oak-pine, and red cedar. Forested areas impede surface runoff and thus contribute to groundwater infiltration. Farmland makes up most of the remaining non-urbanized areas in the County. Vegetated areas in general are more favorable to groundwater recharge than urban areas, due to the artificial surface-drainage systems associated with urbanization.

CHAPTER III

HYDROGEOLOGY

Geologic Setting

The geology of Prince Willaim County is very diverse and in some areas, complex. The greatest diversities occur among the physiographic areas, Bull Run Mountain, the Triassic lowlands, the Piedmont uplands, and the Coastal Plain (Plate 2). All of the three broad groups of rocks, igneous, metamorphic, and sedimentary, are represented.

Bull Run Mountain is underlain by metamorphic rocks, primarily quartzite interlayered with thin beds of phyllite, schist, and/or slate. The Triassic lowland area is underlain by sedimentary rocks which have been intruded in some areas by igneous rocks. The resistant igneous rocks form ridges which run roughly northeast-southwest. The Piedmont uplands is underlain by a complex association of various metamorphic rocks, primarily schist and gneiss, and by igneous rock, primarily granite. The Coastal Plain is underlain by unconsolidated sand, silt, clay and gravel deposits.

In Precambrian time muddy and sandy sediments were laid down on the floor of a sea which then occupied the Piedmont area. During the Cambrian Period, near the end of this period of deposition, volcanic activity resulted in thick lava flows and ash-fall deposits over the sediments. Further west, water-laid sand deposits accumulated in the area now occupied by Bull Run Mountain. During the Ordovician Period, the volcanic activity in the eastern Piedmont subsided, and shale was deposited over the volcanic rocks.

Several episodes of mountain-building activity (culminating in the Appalachian Orogeny) took place throughout the Paleozoic Era, and the volcanic and sedimentary rocks were subjected to extremely high temperatures and pressures which transformed these rocks into their metamorphic equivalents. Shale became schist or slate; sandstone became quartzite, etc. Compressional forces squeezed the rocks into folds during the mountain-building episodes. Molten rock from deep within the earth was injected into the pre-existing rocks while they were deeply buried, and this produced bodies of granitic rocks throughout the Piedmont. Subsequent erosion of the overlying rocks has exposed the granites.

During the Triassic Period, tensional forces tended to pull the earth's crust apart along what is now the Atlantic Coastal area. This created down-faulted sedimentary basins from Nova Scotia through Georgia. After the Triassic Basin in the Northern Virginia area filled with sediment, renewed igneous activity injected molten rock into the Triassic deposits. During the Cretaceous Period and later, the Coastal Plain sediments accumulated over the ancient Piedmont rocks in the eastern part of the County. Stream erosion has altered the surface to give the topography expressed today.

Geologic Formations

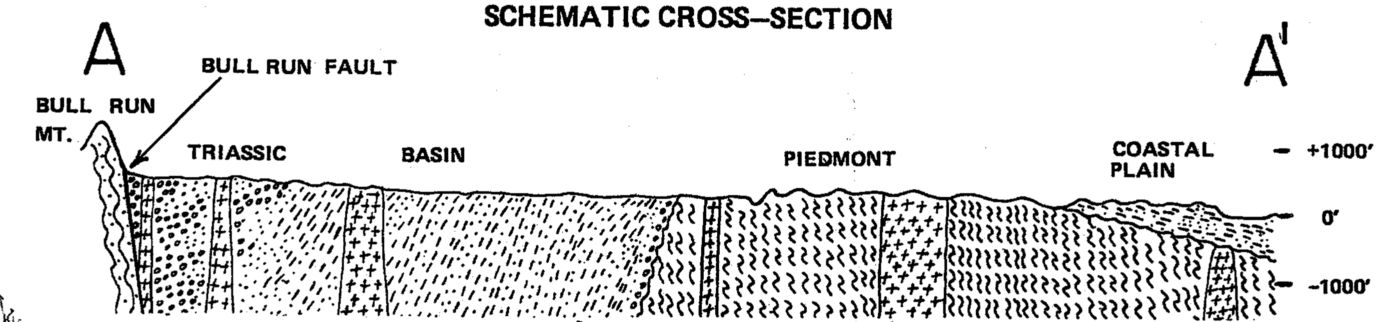
The aeral distribution of the geologic formations in Prince William County is illustrated on Plate 3. Table 2 lists the various rock units in order of oldest at the bottom to youngest at the top and their water-bearing properties. Age relationships are

HYDROGEOLOGY
OF
PRINCE WILLIAM COUNTY

LEGEND

	ROCK UNIT	WATER-BEARING PROPERTIES		ROCK UNIT	WATER-BEARING PROPERTIES
LK	Coastal Plain Sediments	Fair to Good	V	Chopawamsic Formation	Poor to Fair
TRD	Triassic Diabase	Poor	CW	Weverton Quartzite	Poor
TRNS	Triassic Sedimentary Rocks	Good to Very Good	GR	Granitic Rocks	Poor to Fair
OQ	Quantico Slate	Poor	G	Greenstone	Poor
			MSCH	Wissahickon Formation	Poor to Fair

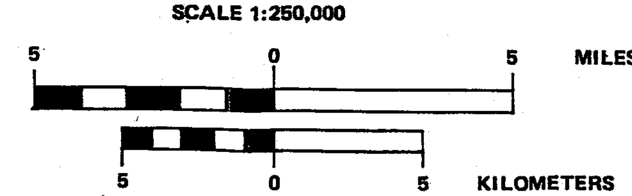
SCHEMATIC CROSS–SECTION



VERTICAL EXAGGERATION ≃ 10 X

- Clay and Silt in Coastal Plain; Shale and Siltstone in Triassic
- Sand in Coastal Plain; Sandstone in Triassic
- Conglomerate
- Intrusive Igneous Rocks: Diabase in Triassic, Granite in Piedmont
- Quartzite
- Foliated Metamorphic Rocks: Schist, Phyllite, and Slate

SCALE 1:250,000



SOURCES: Virginia State Water Control Board – NRO, Virginia Division of Mineral Resources, U. S. Geological Survey

PLATE NO. 3

TABLE 2

PRINCE WILLIAM COUNTY

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

Age (Geologic Period)	Rock Unit and Symbol[1]	Physiographic Occurrence	Lithology	Water-Bearing Properties
Early Cretaceous	Potomac Group (LK)	Coastal Plain	Unconsolidated to poorly consolidated sand, silt, clay, and gravel deposits	Good aquifer where thick; thickness ranges from 0 to 600'; deep wells yield up to 330 gpm[3]
Triassic	Diabase (TRD)	Triassic Lowlands	Dark, blue-gray to black diabase; some basalt and syenite	Very poor aquifer; dry holes common
Triassic	Newark Group (TRNS)	Triassic Lowlands	Red shale, arkosic sandstone and conglomerate	Very good aquifer; deep drilling (up to 1000') feasible; deep wells yield up to 735 gpm
Ordovician	Quantico Slate (OQ)	Piedmont	Dark gray to black graphitic slate	Poor aquifer; limited areal extent, but may be encountered beneath Coastal Plain sediments near Fall Line
Cambrian to Ordovician	Chopawamsic Formation (V)	Piedmont	Schist, gneiss, and greenstone	Poor to fair aquifer

TABLE 2 (Continued)

PRINCE WILLIAM COUNTY

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

Age (Geologic Period)	Rock Unit and Symbol[1]	Physiographic Occurrence	Lithology	Water-Bearing Properties
Cambrian	Weaverton Formation (CW)	Bull Run Mountain	Light gray to white fine grained quartzite	Poor aquifer
Age Uncertain	Granite and Granite Gneiss (GR & GRGN)	Piedmont	Various light gray to dark blue-gray granitic rocks	Poor to fair aquifer
Age Uncertain	Greenstone (G)	Piedmont	Metabasalt, amphibolite and chlorite schist	Poor aquifer; very limited areal extent
Precambrian to Cambrian	Wissahickon Formation (MSCH)	Piedmont	Schist, phyllite, gneiss, and quartzite	Generally a fair aquifer; poor where regolith is thin

1. Symbols refer to aquifer listing in Appendix B and to the Geologic map of Virginia (1963).

2. Includes Patuxent and Patapsco formations; Tertiary and Quaternary deposits not mapped for this report.

3. gpm-gallons per minute.

Sources: Cady (1938), Johnston (1962), Virginia Division of Mineral Resources (1963, Toewe (1966), Southwick et al (1971), and Virginia State Water Control Board - NRO unclear for some of the ancient Piedmont rocks, although relative ages can be determined in some cases. Groundwater characteristics are described on the bases of lithology and physiographic province starting on page 35.

The Wissahickon Formation is the oldest and most widespread rock unit in the Piedmont of Prince William County. The Geologic Map of Virginia (1963) refers to this rock unit as metamorphosed sedimentary rocks, although U. S. Geological Survey publications still use the formal stratigraphic name, Wissahickon Formation (Mixon et al, 1972). It is composed of various metamorphic rocks including green to gray quartz-mica schist, phyllite, and dark gray to white quartzite and gneiss. The contact between various rocks of the Wissahickon are commonly gradational. The schist and phyllite weather readily, producing a deep, yellowish-red to brown silt or silty clay soil. The quartzite and gneiss are more resistant to weathering and produce a thinner, more sandy soil.

An unnamed greenstone body occupies a small area northeast of Manassas along Bull Run. It occurs along the contact of the Wissahickon Formation and the Triassic sedimentary rocks, and is a southerly extension of a sinuous strip of greenstone that runs through Fairfax County. Johnston (1962) described the greenstone as being a heterogenous assemblage of various massive to schistose, ultra-mafic rocks.

The granitic rocks (granite and granite gneiss) in Prince William County are widely distributed throughout the Piedmont. They vary considerable in composition, range in color from dark gray to pink to almost white, and may be massive or somewhat schistose. The granitic rocks are generally highly fractured and well-developed joint systems may be observed behind the Lake Jackson Dam and behind the Occoquan Dam on the Fairfax County side.

The Weverton Formation consists of fine-grained, white to light-gray, massive to thin-bedded quartzite. It is commonly interbedded with thin layers of micaceous phyllite or schist. The only occurrence of the Weverton Formation in Prince William County is on Bull Run Mountain. The Weverton is reportedly 300 to 500 feet thick to the north in Loudoun County (Toewe, 1966). However, this refers to the stratigraphic thickness rather than vertical thickness and, since the strata are steeply inclined to the east, the vertical thickness would be much greater.

The Chopawamsic Formation was named by Southwick et al (1971) for a group of rocks on the eastern margin of the Piedmont that are shown on the Geologic Map of Virginia (1963) as metamorphosed volcanic and sedimentary rocks. The Chopawamsic overlies the Wissahickon Formation and underlies the Quantico Slate. The terms "overlie" and "underlie" are used here in the stratigraphic sense, as the beds and the contacts between the formations are nearly vertical. The Chopawamsic is made up primarily of fine-grained, green to gray schist that was largely derived from volcanic ash and flow deposits. Mixon et al (1972) include a small body of greenstone near Dumfries as part of the Chopawamsic Formation. The stratigraphic thickness of the Chopawamsic is estimated to be 6,000 to 10,000 feet in Prince William County (Southwick et al, 1971).

The Quantico Slate is a dark-gray to black slate that contains abundant graphite and pyrite. It occurs along the eastern margin of the Piedmont, stratigraphically above the Chopawamsic Formation. Most of the slate is covered by overlapping Coastal Plain sediments, but several outcroppings are exposed in the stream valleys of Occoquan, Neabsco, Powells, Quantico, and Chopawamsic creeks.

The Newark Group refers to the sedimentary rocks in the Triassic Basin, and includes conglomerate, sandstone, siltstone, and shale. All of the different sediments are interbedded vertically or interfinger laterally with each other. The conglomerate occurs predominately on the western margin of the Triassic, although some conglomerate beds are present near the eastern boundary. The sandstone, siltstone, and shale deposits are widespread throughout the Triassic region. In recent work, Lee (1976) has redefined the Triassic sedimentary rocks as the Manassas Sandstone, Balls Bluff Siltstone, and the Bull Run Formation. The typical color of the Triassic sediments is deep red or maroon, although local variations are common. The shales are usually thin-bedded and brittle. The beds of the other rock types are more massive in nature. The siltstones are calcareous and the sandstones are commonly arkosic.

Several large bodies of igneous rock are present throughout the Triassic region. These rocks were injected in the molten state into the sedimentary rocks. The principal igneous rock is diabase (commonly called bluestone by well drillers) but basalt and syenite are also present. Most of the igneous rocks occur as dikes, sills, or stocks but it is possible that lava flows and volcanic ash deposits are present since similar occurrences are recognized in nearby Loudoun County (Toewe, 1966).

The injection of the molten igneous rock into the Triassic sediments created a baked zone (contact metamorphism) along the contacts of the dissimilar rocks. The shales have been metamorphosed into a dense black rock called hornfels adjacent to the igneous intrusions. The baked zone extends for some distance beyond the immediate contact, and the typical red color of the shales has been altered to blue-gray or purple. The zone of baked shale is illustrated on the county soils maps (Kaster and Porter, undated), but is not differentiated from the other Triassic sediments on the map for this report.

The Coastal Plain sediments are primarily included within the Potomac Group, which is an assemblage of Lower Cretaceous deposits. The sediments include interfingering and interlayered sand, silt, clay, and gravel deposits. The sand beds occur as elongate lenses rather than sheet like layers. The sands are commonly arkosic (contain abundant feldspar) and the dominant mineral in the clay beds is montmorillonite, a clay mineral that swells when wet and shrinks when dry (Moncure and Force, 1976). The sediments thicken to the east, from a feather edge along the Fall Line to approximately 500 to 600 feet along the Potomac River at Quantico. Several outliers of Coastal Plain sediments occur west of the Fall Line over the Piedmont rocks, but these are too thin to be significant in a groundwater investigation and, therefore, are not mapped for this report.

Geologic Structure

The major structural features of the area trend in a northeast-southwest direction, roughly paralleling the Appalachian Mountain trend. These features include folds, faults, igneous intrusions, and foliation or schistosity of the metamorphic rocks.

Bull Run Mountain is a hogback mountain, which is a ridge produced by highly tilted strata. The rock strata of Bull Run Mountain are inclined steeply to the east.

The eastern flank of Bull Run Mountain is bound by a large fault, named the Bull Run Fault, which trends northeast, parallel to the mountain. This fault forms the western boundary of the Triassic lowlands. It extends for 90 miles in Virginia, from southern Orange County through Prince William County and continues into Maryland. The Bull Run Fault is a normal or gravity fault which is downthrown to the southeast. The fault plane dips to the southeast at an angle of 30° to 50° (Keith, 1893). The vertical displacement (amount of downdropping) is not known, but is probably at least 1,500 to 2,000 feet and possibly more. The Triassic Basin to the southeast was being infilled with sediment when the fault was active. Other normal faults are numerous throughout the Triassic region, but they are much smaller in magnitude than the Bull Run Fault.

The Triassic area is underlain by a sedimentary basin, named the Culpeper Basin, that was formed by the downdropping associated with the Bull Run Fault. It extends for approximately 90 miles in Virginia, as does its associated border fault, and it is about 17 miles wide in Prince William County. The basin is wedge-shaped in nature, being thicker in the west and thinning to a feather edge to the east. The vertical thickness is not known, but it is probably at least 1,500 to 2,000 feet. Some of the similar Triassic basins along the Atlantic Coast are known to be as much as 8,000 feet thick, but no data are available for the total depth of the Culpeper Basin.

The sedimentary rocks of the Triassic Basin are inclined to the northwest, towards the border fault. The angle of inclination of the strata is approximately 15 to 20°, but it is generally more gentle near the eastern margin of the basin, where the strata are almost horizontal in places. The strata become more tilted to the west, and the greatest dips are found near the Bull Run Fault. Fractures are common along the bedding planes, and these serve as recharge zones for groundwater. Secondary joints (fractures) are also present at angles to the bedding-plane fractures, but they are of much less significance.

Intrusions of igneous rock, in the form of dikes and sills, are present throughout the Triassic region. The igneous rock, diabase, was injected in the molten state after deposition of the sediments. Joint systems are present in the diabase, but these rocks are not sufficiently fractured to allow recharge of groundwater in copious amounts.

The most common structural feature in the Piedmont uplands is the schistosity or foliation of the metamorphic rocks. The foliation conforms to the regional northeastward trend, and the dip or angle of inclination is near vertical.

Several large bodies of granitic rocks, which were injected into the metamorphic rocks, are present in the Piedmont. Also present, are several small pegmatite dikes (quartz veins), composed primarily of highly fractured, milky white quartz. This material is commonly called flint rock by well drillers, and it generally produces a water-yielding zone when encountered below the water table in a well. The granitic rocks are shown on the accompanying geologic map, but the pegmatite bodies are too small and numerous to be mapped separately.

A structural feature called the Quantico syncline (Lonsdale, 1927 and Brown, 1954), is present near the Fall Line in the Piedmont rocks. The Quantico syncline trends northeastward, aligned with the major structures of the Appalachian region. The outcrop width of the syncline is approximately one and a half miles, and the eastern flank is overlapped by the Coastal Plain sediments. The dip on the flanks of the syncline is near vertical. These relationships are well illustrated by Mixon et al (1972). The total length of the Quantico syncline is thought to be 24 miles (Brown, 1954).

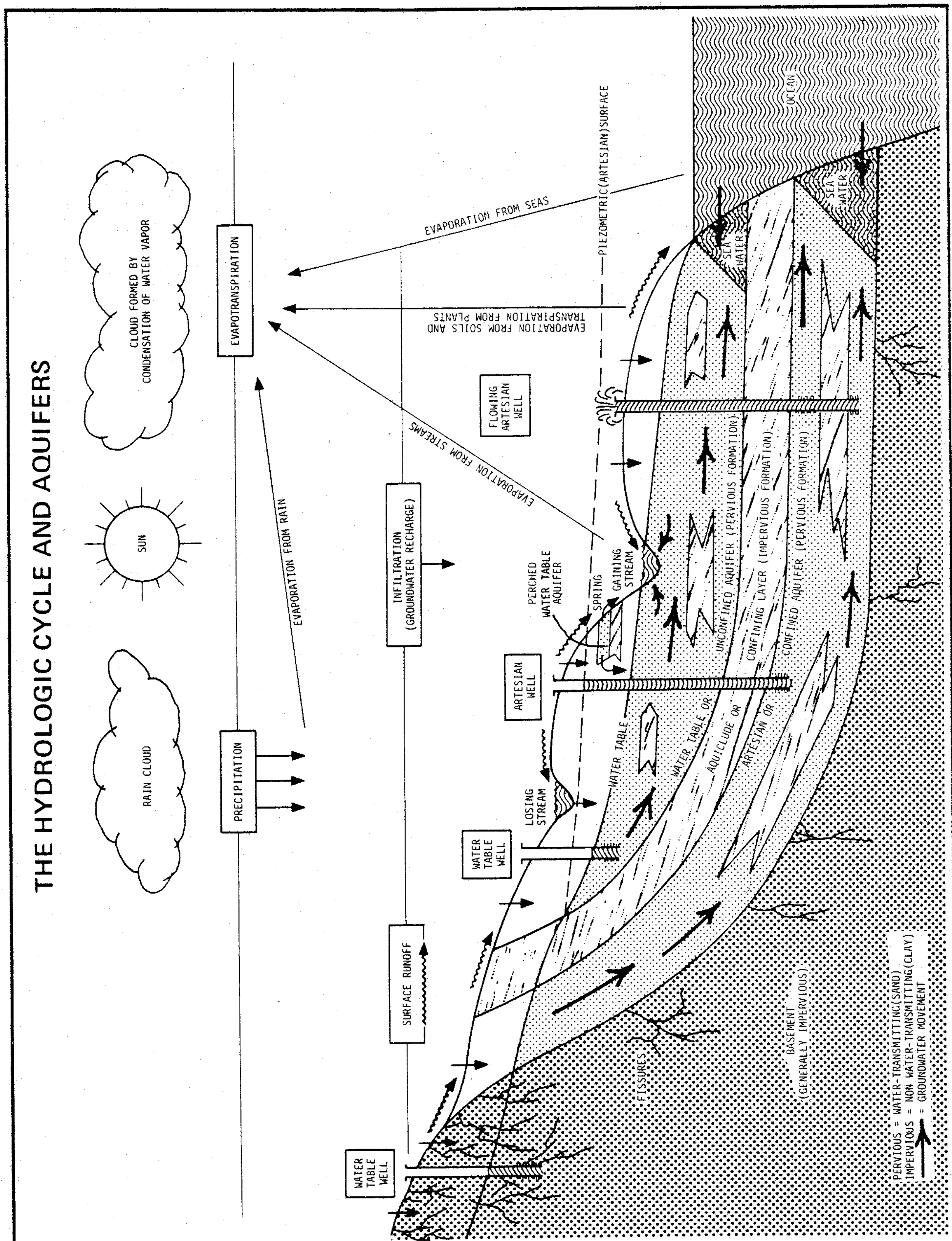
The Coastal Plain deposits occur as a wedge of sediment overlying a basement of ancient Piedmont rocks. The sediments thin to a feather edge near the Fall Line and thicken in an eastward direction (Plates 3 and 5). The surface of the Piedmont basement is irregular in nature, and the maximum thickness of the overlying sediments is approximately 500 to 600 feet near the Potomac River at Quantico. The rate of thickening is greater in the southern part of the County, 120 to 155 feet per mile, than to the north near Woodbridge, where it averages 70 to 100 feet per mile.

Groundwater

Groundwater is an integral part of the earth's water circulation system, which is called the hydrologic cycle (Plate 4). Groundwater originates from precipitation, in the form of rainfall or melting snow. That portion of the precipitation available to groundwater recharge is equal to the total precipitation minus evaporation, transpiration by growing plants, runoff to streams, and the amount held as soil moisture. Some of the water that infiltrates through the soil zone is held by capillary forces above the water table; the remainder moves downward by the force of gravity and replenishes the groundwater, causing the water table to rise.

The surface of the water table is rarely flat, but has undulations usually conforming to the topography. The water table is higher under hills than under valleys. However, the relief of the water table surface is more subdued than the topographic relief. Therefore, the depth to the water table is greater under a hill than under a valley.

The differences of elevation on the water table and the force of gravity cause movement of the groundwater. This movement often results in the natural discharge of groundwater through springs. Springs or seeps occur where the water table intersects the land surface, usually on the sides of slopes and in valleys. Thus, high topographic areas are commonly groundwater recharge zones and low topographic areas are commonly groundwater discharge zones.



Source: State Water Control Board – BWCM

PLATE NO. 4

Groundwater does not flow in "underground streams" except in limestone or dolomite caverns, which do not exist in Prince William County. Groundwater flows through the interconnected pore spaces in sediment and fractures in rock. The rate of movement ranges from a few inches per year to a few feet per day.

Groundwater movement in crystalline rock is affected by structures in the bedrock, particularly fractures such as faults and joints. The direction of movement is affected by the alignment and inclination of the fractures, the rate of movement is influenced by the number and size of the fractures, and the depth of movement is determined by the depth to which the fractures extend.

Groundwater movement may be artificially caused by withdrawals by wells. The pumping of a well will cause the water level in the vicinity of the well to drop, resulting in movement of groundwater towards the well. The vertical distance that the water level in the well drops is termed the drawdown. The drained space between the original water level (static water level) and the lowered water level (pumping water level) is roughly cone shapped, and is termed the cone of depression. The cone of depression spreads outward from the well as it is pumped. The cone of depression will eventually stabilize at some distance from the well if the withdrawal rate is not excessive. If two or more wells are placed too close to each other, the cones of depression of each will intersect and may result in excessive drawdowns and decreased yields.

Aquifers

An aquifer is a geologic formation that is capable of containing and transmitting groundwater. Aquifers may be comprised of unconsolidated sediments or of fractured, consolidated rocks. Groundwater is contained in the pore spaces of sediment, such as sand or gravel, and in fractures or cracks in crystalline rock, such as granite or slate.

Aquifers may be of two types: (1) unconfined or water-table aquifers and (2) confined or artesian aquifers. Both types are present in Prince William County and examples are illustrated in Plate 4.

In an unconfined aquifer, the water table is the upper surface of the zone of saturation. The surface of the water table is at atmospheric pressure, whereas water below this surface is at a higher pressure, due to the weight of the overlying water. In an unconfined aquifer, water is able to infiltrate downward through the zone of aeration and reach the water table.

In an artesian aquifer, the groundwater is separated from the zone of aeration by a confining layer, such as an impermeable clay bed. Groundwater in a confined aquifer is under pressure in excess of atmospheric pressure. When the confining layer is penetrated by a drill bit, the groundwater quickly rises in the bore hole. The water level in an artesian well stands above the aquifer that it taps. If the artesian pressure is sufficiently high, the water may flow freely at the surface. However, a well does not have to flow freely for artesian conditions to exist.

The depth to the static water level of an aquifer can be measured in any well that is not being pumped. If the well is in a confined aquifer and the upper water table is cased-off, the measured water level is termed the artesian surface (or potentiometric surface). In a well tapping an unconfined aquifer in which water from the upper zone is allowed to enter the well, the measured water level is termed the water table. The depth to the groundwater in either case will depend on several factors including: the geologic formation in which the well is drilled, the confining conditions of the aquifer, the topographic position of the well site, the time of year the measurement is taken (water levels fluctuate seasonally), and the proximity to pumping wells.

Groundwater sometimes flows for many miles in extended aquifers, but frequently, especially for unconfined aquifers, it has partly or totally originated from surface infiltration within a radius of a few miles of its occurrence. The recharge area for most water-table wells is the immediate area around the well for a radius of several hundred feet. Recharge of an artesian aquifer may occur from lateral migration from the outcrop area of the aquifer or from vertical leakage through semipervious confining beds.

Piedmont. The igneous and metamorphic rocks in the Piedmont are poor to fair aquifers depending on the local conditions where a well is drilled. The controlling factors include: the thickness of the regolith, the porosity and permeability of the regolith, the topographic position of the well site, the degree of fracturing of the bedrock, the occurrence of pegmatite quartz veins (flint rock), and the lithology or type of rock.

The thickness, porosity, and permeability of the regolith affect the storage capacity and rate of recharge to the aquifer.

According to Nutter and Otton (1969), the lower most portion of the regolith adjacent to fresh bedrock is often the most permeable zone.

The topographic position of the well site is very important, since wells drilled in ravines, valleys, draws, and lower slopes have higher yields statistically than wells drilled on ridges and hilltops. Wells at low areas tend to receive recharge from uplands. Also, the topography in areas of crystalline rocks is an indicator of the degree of fracturing of the bedrock, since streams tend to align themselves along fracture zones.

The importance of fractures in the bedrock to well yield should be self-evident, since fractures are responsible for transmitting water to a well in the Piedmont. Fractures in crystalline rocks are more numerous near the surface and decrease in occurrence with depth. Most water-bearing fractures in Piedmont rocks occur in the upper 150 feet and few exist below 350 feet.

The presence of quartz veins through the bedrock is advantages because the brittle quartz is often fractured. However, the quartz veins will rarely yield more than a few gallons per minute and their occurrence is hard to predict.

The lithology or type of rock in the Piedmont is not the most important factor governing well yields in Prince William County, because most of the area is either schist or granite, which do not differ materially as water producers. However, the greenstone and Quantico Slate should be avoided if possible, as they are definitely inferior aquifers.

In an inventory throughout Northern Virginia, Walp (1960) reported an average yield of 14 gallons per minute (gpm) for 405 wells drilled in the Wissahickon Schist and 14 gpm for 48 wells drilled in Piedmont granitic rocks. Johnston (1962), in a study in neighboring Fairfax County, reported an average yield of 14 gpm for 139 wells in schist and 12 gpm for nine wells in granite. Well yields in the Piedmont of Prince William County can be expected to be consistent with these values, although local variability in geologic and topographic conditions can cause considerable deviations from average yields, either on the high side or the low side.

The highest reported well yield in the Piedmont of Prince William County is 92 gpm (well #35) for a 400 foot well at Occoquan Forest Subdivision about five miles east of Manassas. That well is in granitic rocks that are somewhat schistose. The lowest reported well yield is for a 250 foot dry hole in schist in Prince William Forest Park near Joplin (well #198). A second well (#199), also in schist, drilled approximately 1,500 feet from the dry hole produced only 2 gpm.

The static water levels for Piedmont wells reportedly range from 5 to 55 feet below land surface.

Bull Run Mountain. The Weverton Formation, which occurs only on Bull Run Mountain in the County, is a very poor aquifer. The steep slopes of the mountain are more conductive to surface runoff than to subsurface infiltration so that groundwater recharge is minimal. The dense, crystalline quartzite rock is not highly fractured, and is not conducive to groundwater flow and, therefore, will yield very little water to wells. Also, the regolith is too thin to form a significant groundwater reservoir. Too few wells have been drilled on Bull Run Mountain to provide reliable data on average yields, but more than a few gallons per minute should not be expected, regardless of depth.

Triassic. The Triassic sedimentary rocks of the Newark Group are undoubtedly the most productive and reliable aquifers in the County. This is because the rocks are highly fractured along the sedimentary bedding planes, which are inclined 15° to 20° from the horizontal. The fractures extend much deeper than fractures in the Piedmont rocks, and deep drilling is more feasible in the Triassic (diabase excluded) than in any other region in the County.

The shales, sandstones, and siltstones are thought to be more productive than the conglomerate, which tends to be more massive and less fractured.

The topographic position of the well site is not as significant a factor on well yields in the Newark Group as in the Piedmont. However, Nutter (1975) observed statistically higher yields in low areas as opposed to uplands in the Maryland Triassic.

The lowest yield reported in this study for the Newark Group is 5 gpm (well #28) for a 152 foot well in Gainesville and the highest is 735 gpm (well #83) for a 912 foot well in Manassas. The average yield for 10 wells up to 200 feet in depth is 13 gpm; for 22 wells from 200 to 400 feet, 26 gpm; for 10 wells from 400 to 600 feet, 185 gpm; and for 13 wells from 600 to 1,005 feet, 274 gpm.

It is clear that the Triassic sedimentary rocks are capable of producing water from greater depths than the other aquifers in the County.

All of the deep and highly productive wells for which data were available for this report are in the Manassas area. However, there is every reason to believe that similar yields could be obtained elsewhere in the Triassic region of the County, as long as the areas of diabase occurrence were avoided. Also, the areas of conglomerate occurrence may be somewhat less productive.

The static water levels for wells in the Triassic sedimentary rocks outside of the Manassas area range from 10 to 50 feet. Within the Manassas area, the range is 30 to 170 feet. The greater depths in the Manassas area are undoubtedly due to the relatively large withdrawals that have occurred since 1905 when the city first began using groundwater as a public supply. It is not known how large an area is affected by the drawdowns in the Manassas area, but the effect is probably local rather than regional. The Triassic aquifers are artesian and any one well may encounter several different artesian zones at various depths, each having its own potentiometric surface. This fact must be considered in any attempt to determine the possible effect of large scale groundwater withdrawals in the Manassas area on regional water level declines.

The Triassic diabase is certainly the poorest aquifer in the County. Dry holes are common, especially on ridges and hilltops. Average yields in the best of locations, ravines, draws, and valleys, are probably no better than 5 to 10 gpm. Water-yielding zones are not likely to be encountered deeper than 350 feet and most probably occur within the upper 150 feet.

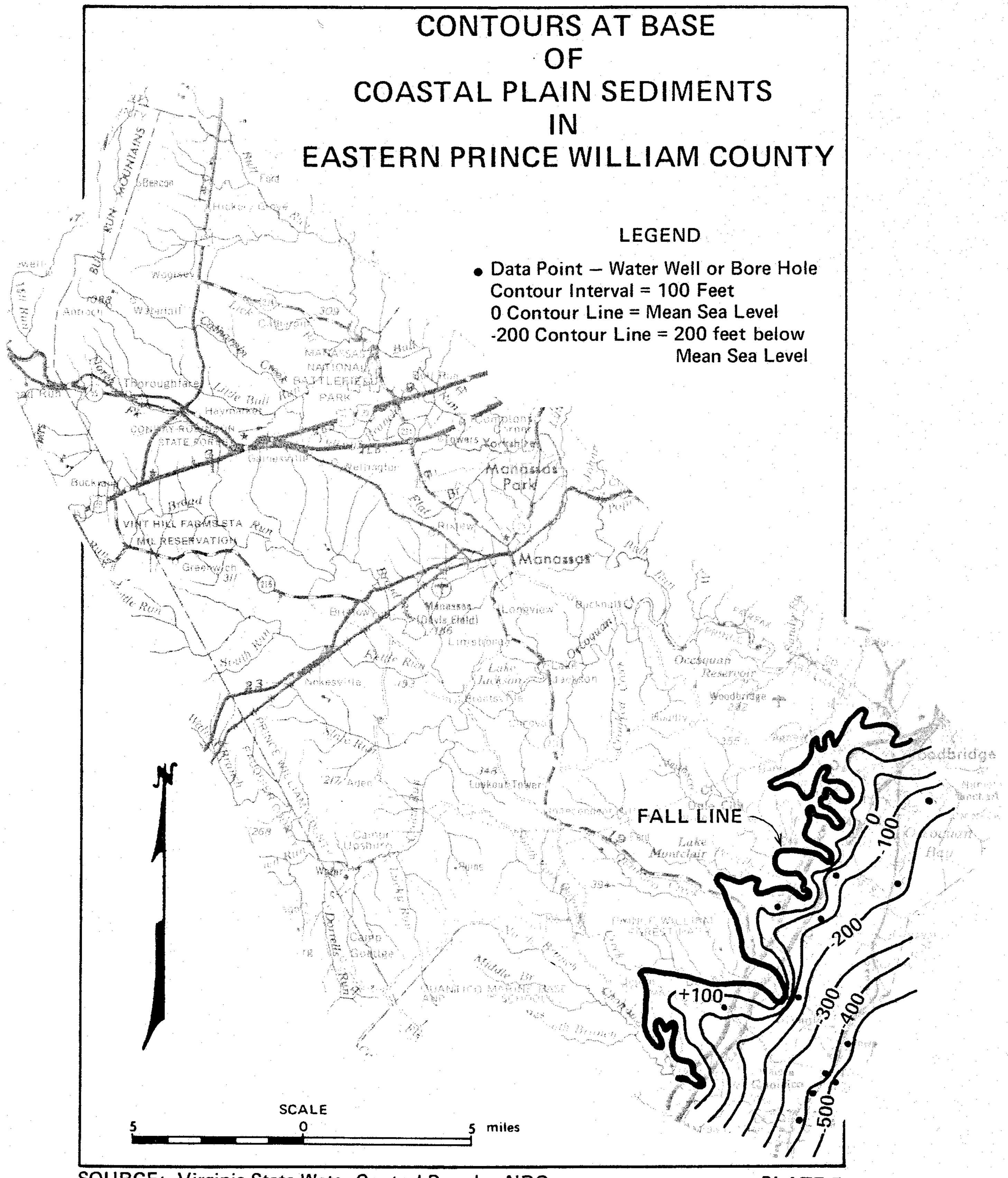
Coastal Plain. The unconsolidated sand beds within the Coastal

Plain sediments are good aquifers. Unfortunately, the sand beds comprise a much smaller proportion of the sediments than the clay beds. Also, the Coastal Plain is relatively thin in Prince William County.

Plate 5 is a contour map that illustrates the elevation of the base of the Coastal Plain sediments, which is the maximum depth that a well should be drilled. Most of the water bearing sands occur between 200 to 350 feet below sea level, and the highest yield wells can be expected southeast of the -200 foot contour line on Plate 5. Wells to the northwest of this line drilled deeper than 200 feet below sea level will encounter nonproductive crystalline rocks of the Piedmont basement.

The average yield for four wells drilled less than 200 feet in the Coastal Plain is 101 gpm; for 9 wells between 200 and 400 feet, 137 gpm; and for two wells from 400 to 600 feet, 211 gpm.

The Coastal Plain contains both artesian and water table aquifers. The static water levels for wells drilled in the Coastal Plain sediments generally range from 4 to 45 feet, although depths of as much as 151 feet have been reported. Cady (1938) reported two artesian wells south of Woodbridge that flowed at the surface, indicating static water levels above ground. Wells drilled at the top of high sandy ridges in the Coastal Plain are likely to have static water levels from 50 to 100 feet.



SOURCE: Virginia State Water Control Board — NRO

PLATE 5

CHAPTER IV

GROUNDWATER QUALITY

The quality of groundwater is a reflection of its chemical, biological, and physical characteristics. The potability and industrial usability of groundwater is dependant on its quality, which is determined by natural occurring phenomena and may be impaired as a consequence of human activities.

Constituents in Natural Groundwater

As water falls through the atmosphere and percolates through soil and rock material, gases and mineral matter become dissolved or suspended in the water. The solids and gases contained in water influence its chemical and physical properties, such as hardness, acidity/alkalinity, corrosiveness, taste, color, odor, etc. Some of the dissolved constituents, such as fluoride (if not excessive), are beneficial; others, such as iron, troublesome. Consultation with the Virginia Department of Health is in order for determining groundwater potability.

The most common constituents of natural groundwater include calcium, magnesium, sodium, bicarbonate, sulfate and chloride. Other constituents commonly present, but usually in lesser amounts, include iron, magnanese, silica, potassium, fluoride and nitrate.

Calcium (Ca) and Magnesium (Mg). These ions are responsible for most of the hardness and scale-forming properties of water (see hardness). A high concentration of magnesium in water can have a laxative effect on its user. Calcium, in high amounts, has been reported to be harmless.

Sodium (Na) and Potassium (K). In high amounts, these ions can give a salty taste to water in combination with chloride. High amounts of sodium in drinking water is reportedly undesirable to persons who suffer from hypertension.

Iron (Fe) and Manganese (Mn). These constituents cause stains in laundry, cooking utensils, and porcelain fixtures. They also contribute to hardness and may impart an objectionable taste and color to food and beverages. The recommended limit for iron and manganese together in drinking water is 0.3 mg/l.

Bicarbonate (HCO_3). Bicarbonate ions are responsible for most of the alkalinity in water and combine with calcium and magnesium to form boiler scale.

Sulfate (SO_4). Sulfate combines with calcium to form boiler scale and may impart a bitter taste to water when present in excess of 500 mg/l. Water containing 1000 mg/l may be cathartic. The recommended limit for sulfate in drinking water is 250 mg/l.

Chloride (Cl). In excess of 100 mg/l, chloride imparts a salty taste. The recommended limit for chloride in drinking water is 250 mg/l.

Fluoride (F). In drinking water, fluoride reportedly reduces the incidence of decay in children's teeth. However, excessive fluoride may cause mottling of the teeth. The recommended limit for fluoride in drinking water is 1.5 mg/l.

Nitrate (NO_3). The final product of oxidation in the nitrogen cycle is nitrate. Water containing more than 45 mg/l of nitrate has been reported to cause methemoglobinemia in infants. High nitrate content may indicate sewage pollution. The recommended limit for drinking water is 45 mg/l, if expressed as nitrate (NO_3) or 10 mg/l expressed as nitrate-nitrogen (NO_3-N).

Total Dissolved Solids (TDS). This factor indicates the total amount of dissolved mineral matter in water. The recommended limit for TDS in drinking water is 500 mg/l.

Specific Conductivity. A measure of the ability of water to conduct an electric current, specific conductivity is an indicator of the relative amount of dissolved minerals in water.

Hardness. Water hardness causes excessive consumption of soap and deposition of scales in pipes, water heaters, and boilers. Water whose hardness is less than 60 mg/l is considered soft; 61 to 120 mg/l, moderately hard; 121 to 180 mg/l, hard; and greater than 180 mg/l, very hard.

pH. A measure of the hydrogen ion concentration, pH indicates whether water will act as a weak acid or an alkaline solution. The pH scale ranges from 0 to 14 with 7.0 being neutral, greater than 7.0 indicating an alkaline solution, and less than 7.0, an acidic solution. Corrosiveness of water generally increases with a decreasing pH, although highly alkaline water may be corrosive. Corrosive water may attack steel casing or copper plumbing.

Water Quality in Prince William County

The quality of the groundwater in Prince William County is highly variable. This variation is primarily due to the different rocks in which the water occurs and the local conditions of the well site, including the construction characteristics of the well and proximity to sources of contamination, such as septic-tank drainfields. Table 3 lists the maximum and minimum concentrations and the median values for the constituents in the groundwater of the various aquifers in the County, based on chemical analyses available for this report. Appendix A is a summary of water quality analyses of samples taken from individual wells throughout the County. The hardness trends of the groundwater are illustrated in Plate 6, based on the data from Appendix A.

Piedmont. Groundwater from the granite and schist aquifers is of similar quality as can be seen in Table 3. The water is soft to moderately hard and contains low to moderate amounts of dissolved mineral matter. It is acid to slightly alkaline and may be corrosive to steel casing and copper pipes.

Iron may be present in objectionable amounts in water from any of the Piedmont rocks. Two of the 15 samples from schist and four of the nine samples from granite contained excessive iron.

The bicarbonate content is relatively high in Piedmont groundwater. The fluoride content is very low and only one of 17 samples contained any significant amount. The sodium, sulfate, chloride, and nitrate contents are low and may indicate local pollution if they appear high in water from a Piedmont well.

Bull Run Mountain. Groundwater from the Weverton Quartzite is softer and lower in dissolved minerals than that from any other aquifer in the County. It is generally acidic and may be corrosive. None of the five samples contained excessive iron

TABLE 3
PRINCE WILLIAM COUNTY
SUMMARY OF ANALYSES OF GROUNDWATER

	pH	SPEC COND	TDS	HARD-NESS	Fe	Ca	Mg	Na	K	HCO_3	SO_4	Cl	F	NO_3	AQUIFER
Minimum	6.0	41	36	12	0	3	0.6	1	0.1	17	0.3	1	0	0	Piedmont
Maximum	8.0	260	258	130	2.1	41	10	17	5.9	123	15	10	0.4	1.3	Schist
Median	6.8	129	108	66	<0.1	17	3	6.3	1.2	55	1.6	2.5	<0.1	0.23	
Minimum	6.1	50	64	25	<0.1	8.9	0.7	5	<0.1	22	0.6	1	0.06	0	Piedmont
Maximum	7.8	215	158	104	2.5	39	5.2	10.5	9	108	2.5	8	0.1	9.3	Granite
Median	6.8	146	100	49	0.13	15	1.9	8	3.7	72	1	5.5	0.08	0.9	
Minimum	6.5	24	7	7.2	0	1.4	0.9	1.7	1.5	11	0	1	0.07	0	Weverton
Maximum	8.1	84	50	39	0.25	9	4	4	1.9	48	1.4	1.5	0.13	0.22	Quartzite
Median	6.7	40	26	16	<0.1	4.1	1.5	2	1.7	19	<0.5	1	0.09	0.04	
Minimum	6.3	35	77	14	<0.1	4	1	1.1	<0.1	14	0.7	1	<0.1	<1	Triassic
Maximum	8.5	1213	853	634	3.6	180	63	90	14.1	249	640	150	1.5	117	Sedimentary
Median	7.6	400	269	217	<0.1	62	17	19	0.9	180	34	9.3	0.1	1.4	Rocks
Minimum	7.3	510	315	284	<0.1	65	26	9.7	0.6	188	33.2	18	<0.1	2.2	Triassic
Maximum	7.6	800	417	452	0.1	87	57	19	1.2	284	39.7	42	<0.1	97	Diabase
Median	7.3	600	351	372	<0.1	78	43	12	0.8	256	39.5	25	<0.1	4.4	
Minimum	5.6	191	159	42	0.02	13	2.4	3.2	2.3	11	0.6	1	<0.1	0.2	Coastal
Maximum	7.4	261	192	94	3.1	24	13	31	7.9	148	11.4	15	0.3	9.7	Plain
Median	6.7	226	167	86	0.5	18.5	8.3	15.8	5.7	69	6.5	8	0.3	1.8	Sediments

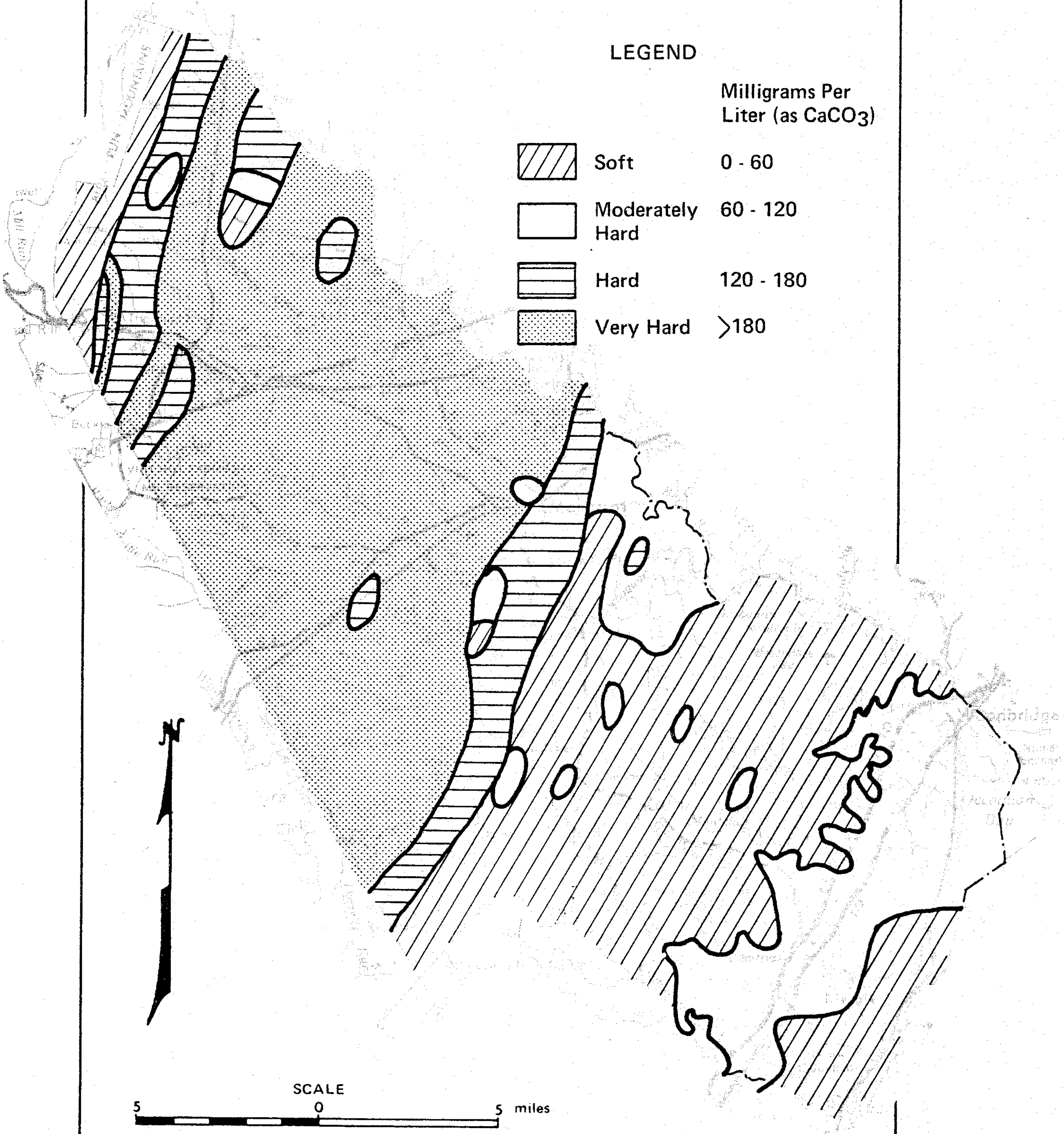
Source: Virginia State Water Control Board - NRO although a significant amount (0.25 mg/l) was present in water from well #181. Fluoride content is low and bicarbonate is the only significant nonmetal ion present.

Triassic. The sedimentary rocks (Newark Group) of the Triassic Basin produce water that is much harder and higher in dissolved solids than that of any other aquifer in the County. Of 40 samples, 25 (62.5 percent) were very hard, 8 (20 percent) were hard, four (10 percent) were moderately hard, and only three (7.5 percent)were soft. The total dissolved solids content commonly exceeds the recommended limit of 500 mg/l.

The water is usually slightly alkaline and rarely corrosive. Iron was excessive in only four of 42 samples. Fluoride is often present but rarely in very high amounts. In addition to the hardness producing calcium and magnesium ions, the sodium content is relatively high, although not excessive. The chloride and nitrate contents are not high unless contamination is present.

Sulfate and bicarbonate are the most abundant nonmetal constituents, with bicarbonate usually predominant. However, the sulfate content commonly exceeds the recommended limit (250 mg/l) in the deep wells in the Manassas area and samples from wells number 65 and 176 reportedly contained 640 mg/l of sulfate. It is possible that sulfur laden water occurs at specific zones in a well. If so, such zones could be isolated by sampling water at various depths in a well. It might then be possible to case-off the high sulfur water, which would reduce the output of the well but diminish the sulfate problem. Water samples from some of the

TRENDS OF GROUNDWATER HARDNESS IN PRINCE WILLIAM COUNTY



SOURCE: Virginia State Water Control Board – NRO

PLATE NO. 6

shallow (less than 200 feet) domestic wells contained significant amounts of sulfate, but none were excessive.

Water softeners are often used in domestic water systems in the Triassic region to eliminate the problems caused by the hard water. Most water softeners work on an ion-exchange principal, whereby the hardness-producing calcium and magnesium ions are replaced by sodium ions. The resulting sodium concentrations can be quite high, which anyone on a low-sodium diet should consider. The water-softening unit can be by-passed by one faucet for consumption or bottled water can be purchased by anyone who desires the benefits of softened water but who wants to limit sodium intake.

The diabase in the Triassic region contains groundwater which is similar in quality to that of the sedimentary rocks, but is lower in sulfate content. The water is very hard, slightly alkaline, and high in dissolved solids. None of the five samples from diabase wells contained excessive iron, but data from neighboring counties indicate that objectionable amounts of iron may occur in diabase groundwater.

Coastal Plain. Groundwater from the Coastal Plain sediments is soft to moderately hard and contains low to moderate amounts of dissolved mineral matter. The water is harder along the western margin of the Coastal Plain near the Fall Line and is softer to the east. The iron content is commonly excessive and the water is acidic to slightly alkaline. Fluoride is often present but not in excessive amounts and bicarbonate is the most common nonmetal ion. Sulfate, nitrate, and chloride may be present but not in high amounts.

Groundwater Contamination

Groundwater Contamination refers to the introduction of an organic or inorganic material, foreign to the native groundwater, that tends to render the groundwater unusable. If contaminants are added to the groundwater to the extent that it becomes nonpotable or unusable, the groundwater is said to be polluted. Groundwater pollution is usually more serious than surface water pollution since reversal is very difficult and costly. The self-cleansing mechanisms available to streams, fresh-water flushing and oxygenation, operate very slowly in groundwater if at all.

Sources of groundwater pollution are many and varied. Miller and Scalf (1974) presented a synopsis of the subject in a nation-wide investigation sponsored by the U. S. Environmental Protection Agency. In Prince William County, the more significant sources of groundwater pollution include: septic-tank systems, sanitary landfills, sewage lagoons, petroleum spills, leaking pipelines, leaking gasoline storage tanks, improperly constructed water wells, certain agricultural activities (fertilizers, pesticides, feedlot and barnyard wastes), salt-water intrusion (from the Potomac Estuary), highway deicing salts, infiltration of poor quality surface water from lakes and streams, and spray-irrigation waste disposal sites.

Septic tank drainfields, by sheer volume of waste water discharged, have the greatest potential for contaminating groundwater. A drainfield is considered failing if the sewage backs up in the house or floods the land surface. Therefore, a properly operating drainfield acts as a source for groundwater recharge. Miller and Scalf (1974) state that "Studies have shown that in many housing developments recycling of liquid wastes is an inevitable fact of life."

Septic-tank systems are commonly believed to purify sewage. Actually, the degree of treatment that waste water receives in a septic system is rarely high. In suitable soils, most bacteria are effectively removed by filtration and biological degradation. However, many soils have a low capacity for the purification of waste. Some soil profiles are too thin to assimilate all of the wastes. Moreover, not all of the undesirable constituents of domestic sewage are completely biodegradable. Referring to the disposal of domestic wastes in septic-tank systems, Miller et al (1974) state, "Under normal conditions of soil pH, efficient removal of phosphates can take place, but chlorides, nitrates, sulfates, and bicarbonates can enter and move freely within a groundwater body."

Nitrates are the most significant constituents (other than bacteria or viruses) of domestic sewage pertinent to groundwater quality. The nitrate content of groundwater is of concern for three reasons: it is an indicator of sewage contamination, it has been identified in medical studies as a possible carcinogen, and it has been identified as a causal agent of a disease in infants known as methemoglobinemia (commonly called "blue babies"). The recommended public health limit for nitrate in drinking water has been set at 45 mg/l NO_3 (10 mg/l if reported as NO_3-N).

In Prince William County, the nitrate content of natural groundwater is quite low. High concentrations of nitrate most likely indicate contamination. The most likely sources are septic tank effluent and nitrogen fertilizers. In areas where infiltration of nitrogen fertilizers is insignificant, the nitrate content is a good tracer for septic tank contamination.

The Triassic lowlands is probably the most vulnerable area to nitrate contamination in Prince William County. Most of the area is unsewered and residential development is increasing rapidly. The soils are relatively thin and their capability for assimilating and filtering wastes is limited. The shale and sandstone bedrock is highly fractured. The fractures are inclined 15^o to 20^o from the horizontal, providing a natural conduit to the water table for liquid contaminants with little opportunity for filtration and quality improvement.

Nutter (1975) investigated nitrate contamination in the Triassic rocks in Maryland and found that in the village of Graceham, six out of 11 wells sampled contained nitrate in excess of 45 mg/l. Only one of the 11 wells sampled contained less than 30 mg/l. The average age of the wells and septic systems in Graceham is 30 years and the lots are very small.

The age of a septic system is a significant factor in groundwater quality since continuous nitrogen loading causes a build-up of nitrate over a period of years. Lot size and housing density are also very important. In a high-density area, septic tank effluent can constitute a large portion of the groundwater recharge and thus cause contamination.

Pollution of groundwater by petroleum hydrocarbons is a very serious problem that is relatively common. Most instances are confined to local areas and involve only one or a few wells. However, there have been cases of large scale groundwater pollution from petroleum products, (McKee et al, 1972 and Osgood, 1974). In Prince William County, minor cases have occurred but, as yet, no major ones.

The principal causes of hydrocarbon contamination include: leakage from storage tanks, leakage from buried pipelines, spills or leaks at bulk storage areas, and transportation spills. Many types of petroleum products are involved, but gasoline contamination is the most common, usually resulting from leaks in buried storage tanks at service stations. Slow leaks can go unnoticed at a service station until a well becomes polluted, neighbors smell gasoline fumes in their houses, or customers get water in the gasoline thay purchase.

The human threshold for the detection of gasoline can be as low as 0.005 mg/l, so a small amount of gasoline can render a water well unusable. Recent studies have shown that certain bacteria will degrade gasoline in the groundwater environment if adequate nutrients and dissolved oxygen are available. However, there are cases in which gasoline has remained in soil for more than 70 years (McKee et al, 1972).

The clean-up of subsurface petroleum spills is difficult, costly, and often ineffective. Alternate water supplies often have to be found when a well is impaired. A publication which offers solutions to problems involving hydrocarbon contamination of groundwater has been prepared by the American Petroleum Institute (1972).

It is beyond the scope of this report to provide a detailed discussion of all of the causes and effects of groundwater pollution. Groundwater conditions are so variable and potential contaminants are so numerous that most cases are unique. Any known or suspected case should be reported to the appropriate County or State health officials and/or to the State Water Control Board.

CHAPTER V

GROUNDWATER DEVELOPMENT

General Setting

Groundwater is widely developed in Prince William County in domestic and public water systems. Water wells in the County are of three types: drilled, bored and hand-dug. Most drilled wells are now constructed by rotary drilling machines. Bored wells are constructed by large diameter (24 to 48 inch) boring machines or earth augers. Hand-dug wells, once common in the Piedmont and Coastal Plain (Cady, 1938), are now rarely used for potable water supplies.

Drilled wells are usually 4 to 18 inches in diameter. Steel casing is installed from the surface through the weathered zone and seated into the bedrock. Wells in the Coastal Plain are cased to the bottom of the hole to keep the sediments from caving in. Water enters such a well through perforations or screens placed strategically in the casing at water-bearing zones, which are usually sand layers. The area around the screen is often packed with fine gravel to prevent silt and sand grains from clogging the screen. The zone above the screen between the outside of the casing and the well bore (annular space) is grouted with cement from some predetermined depth to the surface. Cement grout prevents surface containants from seeping down the well bore.

Bored wells are common in the Piedmont and Coastal Plain. In the Piedmont, they are terminated in the weathered zone since boring machines cannot penetrate hard rock. Bored wells are lined with concrete pipe instead of steel casing. Water enters a bored well at the bottom which is open. Bored wells are not usually grouted except at the surface and, therefore, are more susceptible to contamination than properly constructed drilled wells. Bored and hand-dug wells are also more vulnerable in times of prolonged drought, since their depths are limited.

Public Supplies

The construction of public water-supply wells is regulated by the Virginia Department of Health (1974). A well is designated a public supply if it serves 15 connections or 25 people. Public water-wells are required to be cased and grouted to a depth of at least 50 feet (sometimes greater depths are required) and to provide a supply of at least 0.5 gallons per minute per connection.

Public water-supply wells are relatively numerous in Prince William County. The highest concentration is in the Manassas area where the wells produce from the artesian aquifers of the Triassic sedimentary rocks. The town of Manassas has 13 wells on a stand-by basis to augment its surface water supply from the Broad Run Reservoir during emergencies. The Greater Manassas Sanitary District, which serves a residential area north of the town of Manassas, has nine wells and, as of this writing, is preparing to drill the tenth. The nine wells range in depth from 300 to 900 feet and produce a total of 1.5 million gallons per day (mgd). The Yorkshire Sanitary District has three wells ranging in depth from 343 to 790 feet.

These wells procude a total of 0.3 mgd. The town of Manassas Park obtains 0.5 mgd from four wells that are 807 to 1000 feet deep.

Outside the Manassas area, several housing developments, schools, and two State Prison camps depend on public water-supply wells. Also, the federally-owned Prince William Forest Park has several wells to serve picnic and campground facilities. Industrial development of groundwater in the County is not high.

Domestic Supplies

Domestic water supplies in rural areas of the County depend almost exclusively on groundwater. Domestic wells may be either drilled, bored or hand-dug. Bored wells are common in the Piedmont and Coastal Plain while most of the wells in the Triassic region are drilled. Springs are rarely utilized for domestic water supplies in Prince William County. Prospective groundwater users should consult with a hydrogeologist and/or a water well contractor for constructing a water well, and with the Department of Health as to the potability of the water.

Key Water Wells

Appendix B lists many of the significant water wells in Prince William County with some of their construction characteristics, their yields, and the aquifers from which they produce. Most of the public water-supply wells are listed in addition to many domestic, institutional, and industrial wells. The last column in Appendix B indicates the usage (public, domestic, government, industrial, etc.) of the well. Also, most wells from which water quality samples were taken are included and the Bureau of Water Control Management well numbers correspond to the same numbers in the chemical analysis data in Appendix A.

The locations of key water wells throughout the County are illustrated in Plate 7. Almost half of the wells in Appendix B are shown on the map and nearly all of the wells in Appendix A are shown. The well numbers on the map apply to both appendices.

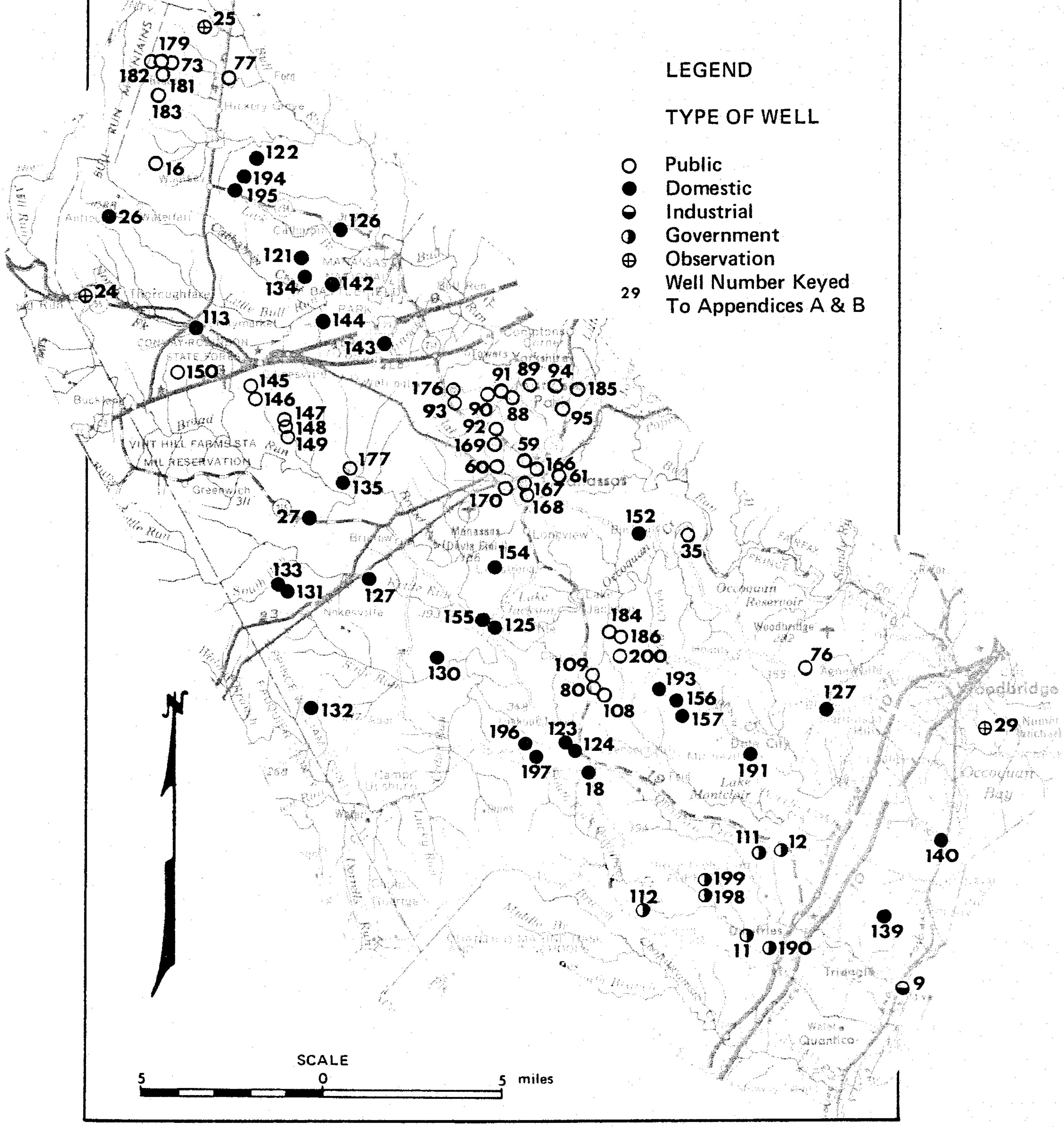
Wells number 22, 23, 24 and 25 are water-level observation wells maintained by the U.S. Geological Survey. Records from these are available in "Water Resources Data for Virginia" which is published annually by that agency. Well number 29 is a water-level observation well maintained by the State Water Control Board, from which its data may be obtained. Wells 22,23, and 29 record water-level data from Coastal Plain aquifers near the Potomac River. Wells 24 and 25 record data for Triassic shale and sandstone aquifers in the western portion of the County.

The Groundwater Act of 1973

The General Assembly of Virginia passed the Groundwater Act of 1973 (Chapter 3.4, Title 62.1, Code of Virginia, 1950, as amended) "...in order to conserve, protect and beneficially utilize the groundwater of this State and to ensure the preservation of the public welfare, safety and health ..." Concern for adequate groundwater supplies in the future and protection of groundwater quality prompted this legislation.

The Groundwater Act provides for the declaration of a Critical

KEY WATER WELLS IN PRINCE WILLIAM COUNTY



SOURCE: Virginia State Water Control Board — NRO

PLATE NO. 7

Groundwater Area (CGA) in a geographically-defined region which experiences or can be expected to experience problems with interference of wells, water level declines, overdraft of groundwater, or quality of groundwater.

Requests for a declaration of a CGA can be made by local government, the State Water Control Board, or the public at large. In either case, a detailed study of the proposed CGA would be made and public hearings would be convened to determine the necessity and desirability of designating an area a CGA. As of this writing, no area in Prince William County has been declared a CGA.

Industrial and commercial groundwater users in a CGA who withdraw more than 50,000 gpd are required to file a Registration Statement (Form GW-4) with the State Water Control Board. Prior to the construction of a new well in a CGA, the owner is required to submit an application and Permit to Construct a Water Well and to Use Groundwater (Form GW-3).

In all groundwater areas, users are required to submit a Water Well Completion Report (Form GW-2) for new wells. All public and industrial users are required to submit a Groundwater Pumpage and Use Report (Form GW-6) to the Board quarterly. When an industrial or public well is to be abandoned, the owner must submit an Application and Report - Abandonment of Water Well (Form GW-5).

Further explanations are included in the Guide for Water Well Contractors and Groundwater Users and in the Rules of the Board and Standards for Water Wells, both publications by the Virginia State

Water Control Board (1974).

Groundwater Availability

The availability of groundwater in areas of the County is illustrated in Plate 8. This map is based on the occurrence of the geologic formations and their general water-bearing properties. Also, local areas which are known to be particularly favorable or unfavorable to groundwater development are designated.

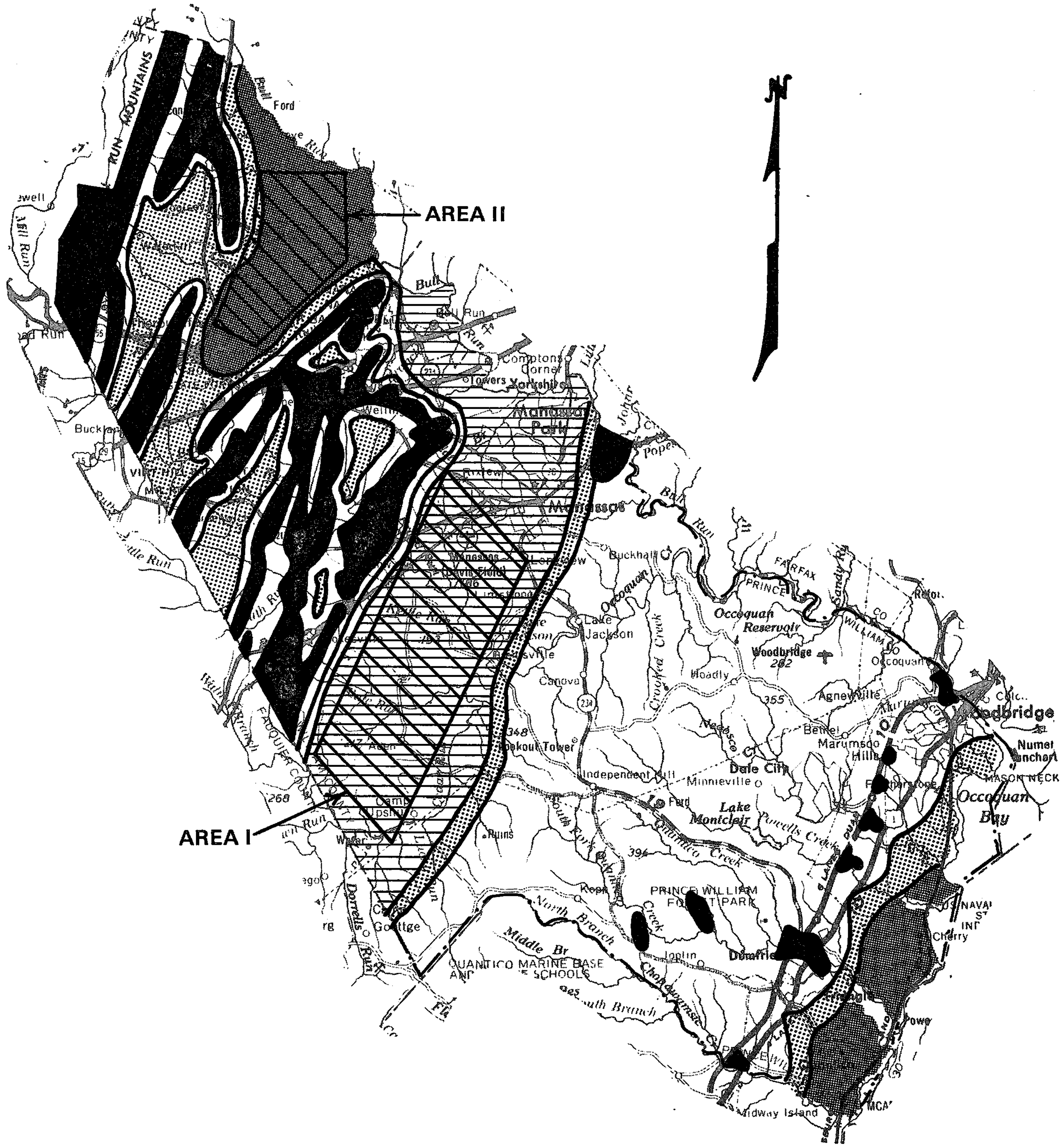
It must be realized that the map in Plate 8 is of a general nature and all special areas that are either anomalously high or low in productivity are not and cannot be shown. This is especially true of the Piedmont, which is a very complex and insufficiently known area. Well yields in the Piedmont may range from zero to nearly 100 gpm and it is not possible to accurately predict where the areas of low yield and high yield will be.

Piedmont. Groundwater is readily available in most of the Piedmont region of Prince William County. However, there are limits to the amount that can be produced within a given area. Also, as pointed out in Chapter III, there are local areas where well yields are very low.

Small to moderate sized housing developments or light industries can depend on groundwater supplies in most areas of the Piedmont. Most developments require more than one well for adequate supplies and it is not uncommon for one or more wells in a well field to be failures.

Drilling deeper than 350 feet is rarely feasible in the Piedmont rocks unless deeper water-yielding zones are known to exist

GROUNDWATER AVAILABILITY IN PRINCE WILLIAM COUNTY



LEGEND

		POTENTIAL WELL YIELD (gpm)
(solid black)	Poor	<10
(white)	Fair	10-25
(light stipple)	Good	25-100
(dark stipple)	Very Good	100-250
(horizontal lines)	Excellent	>250
(diagonal hatching)	Areas For Potential Development of Well Fields	

SCALE 1:250,000

5 0 5 MILES

5 0 5 KILOMETERS

SOURCE: Virginia State Water Control Board – NRO

PLATE NO. 8

in a specific area. If sufficient supplies have not been obtained by that depth, it is usually better to pick a new site rather than drill deeper.

Topographic considerations are very important in picking well sites in the Piedmont. Wells situated in valleys, draws, ravines, or lower slopes are likely to have higher yields than wells situated on hilltops, ridges, or upper slopes. Piedmont wells may be expected to yield an average of 10 to 15 gpm. Individual wells may of course deviate widely from the average.

Bull Run Mountain. The availability of groundwater on Bull Run Mountain is very low. Well yields are not likely to be more than a few gallons per minute, and dry holes would not be unlikely. Wells for anything other than domestic use should not be considered.

Triassic. The Triassic sedimentary rocks (Newark Group) contain greater amounts of groundwater than any other rock unit in Prince William County. Well yields are usually sufficiently high so that groundwater resources may be utilized for domestic, agricultural, industrial, public, or municipal purposes.

However, the water quality may not be suitable for some industrial purposes. For example, the hardness would be too high to use the water in steam boilers, etc. The water is potable but may be objectionable for use in some food processing industries due to the high amount of dissolved mineral matter.

To develop high-yield wells in the Triassic region, sites should be picked as far from diabase outcrops as possible; at least

1000 feet and preferably further. The County soils maps, mentioned in Chapter II, can be used to determine diabase occurrence. Sites in shale or sandstone soil groups are more desirable than those in baked shale or conglomerate soil groups. Sites in low topographic settings, such as valleys, draws, or lower slopes, are likely to have higher yields than sites on hilltops, ridges, or upper slopes, although topographic considerations are not as critical as in the Piedmont. Well depths should be 600 to 1000 feet. Such wells may be expected to yield an average of 274 gpm or possibly better. If diabase is encountered at some depth beneath sandstone or shale, which is possible in areas near diabase outcrops, drilling should be terminated at that depth.

Domestic wells in the Triassic sedimentary rocks need only be 100 to 150 feet deep usually, and about six inches in diameter and may be expected to yield 10 to 15 gpm.

Two areas have been identified by this study for potential development of well fields within the Triassic sedimentary rocks (Plate 8). The economic, legal, and political constraints of developing such as a well field cannot be evaluated in this report and, therefore, are not considered. It is obvious that problems of this nature would have to be dealt with and resolved before any large-scale groundwater development could occur.

Area I in Plate 8 occupies approximately 27 square miles. Area I is along the same geologic trend as the Manassas area and the rocks should have similar hydrologic properties. If so, an average yield of 274 gpm can be assumed for wells drilled to a depth of 600 to 1000 feet. If wells were spaced one mile apart, 27 wells could be drilled in Area I and could produce a total of 10.6 mgd, if pumped on a 24 hour basis.

A natural recharge rate of 0.39 mgd per square mile would be required to sustain the production. This would require that 8.2 inches or 20.5 per cent of the annual average of 40 inches of precipitation result in groundwater recharge. A water budget for the area would have to be computed to determine if 8.2 inches of the annual average of 40 inches of precipitation can be expected to recharge the groundwater. Guidelines for preparing a water budget are given by Carter (undated).

Similar estimates could be made for groundwater potential in Area II, but no deep wells are known to exist there. The rocks in Area II may be somewhat different than in Area I or the Manassas area. Area II occupies a more central to westerly portion of the Triassic Basin and probably contains more strata of conglomerate, which might make it less productive. It is not known what the average yield of wells in Area II might be.

The diabase in the Triassic region has very little available groundwater. Sufficient supplies for domestic purposes are ususally obtainable but dry holes are by no means uncommon. High yield wells cannot be expected and should not be attempted. Deep drilling is futile in the diabase and wells should terminate at 350 feet. Well sites should be picked at topographically low areas as explained in the previous sections. Many wells attempted on hilltops and ridges in diabase are completely dry.

Coastal Plain. Groundwater availability in the Coastal Plain sediments is generally good, although the limited areal extent and relative thinness of the sediments in Prince William County restrict the amount that can be developed.

Sufficient yields for domestic or light industrial use (up to 50,000 gpd) should be no problem anywhere in the Coastal Plain. Well yields averaging 250,000 gpd can be expected in the southeastern portion of the Coastal Plain. This would be the area shown on Plate 5 between the -200 foot contour line and the Potomac River. The highest water-yielding zones can be expected between 200 and 350 feet below sea level. The exact depth can be calculated by adding the above figures to the elevation of the well site which can be taken from the appropriate U.S. Geological Survey topographic map.

Construction of drilled wells in the Coastal Plain should be based on the following guidelines. The wells should be cased to total depth to prevent the borehole from caving in. Screens have to be strategically placed in the casing to allow water to enter the well at the appropriate water-bearing zone. These zones should be gravel-packed around the screen to improve the yield and to prevent fine sand grains from clogging the screen. The annular space between the casing and the borehole should be grouted with cement to prevent surface contaminants from seeping down the well. The casing should extend at least a foot above ground level to prevent surface water from flooding the well vent, and surface drainage should be directed away from the well. Well yields are generally not affected by the topographic setting of the well site in the Coastal Plain.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

It is anticipated that this report, while of a general nature, may be used in groundwater resource planning and development for public water-systems, and in providing guidelines for well-site selection for private water-systems. It should be emphasized that long-range planning efforts which depend on development of groundwater resources to supplement present water supplies should be accompanied by a study of the groundwater conditions of the specific area to be developed. The cost of drilling test wells in a promising area can be more than offset by the knowledge gained of groundwater availability, because it is much cheaper to develop groundwater than surface water.

In summation, it can be stated that by far the most promising areas for successful development of groundwater are in the Triassic sedimentary rocks. The Coastal Plain sediments are reliable for providing good well yields, as long as the wells are located a sufficient distance east of the Fall Line so that a substantial thickness (over 200 feet) of sediments is present. The granite and schist aquifers of the Piedmont are generally reliable sources of groundwater, but their limitations for individual well yeilds must be realized. Also, the importance of locating wells at low topographic positions when possible in the Piedmont, should again be emphasized. Well drilling in the Triassic diabase and on Bull Run Mountain should be avoided if at all possible. If a well must be drilled in the diabase, it should be located at the lowest topographic site available without placing the well in jeopardy of being flooded.

The relatively poor quality of the groundwater from the Triassic sedimentary rocks may limit industrial usage. However, the poor quality is mostly due to hardness, high dissolved mineral content, and high sulfate, and does not necessarily affect potability. Also, iron appears to be less of a problem than in the other aquifers of the County.

Protection of groundwater from contamination is of utmost importance. The clensing of a polluted aquifer by natural flushing may take decades or centuries after the source of pollution is abated. The Triassic area is especially vulnerable to nitrate contamination from septic tanks. The practice of expanding septic tank usage in this area should receive close scrutiny.

Two areas have been identified within the Triassic sedimentary rocks for potential development of well fields. The larger area possibly could yield 10.6 mgd without depleting the aquifer.

APPENDIX A

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR PRINCE WILLIAM COUNTY

The computer printout on the following pages lists basic groundwater quality data available for many of the wells listed in the water well data summary (Appendix B). There are some quality analyses listed for wells not included in Appendix B; however, well data is available for these wells and may be obtained by contacting the State Water Control Board's Northern Regional Office in Alexandria or the Headquarters Office in Richmond.

V I R G I N I A   S T A T E   W A T E R   C O N T R O L   B O A R D

B U R E A U   O F   S U R V E I L L A N C E   A N D   F I E L D   S T U D I E S

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR PRINCE WILLIAM

****

THE FOLLOWING LIST OF GROUNDWATER QUALITY DATA SUMMARIZES BASIC DATA OBTAINED FROM ANALYSES OF GROUNDWATER, COLLECTED FROM WELLS AND SPRINGS, WHICH ARE ON PERMANENT FILE IN THE OFFICES OF THE VIRGINIA STATE WATER CONTROL BOARD. ADDITIONAL GROUNDWATER QUALITY INFORMATION FOR MANY OF THESE WELLS AND SPRINGS IS AVAILABLE AND CAN BE OBTAINED BY CONTACTING THE APPROPRIATE REGIONAL OFFICE OR THE BUREAU OF SURVEILLANCE AND FIELD STUDIES AT THE AGENCY HEADQUARTERS IN RICHMOND.

************ EXPLANATION OF PARAMETERS ************

SWCB NO: STATE WATER CONTROL BOARD NUMBER - A SEQUENTIAL NUMBERING SYSTEM USED WITHIN A COUNTY; WHEN REFERRING TO A SPECIFIC WELL USE THIS NUMBER

OWNER AND/OR PLACE: IDENTIFIES ORIGINAL OR CURRENT WELL OWNER AND/OR LOCATION OF WELL.

DATE SAMP: DATE SAMPLED - MONTH AND YEAR IN WHICH WATER SAMPLE WAS COLLECTED.

PH: HYDROGEN ION CONCENTRATION - BASED ON A SCALE OF 1 THROUGH 14, WATER WITH A PH GREATER THAN 7.0 IS CONSIDERED TO BE BASIC OR ALKALINE; THE LARGER THE PH VALUE, THE MORE ALKALINE THE WATER. WATER WITH A PH LESS THAN 7.0 IS CONSIDERED TO BE ACIDIC; THE SMALLER THE PH VALUE, THE MORE ACIDIC THE WATER.

SPEC COND: SPECIFIC CONDUCTIVITY - AN INDICATOR OF THE RELATIVE AMOUNT OF DISSOLVED MINERALS IN WATER; HIGHER VALUES INDICATE GREATER AMOUNTS OF DISSOLVED MINERALS; UNIT OF MEASUREMENT IS MICROMHO

T-DIS SOLID: TOTAL DISSOLVED SOLIDS - INDICATES TOTAL AMOUNT OF DISSOLVED MINERALS IN WATER; UNIT OF MEASUREMENT IS MILLIGRAMS PER LITER

HARDNESS TOTAL: TOTAL HARDNESS - CAUSED BY THE PRESENCE OF CALCIUM, MAGNESIUM, IRON, ZINC , AND OTHER TRACE METALS. UNIT OF MEASURE IS MILLIGRAMS PER LITER.

HARDNESS CA,MG: CALCIUM-MAGNESIUM HARDNESS - INDICATES THAT PORTION OF TOTAL HARDNESS CAUSED BY CALCIUM AND MAGNESIUM, WHICH ARE GENERALLY RESPONSIBLE FOR ALMOST ALL HARDNESS IN WATER. UNIT OF MEASURE IS MILLIGRAMS PER LITER.

THE AMOUNT OF HARDNESS IN WATER WILL AFFECT THE ABILITY OF SOAP TO LATHER OR CLEANSE BECAUSE OF THE TENDENCY OF THE IONS CAUSING HARDNESS TO REACT WITH SOAP. THE HIGHER THE HARDNESS OF WATER, THE MORE DIFFICULT IT IS FOR SOAP TO LATHER.

NOTE: TOTAL HARDNESS IS GENERALLY DETERMINED BY CHEMICAL TITRATION WHEREAS CALCIUM-MAGNESIUM HARDNESS IS GENERALLY DETERMINED BY MATHEMATICAL CALCULATION FROM CHEMICALLY-DETERMINED VALUES FOR CALCIUM AND MAGNESIUM. BECAUSE OF THIS DIFFERENCE IN DETERMINATION, THE CALCIUM-MAGNESIUM HARDNESS VALUES FOR SOME ANALYSES WILL BE LARGER THAN THE TOTAL HARDNESS VALUE.

******** PARAMETERS LISTED BELOW ARE MEASURED IN MILLIGRAMS PER LITER ********

FE: IRON	MN: MANGANESE	CA: CALCIUM
MG: MAGNESIUM	NA: SODIUM	K: POTASSIUM
HCO3: BICARBONATE	SO4: SULFATE	CL: CHLORIDE
	NO3: NITRATE (AS NO3)	

V I R G I N I A   S T A T E   W A T E R   C O N T R O L   B O A R D

B U R E A U   O F   S U R V E I L L A N C E   A N D   F I E L D   S T U D I E S

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR PRINCE WILLIAM

****

SWCB NO	OWNER AND/OR PLACE	DATE SAMP	PH	SPEC COND	T-DIS SOLID	HARDNESS TOTAL	CA,MG	FE	MN	CA	MG	NA	K	HCO3	SO4	CL	NO3
12	PRINCE WM FOREST PK	7 68	6.5	108	88		38	0.00		9.4	3.4	5.5	1.2	55	4.6	4.2	4.9
13	PRINCE WM FOREST PK	7 68	7.5	245	152		94	0.15		23.0	9.1	6.7	5.9	122	15.0	3.0	0.4
14	PRINCE WM FOREST PK	7 68	7.5	41	36		12	0.01		3.0	1.1	3.0	1.2	19	2.2	2.9	0.9
29	OBS WELL #29, WOODBRDG	54 72	7.4	261	159		86	0.02		13.0	13.0	27.0	7.9	148	0.6	12.0	0.9
35	OCCOQUAN FOREST	7 73	7.8	145	100	61	64	0.06	0.00	21.8	2.3	6.8	1.1		1.0	3.5	0.0
59	TOWN OF MANASSAS	7 74	7.9	220	161	83	101	0.74	0.05	28.5	4.8	22.5	1.7		36.8	15.0	0.4
62	MANASSAS PARK #1	1 73	8.1		241	167	166	0.00	0.00	45.6	12.8	13.5	0.9		28.3	3.1	2.7
62	MANASSAS PARK #1	2 71	8.1		253	173	183	0.00	0.00	47.3	16.0	14.0	1.0		30.0	2.0	1.8
63	MANASSAS PARK #3	1 73	8.1		198	142	141	0.00	0.00	45.7	6.8	10.5	0.6		5.0	5.7	6.2
63	MANASSAS PARK #3	2 71	8.0		195	139	142	0.00	0.00	44.9	7.5	10.0	0.7		3.3	3.5	3.5
64	MANASSAS PARK #4	1 73	8.1		627	409	408	0.02	0.00	70.5	56.6	21.0	1.6		259.0	5.2	1.8
64	MANASSAS PARK #4	2 71	8.1		658	448	474	3.02	0.03	100.0	54.7	20.3	0.2		280.0	4.0	1.3
65	MANASSAS PARK #6	1 73	7.8		725	421	420	0.10	0.03	112.2	34.2	29.5	1.6		640.0	10.4	0.9
65	MANASSAS PARK #6	2 71	7.9		680	453	481	0.78	0.05	137.0	34.0	30.0	1.7		300.0	8.0	0.9
66	OAK RIDGE ESTATES	7 74	8.0	178	137	78	82	0.05	0.00	21.6	7.0	8.5	1.4		2.3	1.5	0.0
73	BULL RUN MTN ESTATES	11 73	6.5	20	44	6	6	0.18	0.02	1.8	0.7	1.1	0.8		0.0	1.5	0.0
76	FIELD UNIT #3	7 71	2.9		309	47	39	0.13	0.02	12.2	2.1	8.0	1.0		1.0		
77	FIELD UNIT #3	3 71	7.7		479	215	210	0.08	0.05	72.0	7.5	74.0	0.7		186.0	11.5	0.0
81	MANASSAS PARK #9	11 71	8.0				654	0.06	0.00	151.0	62.5	229.4		229	493.8	27.0	1.3
88	G M S D #1	1 73	8.3		699	368	367	0.00	0.03	90.6	34.5	75.0	1.1		400.0	18.2	3.1
89	G M S D #2	1 73	8.1		398	256	255	0.02	0.01	44.8	34.9	19.0	0.9		84.4	14.5	2.7
90	G M S D #5	1 73	8.4		462	337	336	0.10	0.00	60.1	45.4	27.0	0.9		122.0	9.3	3.1
91	G M S D #6	1 73	8.4		309	239	238	0.10	0.00	48.1	28.9	21.0	0.9		37.2	6.7	3.1

NOTE--ALL ZEROS (00.00) - ANALYSED, NOT DETECTED; ALL NINES (99.99) - COULD NOT BE STORED, REFER TO ANALYSIS

V I R G I N I A   S T A T E   W A T E R   C O N T R O L   B O A R D

B U R E A U   O F   S U R V E I L L A N C E   A N D   F I E L D   S T U D I E S

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR PRINCE WILLIAM

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SWCB NO	OWNER AND/OR PLACE	DATE SAMP	PH	SPEC COND	T-DIS SOLID	HARDNESS TOTAL	CA,MG	FE	MN	CA	MG	NA	K	HCO3	SO4	CL	NO3
92	G M S D #7	1 73	7.9		655	344	343	0.18	0.01	80.1	34.9	50.5	1.1		300.0	13.5	3.5
92	G M S D #7	9 72	8.0		657	388	386	0.10	0.02	110.0	27.2	49.0	1.1		300.0	13.0	0.0
93	G M S D #4	1 73	8.1		765	356	355	0.07	0.01	81.7	36.9	80.0	1.0		400.0	13.5	0.0
121	CARL HENGEN	5 74	7.3	1213			613	0.00		180.0	40.0	90.0	0.3			150.0	117.0
122	GREENVILLE FARMS	5 74	7.5	202			89	0.00		26.0	5.9	50.0	0.1			4.0	7.5
123	SHIFLETT	5 74	6.1	50			27	0.10		10.0	0.7	5.0	0.0			1.0	1.8
124	GRANDMA'S ATTIC	5 74	6.8	185			103	2.50		39.0	1.6	8.0	9.0			6.0	0.4
125	F E MARTIN	5 74	7.8	300			171	0.00		52.0	10.1	13.0	14.1			1.0	2.7
126	J E HOWARD	5 74	7.8	410			162	0.00		62.0	1.9	18.0	0.8			15.0	4.0
127	S PUFFENDARGER	6 74	6.2	100			48	0.30		11.0	5.2	8.3	4.1			8.0	9.3
128	D SAVAGE	6 74	6.9	280			139	0.10		41.0	9.0	11.8	2.5			11.0	4.0
129	BRADFORD LOWE	6 74	6.8	215			102	0.10		39.0	1.3	8.8	4.4			7.0	1.3
130	H F CHANDLER	7 74	7.5	440			253	0.10		62.0	24.0	19.0	0.1			11.0	26.6
131	J CAPARALETTI	7 74	7.6	800			451	0.10		87.0	57.0	16.0	1.2			42.0	97.5
132	G MCMILLAN	7 74	7.5	450			266	0.10		69.0	23.0	16.5	0.6			5.0	2.2
133	C LYONS	7 74	7.3	600			284	0.10		71.0	26.0	19.0	0.6			25.0	53.2
134	G CARROLL	7 74	7.4	420			243	0.10		69.0	17.4	18.5	0.5			9.0	4.0
135	M L DU CHARME	8 74	7.5				531	3.60		175.0	23.0	36.0	0.8			9.0	0.0
139	A SCARDINA	12 74	7.4	270	192		174	0.00		66.0	2.4	3.2	2.3		6.5	4.0	0.0
140	WM HAMPTON	12 74	6.7	191	167		94	0.50		24.0	8.3	4.6	5.7		11.4	15.0	3.1
142	H G SIMPSON	1 75	7.6	490	406		207	0.10		72.0	6.8	34.0	0.1		106.0	13.0	2.7
143	EARL HEDRICK	1 75	7.2	500	399		3	0.10		1.0	0.2	172.0	0.1		48.0	14.0	1.3
144	ERNEST RHYMER	1 75	7.4	390	280		220	0.00		58.0	18.4	17.5	0.6		6.0	2.0	2.7
152	WM EARHEART	3 75	6.5	170	131		130	0.20		41.0	6.8	6.3	1.6		9.6	8.0	0.9

NOTE--ALL ZEROS (00.00) - ANALYSED, NOT DETECTED; ALL NINES (99.99) - COULD NOT BE STORED, REFER TO ANALYSIS

VIRGINIA STATE WATER CONTROL BOARD

BUREAU OF SURVEILLANCE AND FIELD STUDIES

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR PRINCE WILLIAM

****

SWCB NO	OWNER AND/OR PLACE	DATE SAMP	PH	SPEC COND	T-DIS SOLID	HARDNESS TOTAL	HARDNESS CA,MG	FE	MN	CA	MG	NA	K	HCO3	SO4	CL	NO3
154	J CARR	3 75	6.5	130	111		87	0.10		27.0	4.8	8.8	0.8		5.6	3.0	0.9
155	T A KELLY	3 75	6.3	580	79		30	0.00		8.0	2.5	6.1	0.2		2.1	1.0	4.4
156	E HARTMAN	3 75	6.0	552	68		32	0.00		12.0	0.6	4.8	0.5		0.6	1.0	0.0
157	J A BAILEY	3 75	6.1	990	137		50	0.00		17.0	2.0	9.9	0.5		1.0	10.0	1.3
164	GAINSVILLE ACRES	7 74	7.8	260	193	142	144	0.04	0.00	42.0	9.6	9.0	1.3		9.5	7.5	2.2
166	MANASSAS	7 74	7.1	220	183	82	92	0.16	0.10	30.5	3.7	19.7	1.3		13.8	28.0	22.2
170	MANASSAS	7 74	8.2	325	257	12	229	0.05	0.00	70.4	12.9	11.5	1.2		13.2	10.2	0.4
171	MR ROBISONN	11 75	7.4	410	269		205	0.00		66.0	10.0	6.0	0.1		31.1	5.0	0.4
172	CHARLES POWERS	11 75	7.0	400	254		188	0.00		60.0	9.5	2.0	0.1		23.0	7.0	1.3
173	GEIL	11 75	7.2	290	197		145	0.00		40.0	11.0	3.0	0.0		2000.2	4.0	0.9
174	RICHARD BURATTI	11 75	6.8	300	287		9	0.00		3.0	0.4	103.0	4.3		24.3	19.0	16.4
176	G M S D SINCLAIR WELL	1 73	8.0		971	536	535	0.02	0.02	128.2	52.4	59.5	1.6		640.0	21.3	2.2
177	ST BENEDICT CONVENT	11 73	7.9	680	546	270	269	0.04	0.01	71.2	22.2	26.0	1.2		225.0	14.0	6.2
178	LAKEVIEW ESTATES	7 74	8.0	380	249	203	204	0.04	0.00	48.0	20.6	14.5	0.9		5.1	23.5	4.0
178	LAKEVIEW ESTATES	7 74	8.0	357	260	203	193	0.02	0.00	47.5	18.2	15.2	1.0		7.2	22.0	4.0
179	BULL RUN MT ESTATES #1	10 73	6.5	29	26	10	10	0.00	0.00	2.4	1.0	2.0	1.7		0.0	1.0	0.0
180	BULL RUN MT ESTATES #2	10 73	6.6	24	7	10	7	0.00	0.00	1.4	0.9	1.9	1.5		0.0	1.5	0.0
181	BULL RUN MT ESTATES #3	10 73	6.9	54	10	24	22	0.25	0.01	4.1	2.8	3.1	1.7		0.0	1.0	0.0
182	BULL RUN MT ESTATES #4	10 73	6.7	40	31	18	16	0.06	0.09	4.1	1.5	1.7	1.7		0.0	1.5	0.0
183	BULL RUN MT ESTATES #5	10 73	8.1	84	50	40	38	0.00	0.01	9.0	4.0	4.0	1.9		1.4	1.0	0.0
187	STUART ADAMS	4 75	6.8	88	73		15	0.40		5.0	0.7	16.7	0.6		1.6	3.0	3.5
191	CHAS R PARKER	6 75	6.8	110	77		65	0.00		22.0	2.6	3.1	0.8		1.1	2.0	0.9
192	JAMES A BAILEY	6 75	6.7	260	258		107	1.40		35.0	4.8	17.0	5.1		1.6	53.0	2.2
193	WILLIAM L ATTKISSON	6 75	6.2	51	131		16	0.00		5.0	1.0	5.5	0.1		0.3	2.0	2.2

NOTE--ALL ZEROS (00.00) - ANALYSED, NOT DETECTED; ALL NINES (99.99) - COULD NOT BE STORED, REFER TO ANALYSIS

V I R G I N I A   S T A T E   W A T E R   C O N T R O L   B O A R D

B U R E A U   O F   S U R V E I L L A N C E   A N D   F I E L D   S T U D I E S

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR PRINCE WILLIAM

****

SWCB NO	OWNER AND/OR PLACE	DATE SAMP	PH	SPEC COND	T-DIS SOLID	HARDNESS TOTAL CA,MG	FE	MN	CA	MG	NA	K	HCO3	SO4	CL	NO3
194	RICHARD M SMITH	6 75	6.8	90	123	40	0.00		11.0	3.2	6.3	0.8		5.8	4.0	10.6
195	TALLANT	6 75	6.7	35	77	14	0.00		4.0	1.0	4.1	0.5		0.7	1.0	2.7
196	ROBERT HILEMAN JR	8 75	7.5	142	148	66	2.10	0.00	20.0	4.1	8.0	2.1		6.4	2.0	0.0
197	ROBERT DELACHEVROTIERE	8 75	6.6	84	120	36	0.10	0.00	12.0	1.6	1.0	1.6		3.4	2.0	0.4

NOTE--ALL ZEROS (00.00) - ANALYSED, NOT DETECTED; ALL NINES (99.99) - COULD NOT BE STORED, REFER TO ANALYSIS

APPENDIX B

SUMMARY OF WATER WELL DATA FOR PRINCE WILLIAM COUNTY

The computer printout on the following pages lists basic well data for wells in Prince William County. This printout is updated frequently to include information from new Water Well Completion Reports which are constantly being submitted by water well drillers. The information under the heading "Aquifer" may be cross-referenced with Table 2, Chapter III.

VIRGINIA STATE WATER CONTROL BOARD

BUREAU OF WATER CONTROL MANAGEMENT

SUMMARY OF WATER WELL DATA FOR PRINCE WILLIAM COUNTY

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THE FOLLOWING LIST OF WELL DATA SUMMARIZES BASIC DATA OBTAINED FROM WATER WELL COMPLETION REPORTS WHICH ARE ON PERMANENT FILE IN THE OFFICES OF THE VIRGINIA STATE WATER CONTROL BOARD. ADDITIONAL INFORMATION FOR MANY OF THE WELLS IS AVAILABLE AND CAN BE OBTAINED BY CONTACTING THE APPROPRIATE REGIONAL OFFICE OR THE BUREAU OF WATER CONTROL MANAGEMENT AT THE AGENCY HEADQUARTERS IN RICHMOND.

************ EXPLANATION OF PARAMETERS ************

SWCB NO: STATE WATER CONTROL BOARD NUMBER - A SEQUENTIAL NUMBERING SYSTEM USED WITHIN A COUNTY; WHEN REFERRING TO A SPECIFIC WELL USE THIS NUMBER

OWNER AND/OR PLACE: IDENTIFIES ORIGINAL OR CURRENT WELL OWNER AND/OR LOCATION OF WELL

YEAR COMP: YEAR IN WHICH WELL CONSTRUCTION WAS COMPLETED

LOG: TYPE OF LOG ON FILE FOR WELL; D = DRILLERS, E = ELECTRIC, G = GEOLOGIC

ELEV: ELEVATION - MEASURED IN FEET ABOVE MEAN SEA LEVEL

TOTAL DEPTH: TOTAL DEPTH DRILLED, IN FEET, WITH RESPECT TO LAND SURFACE

BEDROCK: DEPTH TO BEDROCK, IN FEET, WITH RESPECT TO LAND SURFACE

CASING: MAXIMUM AND MINIMUM DIAMETER OF CASING, IN INCHES, USED IN WELL

DEVEL ZONE: DEVELOPED ZONE - INTERVALS, IN FEET, WHERE AQUIFERS TAPPED AND/OR SCREENED

AQUIFER: WATER-BEARING UNIT; ABBREVIATIONS USED INDICATE GEOLOGIC AGE OF UNIT AND ARE CONSISTENT WITH "GEOLOGIC MAP OF VIRGINIA" (DIVISION OF MINERAL RESOURCES - 1963)

STATIC LEVEL: DEPTH, IN FEET, TO WATER WITH RESPECT TO LAND SURFACE; MEASUREMENTS TAKEN WHEN WELL IS NOT PUMPED AND ARE GENERALLY THOSE RECORDED ON COMPLETION DATE

YIELD: REPORTED OR MEASURED PRODUCTION, IN GALLONS PER MINUTE

DRAWDOWN: DIFFERENCE, IN FEET, BETWEEN STATIC LEVEL AND PUMPING LEVEL; I.E., REPORTED OR MEASURED DROP, IN FEET, IN WATER LEVEL DUE TO PUMPING

SPEC CAPAC: SPECIFIC CAPACITY - YIELD PER UNIT OF DRAWDOWN EXPRESSED AS GALLONS PER MINUTE PER FOOT OF DRAWDOWN

HRS: HOURS - DURATION OF PUMP TEST, IN HOURS, FROM WHICH THE PRECEDING THREE ITEMS WERE DERIVED

USE: USE OF WATER OR WELL UNDER CONSIDERATION; DOM = DOMESTIC, PUB = PUBLIC, GOV = GOVERNMENT, IND = INDUSTRIAL, COM = COMMERCIAL, INS = INSTITUTIONAL, ABD = ABANDONED, DST = DESTROYED, IRR = IRRIGATION, RCH = ARTIFICIAL RECHARGE

V I R G I N I A   S T A T E   W A T E R   C O N T R O L   B O A R D

B U R E A U   O F   W A T E R   C O N T R O L   M A N A G E M E N T

SUMMARY OF WATER WELL DATA FOR PRINCE WILLIAM COUNTY

****

SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX	CASING MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
1	QUANTICO MARINE BASE	17	D		345		10	8	310	336	LK		70				GOV
2	I-95 WEIGHING STATION	63	C		372	57						55	5	158	.03	3	GOV
3	SYDNOR, TRIANGLE	61	D		327	322						130	9			6	DST
4	SYDNOR, TRIANGLE	60	D		352	350											DST
5	SYDNOR, TRIANGLE	59	E		282												DST
6	DUMFRIES-TRIANGLE S D TRIANGLE	59	D		210	26	6					6	43	161	.26	9	PUB
7	VEPCO	66	D		359		6	4				62					IND
8	VEPCO		D	29	327												DST
9	VEPCO	48	D	61	596	553	10	4	305	355	LK		101			168	IND
10	VEPCO		D	36	167												IND
11	PR WILLIAM FOREST PK	68	D G		200	9	6				V	5	3	195	.01	1	GOV
12	PR WILLIAM FOREST PK	68	D G		200	105	6				V	27	3	121	.02	8	GOV
13	PR WILLIAM FOREST PK	68	D G		100	38	6				V	8	16	56	.28	8	GOV
14	PR WILLIAM FOREST PK	68	D G		100	45	6				MSCH	8	10	57	.17	4	GOV
15	PR WILLIAM FOREST PK	68	D G		90	35					MSCH						DST
16	EVERGREEN FARM DEV	69	D	445	715	40	6				TRNS	20	36	185	.19	24	PUB
17	GAINSVILLE ESSO STA	67	D		204	10	6				TRNS	30	30				COM
18	MANASSAS AIR FORCE B	64	D		295	181	6				GR	11	22	249	.08	48	GOV
19	MANASSAS AIR FORCE D	59	D		234	114	6				GR	24	35			48	GOV
20	GEORGE C LANDUTH	61	D		230	165	4		65	80			1			6	DST
21	GEORGE C LANDUTH	61	D		282	170	8	5				147	8			3	DOM
22	USGS OBSERVATION WELL	69		100	200		10	6	156	176	LK	22	150			8	GOV
23	USGS OBSERVATION WELL	69		100	115		6		95	105	LK		152				GOV
24	USGS TEST WELL	68	CEG	400	345	10	7				TRNS	10	20			1	GOV
25	USGS TEST WELL	68	D G		165		7				TRNS	40	13				GOV
26	USGS TEST WELL	68	D G	570	250	90	10	7			CPCC		8				GOV
27	A T & T	69	D		410	30	6				TRNS	72	32	4	8.00	12	COM
28	E H WILSON	48	D		152	25	6				TRNS	25	5	127	.03	2	COM
29	OBSERVATION WELL #29 U S ARMY	50	D	5	174	151	10	6			LK	3	38	126	.30	4	GOV
30	C W ALPAUGH	50	D		111	22	6				GR	14	10	89	.11		DOM
31	WYACONDA	55	D		323	18	8					60	110	202	.54	12	DOM
32	QUANTICO MARINE BASE	49	D		373	373	18	10	223	273	LK	151	150	47	3.19	9	GOV
33	QUANTICO MARINE BASE	49	D		365	340	18	6	227	232	LK		330			7	GOV
34	QUANTICO MARINE BASE		D		361	361											GOV
35	RESEARCH HOMES INC OCCOQUAN FOREST	69			400		6				GR	40	92				PUB
36	QUANTICO MARINE BASE		D		555	505											GOV
37	QUANTICO DEF HOUSING	42	D		295	291											PUB
38	MANASSAS SAN DIST	69	D		555	3	8				TRNS	90	300	202	1.48	24	PUB
39	LOMOND WATER CORP	64	D		577	85	6						60	517	.11	24	PUB
40	LOMOND WATER CORP	64	D		705	28	6						110			24	PUB
41	VA PACKING CO	47			125		4										IND

VIRGINIA STATE WATER CONTROL BOARD

BUREAU OF WATER CONTROL MANAGEMENT

SUMMARY OF WATER WELL DATA FOR PRINCE WILLIAM COUNTY

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SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX	CASING MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
42	LOMOND WATER CORP	64	D		482	30	6					11	60	471	.12	72	PUB
43	I J BREEDEN INC YORKSHIRE ACRES	46	D		209	24	6				TRNS	45	20			4	PUB
44	I J BREEDEN INC YORKSHIRE ACRES	46	D		205	80	8				TRNS	40	18			12	PUB
45	WOODBRIDGE CLAY PRODU	58		225	650							150					PUB
46	I J BREEDEN INC YORKSHIRE ACRES	52	D		203	85	6				TRNS	35	28	39	.71	24	PUB
47	I J BREEDEN INC YORKSHIRE ACRES	53	D		205	23	8				TRNS	65	20	45	.44	8	PUB
48	I J BREEDEN INC YORKSHIRE ACRES	55	D		510	7	8				TRNS	105	100	68	1.47	24	PUB
49	I J BREEDEN INC YORKSHIRE ACRES	56	D		805	42	8				TRNS	105	80	165	.48	8	PUB
50	I J BREEDEN INC YORKSHIRE ACRES	36			127												PUB
51	I J BREEDEN INC YORKSHIRE ACRES		D		181	10					TRNS	30	18			4	PUB
52	I J BREEDEN INC YORKSHIRE ACRES		D		207	20						40	18			4	PUB
53	I J BREEDEN INC YORKSHIRE ACRES				135		6						20	85	.23		ABD
54	I J BREEDEN INC YORKSHIRE ACRES	59	D	200	254	7					TRNS		50	6	8.33	12	PUB
55	FEATHERSTONE WASTE DISPOSAL SITE	91	E	30	240												IND
56	I J BREEDEN INC YORKSHIRE ACRES	61	D		417	10	8				TRNS	55	50	5	10.00	24	PUB
57	I J BREEDEN INC YORKSHIRE ACRES	63			500		8										PUB
58	TOWN OF MANASSAS	53	D		400	8	8				TRNS	65	200	235	.85	16	PUB
59	TOWN OF MANASSAS	50	D		485	3	8				TRNS	75	66			24	PUB
60	TOWN OF MANASSAS	68	D G		800	4	8				TRNS	133	305	232	1.31	30	PUB
61	TOWN OF MANASSAS	65	D		1000	7	8				TRNS	72	132	233	.56		PUB
62	MANASSAS PARK INC	54	D		875	10	8				TRNS	60	175	340	.51	3	PUB
63	MANASSAS DEV CORP	55	D		807	10	8				TRNS	60	120			24	PUB
64	MANASSAS PARK	55	D		1000	8	8				TRNS	60	250	106	2.35	34	PUB
65					945		8					35	513				PUB
66		73	D		380	115	6				MSCH	100	18			1	PUB
	OAK RIDGE ESTATES																
67	FIELD UNIT #26	49			178	10	6				TRNS	10	10	172	.05	2	INS
68	U S ARMY	51	D		110		8	6			LK	23	73	10	7.30		GOV
69	U S ARMY	51	D		105		8	6			LK	4	30	72	.41	24	GOV
70	GAINSVILLE ELEM SCH	70	D		324	10	6				TRNS	35	20			4	INS

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SUMMARY OF WATER WELL DATA FOR PRINCE WILLIAM COUNTY

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SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX	CASING MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
71	VA DEPT OF HIGHWAYS	70	D		340	20	6				TRNS		60			2	GOV
72	SCHOOL BUS SHOP	70	D		349	10	6				TRNS		40				GOV
73	BULL RUN MT ESTATES#7	70	D	620	400	140	6				TR	34	75			6	PUB
74	BULL RUN MT ESTATES#6	70	D	590	830												PUB
75	FBI PHASE 2	70	D		550	50	8					20	150				GOV
76	FIELD UNIT #6	63			275	60	6				GRGN		4				GOV
77	FIELD UNIT #26	57			304		6				TRNS	28	45	16	2.81	2	GOV
78	OAK RIDGE ESTATES	71			325		6										GOV
79	LEAZER PUMP & WELL CO	71	D		340	30	6				TRNS	70	140	155	.90	6	IND
80	FOREST GROVE TRAILER	71	D	400	247	40	6				GR	18	29	215	.13	31	PUB
81	TOWN OF MANASSAS PARK	71	D		925	8	12				TRNS	61	554	197	2.81	24	PUB
82	VULCAN MATERIALS CO	72	D		310	10	6				TRNS	37	120	273	.43	4	IND
88	GR MANASSAS SAN DIST				900		6				TRNS						PUB
	LOCH LOMOND																
89	GR MANASSAS SAN DIST				305						TRNS						PUB
	LOCH LOMOND																
90	GR MANASSAS SAN DIST				300						TRNS						PUB
	LOCH LOMOND																
91	GR MANASSAS SAN DIST				397						TRNS						PUB
	LOCH LOMOND																
92	GR MANASSAS SAN DIST				832	8					TRNS						PUB
	SUNNYBROOK ESTATES																
93	GR MANASSAS SAN DIST				350						TRNS						PUB
	WESTGATE																
94	YORKSHIRE SAN DIST				343						TRNS						PUB
	YORKSHIRE ACRES																
95	YORKSHIRE SAN DIST				790						TRNS						PUB
	YORKSHIRE ACRES																
96	NOKESVILLE SCHOOL	56			250		6				TRNS	26					INS
97	COLES ELEM SCHOOL	16			250	38	6					31					INS
98	GAINSVILLE DIST SCH	70			290	25	6				TRNS						INS
99	GEORGE E TYLER SCHOOL	68			250	25	6				TRNS						INS
100	WASHINGTON-REID SCH	52			200		6										INS
101	ANTIOCH-MCC SCH	06			150		6				TRNS						INS
102	BRENTSVILLE DIST H S				350		6				TRNS						INS
103	WOODBINE SCHOOL				75		6				GR						INS
104	YORKSHIRE ELEM SCHOOL				250		6										INS
105	BUCK HALL PROPERTIES	69			400	30	6					40	92	275	.33	24	PUB
106	COLONIAL PIPELINE COP	64	E		185												IND
107	SOCONY MOBIL OIL CO	64	E		224						GR						GOV
108	FOREST GROVE TRAILER	71	D	400	267	55	6	5			GR	46	6			4	ABD
109	FOREST GROVE TRAILER	72		400	222		6				GR	31	45	206	.21	24	PUB
110	RESEARCH HOMES, INC.	73	D		400	40	6				GR	40	23	400	.05	25	PUB
111	U S GEOLOGICAL SURVEY	73	DEG		350	1	6				V	43	1				GOV

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SUMMARY OF WATER WELL DATA FOR PRINCE WILLIAM COUNTY

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SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX	CASING MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
112	U S GEOLOGICAL SURVEY	73	DEG		490	1	6				MSCH		7	92	.07	24	GOV
113	VIRGINIA TRACTOR CO.	73	D		325		6				TRNS	41	15	200	.07	3	IND
114	J.C. SCOTT AND ASSOC. WOODPINE WOODS SUB	73			90		6				GR	20	20			8	PUB
115	J.C. SCOTT AND ASSOC. WOODRINE WOODS SUB	73			105		6				GR	95	18			8	PUB
116	J.C. SCOTT AND ASSOC. WOODRINE WOODS SUB	73			305		6				GR	301	6			8	PUB
117	J.C. SCOTT AND ASSOC. WOODRINE WOODS SUB	73			145		6				GR	35	9			8	PUB
118	J.C. SCOTT AND ASSOC. WOODRINE WOODS SUB	73			145		6				GR	30	12			8	PUB
119	J.C. SCOTT AND ASSOC. WOODRINE WOODS SUB	73			225		6				GR	35	15			8	PUB
120	J C SCOTT & ASSOC. #1 WOODRINE WOODS SUB.	73			125		6				R	20	20			8	PUB
121	C HENGEN	70		360							TRNS						DOM
122	GREENVILLE FARM			360							TRNS						DOM
123	F SHIFLETT	60		390	36			36			GR						DOM
124	GRANDMA'S ATTIC			413	35			36			GR						COM
125	F F MARTIN			190	160						TRNS						DOM
126	J F HOWARD	64		302							TRNS						DOM
127	S PUFFENDARGER	58		265	24			30			GRGN	14					DOM
128	D SAVAGE			250	100						TRNS						DOM
129	R LOWF			400	200						GR						PUB
130	H F CHANDLER	73		185	105	20		6	1000		TRNS	2	17				DOM
131	J CAPORALETTI			315	100						TRD						DOM
132	G MCMILLAN	72		248	100			4			TRNS						DOM
133	C LYONS			305	180						TRD						DOM
134	G W CARROLL			330	110						TRNS						DOM
135	M L DU CHARME			215	80			4			TRNS						DOM
137	RONALD BOWERS			290	7						QAL						DOM
138	MR VIETMEYER			105							LK						DOM
139	ANTHONY SCARDINA	72		205	180		30				LK						DOM
140	WILLIAM HAMPTON			40	30						LK						DOM
141	ARTHUR WILLIAMS	74			57		24					28					DOM
142	H G SIMPSON JR			270							TRNS						DOM
143	EARL HEDRICK			245							TRNS						DOM
144	ERNEST RHYMER			310	100						TRNS						DOM
145	LAKE VIEW ESTATES	70		348	300						TRNS		100				PUB
146	LAKEVIEW ESTATES			330	300						TRNS		100				PUB
147	SOMMERS FARM SUB			275	500						TRD		2				PUB
148	SOMMERS FARM SUB			282	120						TRD		3				PUB
149	SOMMERS FARM SUB			278							TRD		3				PUB

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SUMMARY OF WATER WELL DATA FOR PRINCE WILLIAM COUNTY

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SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
150	GAINSVILLE UTILITIES	74		374	305		6			TRNS	30	25			8	PUB
151	EARL TAPP	75			64		24				31					DOM
152	WILLIAM L EARHEART	73		280	55					MSCH						DOM
153	REV HARRY OWENS			350	40					GRGN						DOM
154	JOSEPH CARR	71		280						TRNS						DOM
155	THOMAS A KELLEY			180						TRNS						DOM
156	ELIZABETH HARTMAN	73		382	46		24			MSCH		7				DOM
157	JAMES A BAILEY	55		372	89					MSCH		1				DOM
158	BOB FARMER/MARSH	75			148					TRNS		8				DOM
159	MICHAEL K COX	75			105		6			TRNS		10				DOM
160	ED DOFFIN	75			145		6			TRNS	50	12				DOM
161	JACK WEAVER	75			140		6			TRNS		15				DOM
162	NEIL OSBORN	75			200		6			TRNS		7				DOM
163	JACOB HARRIS	75			200		6			TRNS		30				DOM
164	GAINSVILLE ACRES #1															PUB
165	TOWN OF MANASSAS #1				531		8			TRNS						PUB
166	TOWN OF MANASSAS #4				290		6			TRNS						PUB
167	TOWN OF MANASSAS #5				452		8			TRNS						PUB
168	TOWN OF MANASSAS #7				250		8			TRNS						PUB
169	TOWN OF MANASSES #8				850					TRNS		200				PUB
170	TOWN OF MANASSAS #9				910					TRNS		176				PUB
171	MR ROBISONN	75		205	148	17	5			TRNS	51	20	50	.40	2	PUB
172	CHARLES POWERS	75		185			8			TRNS	168		82		10	PUB
173	GFIL	72		260	85		8			TRNS	168	300	87	3.44	12	PUB
174	RICHARD BURATTI	72		365	240					TRNS	164	275	80	3.43	12	PUB
175	MICHAEL ALVEY			348			8			TRNS	170	400	80	5.00	12	PUB
176	MANASSAS SAN DIST #8				555		8			TRNS		400				PUB
177	ST BENEDICT CONVENT				200		6			TRNS	40	36	20	1.80	1	INS
179	BULL RUN MT ESTATES#1			880	305		6			CW		7				PUB
180	BULL RUN MT ESTATES#2			860	327		8			CW		26				PUB
181	BULL RUN MT ESTATES#3			620	410		6			CW		6				PUB
182	BULL RUN MT ESTATES#4			1030	482		6			CW		4				PUB
183	BULL RUN MT ESTATES#5			570	805		6			CW		15				PUB
184	SHELL & ASSOCIATES #2	75	D		400	120	6			MSCH	44	9	52	.17	48	PUB
185	YORKSHIRE SANITARY DT	75	D		400		8			TRNS	50	205	310	.66	48	PUB
186	SHELL & ASSOCIATES #1	75	D		250		6			MSCH	47	36	51	.70	48	PUB
187	STUART ADAMS			380	150		6			GR						DOM
188	JOF HILL LOT #60				370	290				MSCH		1				DOM
	RIDGEWOOD ESTATES															
188	JIMMY KOUACKS LOT 120									MSCH						DOM
189	RIDGEWOOD ESTATES				145							5				DOM
190	U S GEOLOGICAL SURVEY	75	D		305		6				69	12	71	.16	24	GOV
191	CHAS R PARKER	73			330					MSCH						DOM
192	JAMES A BAILEY	75		372	48					MSCH	17					DOM
193	WILLIAM L ATTKISSON	68		385	60					MSCH						DOM

VIRGINIA STATE WATER CONTROL BOARD

BUREAU OF WATER CONTROL MANAGEMENT

SUMMARY OF WATER WELL DATA FOR PRINCE WILLIAM COUNTY

SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX	CASING MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
194	RICHARD M SMITH			430							TRNS						DOM
195	TALLANT			455	220						TRNS						DOM
196	ROBERT HILEMAN JR			350			6				MSCH						DOM
197	ROBERT DELA CHEVROTIE			355			36				MSCH						DOM
198	US GEOLOGICAL SURVEY	75	D		250	42								250			DOM
199	US GEOLOGICAL SURVEY	75	D		192	143	6						2	192	.01	4	PUB
200	D L TYLEE	75	D		380	250	6					60	33	230	.14	48	COM
201	D L TYLEE	75	D		320	160	6					80	22	240	.09	48	COM
202	BIG BOB MOBILE HOMES	75		405	78		24					35					DOM
203	BIG BOB MOBILE HOMES	75		405	75		24					32					DOM
204	HARVEY CONSTRUCTION	75			145		6						8				DOM
205	HARVEY CONSTRUCTION	76			188		6						4				DOM
206	DAVID N SINES LOT 53	74			121		6						15				DOM
207	ROGER BURKE	75			125		6						7				DOM
208	MANASSAS SANITARY	76	D		700	65		8					106	357	.29	48	PUB

GLOSSARY OF TERMS

ALLUVIUM: A general term for sediments deposited during recent geologic time by a stream or river.

ANTICLINE: An arch or fold in rock strate that is convex upward.

AQUICLUDE: A geologic formation which is not permeable enough to furnish an appreciable supply of water to a well or spring.

AQUIFER: A geologic formation, group of formations, or part of a formation capable of supplying water to wells and springs in usable quantities. An aquifer is unconfined (water table) if the surface of the water table is at atmospheric pressure or confined (artesian) if the upper surface of the groundwater is under pressure in excess of atmospheric pressure due to the presence of an overlying, confining formation (aquiclude).

BEDDING PLANE: A plane surface separating layers in stratified rocks.

BEDROCK: A solid rock exposed at the surface or overlain by unconsolidated materials.

CATCHMENT: The area comprising the actual water intake area for aquifer recharge and all areas that contribute surface water to the intake area.

CLASTIC:	Consisting of fragments of rocks or of organic structures that have been transported mechanically to a place of deposition. Sandstone and shale are the most common clastics.
COLLUVIUM:	Loose soil material or rock fragments deposited by the action of gravity, usually at the base of a slope or cliff.
DIP:	The angle at which a rock bed is inclined from the horizontal.
DRAWDOWN:	The measured difference between static level and pumping level in a well; i.e. the drop in the water level due to pumping.
EVAPOTRANSPIRATION:	The two processes, evaporation and transpiration, by which water returns to the atmosphere; transpiration is the discharge of water vapor by plants.
FAULT:	A fracture or fracture zone along which there has been movement of two rock masses relative to one another parallel to the fracture. The movement may be a few inches or many miles, horizontal or vertical.
FLOOD PLAIN:	The strip of relatively smooth land adjacent to a river channel and built of alluvium carried by the river during floods. The flood plain is covered by water when the river is in flood.

FOLD:	A curve or bend in rock strata.
FORMATION:	An assemblage of rock masses grouped together into a unit that is convenient for description or mapping.
FRACTURE:	Breaks in rocks due to intense folding or faulting.
GPD:	Gallons per day.
GPM:	Gallons per minute.
GROUNDWATER:	Water occurring in the zone of saturation beneath the land surface.
HYDROLOGY:	The science that relates to the water of the earth.
IGNEOUS:	Rocks or minerals that solidified from molten rock (magma).
INTRUSIVE:	Refers to igneous rocks which have penetrated into or between older rocks while molten but have solidified before reaching the surface.
JOINT:	A fracture in rock along which no appreciable movement has occurred.
LITHOLOGY:	The composition and structure of rock.
METAMORPHIC:	Refers to any rocks derived from pre-existing rocks in response to pronounced changes of temperature, pressure and chemical environment.
MGD:	Million gallons per day.
PERCOLATION:	Movement of water through the interstices of rocks or soils except movement through large openings such as solution channels.

PERMEABILITY: A measure of ability of a rock, sediment or soil to transmit water.

POROSITY: The property of a rock, soil, or other material of containing spaces or voids; the ratio of the void space to the total volume in a given sample of rock or soil, expressed as a percentage.

POTENTIOMETRIC SURFACE: The level to which water will rise in a cased well; describes the water table surface or the artesian surface depending on the confining conditions of the aquifer.

PUBLIC SUPPLY: As defined by the Virginia Department of Health, a water system serving 25 individuals or more than 15 residential connections.

PUMPING LEVEL: Depth to water in a well when the well is being pumped.

RECHARGE: The addition of water to an aquifer by natural infiltration or artificial means.

RUNOFF: That part of precipitation that appears in streams; includes surface runoff and groundwater flow that reaches streams. Groundwater runoff is a measure of the change in groundwater storage and indicates rate of groundwater recharge.

SEDIMENT: Material borne and deposited by water, wind, or glaciers.

SEDIMENTARY: Refers to rocks formed from the consolidation of sediments.

STATIC LEVEL:	Depth to water in a well when the well is not being pumped.
SYNCLINE:	A fold in rock strata that is convex downward.
TERRACE:	A level or gently inclined surface bordering a stream which represents a former level of the stream. Terraces are composed of alluvium produced by renewed downcutting of the flood plain or valley floor by the stream.
UNCONSOLIDATED:	A sediment that is loosely arranged or whose particles are not cemented together.
WATER TABLE:	The upper surface of the zone of rock or soil saturated with ground water.

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VIRGINIA STATE WATER CONTROL BOARD
P. O. Box 11143, 2111 North Hamilton Street
Richmond, Virginia 23230
(804) 786-1411

1 **Southwestern Regional Office**
408 East Main Street
P. O. Box 976
Abingdon, VA 23210
(703) 628-5183

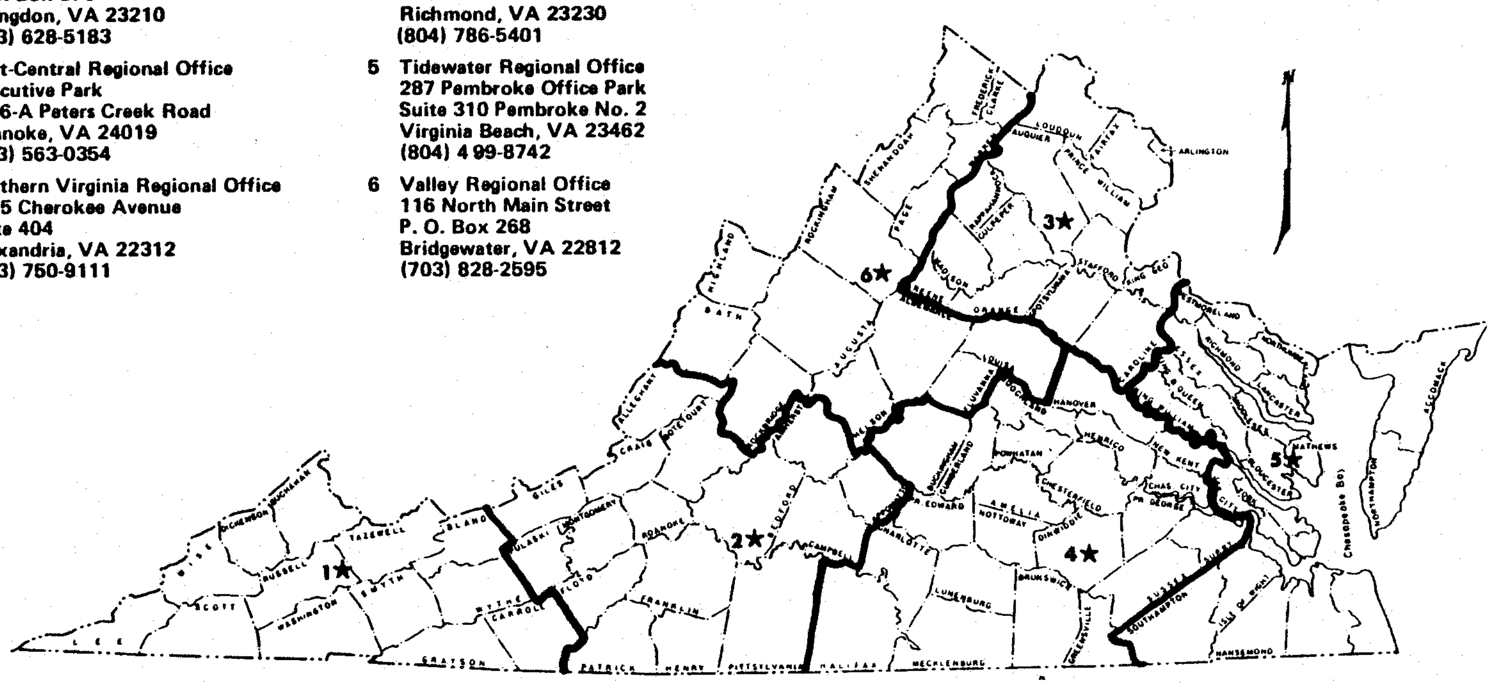
2 **West-Central Regional Office**
Executive Park
5306-A Peters Creek Road
Roanoke, VA 24019
(703) 563-0354

3 **Northern Virginia Regional Office**
5515 Cherokee Avenue
Suite 404
Alexandria, VA 22312
(703) 750-9111

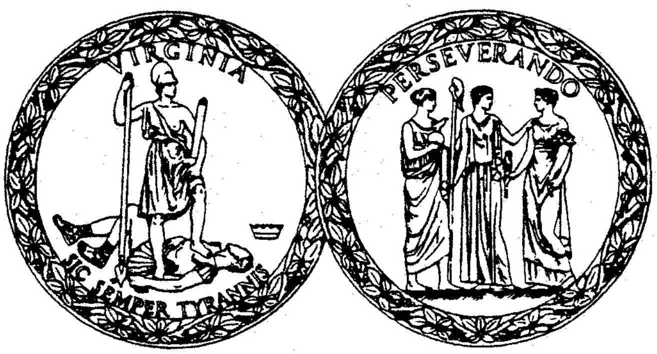
4 **Piedmont Regional Office**
4010 West Broad Street
P. O. Box 6616
Richmond, VA 23230
(804) 786-5401

5 **Tidewater Regional Office**
287 Pembroke Office Park
Suite 310 Pembroke No. 2
Virginia Beach, VA 23462
(804) 499-8742

6 **Valley Regional Office**
116 North Main Street
P. O. Box 268
Bridgewater, VA 22812
(703) 828-2595



Source: Virginia State Water Control Board — BWCM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