

Workplan with Recommendations for NAWQA Cycle II Activities -- Piedmont Aquifer System

by

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INTRODUCTION

In Cycle I of the National Water-Quality Assessment (NAWQA) Program's study of ground-water resources, the primary scale for analysis was the Study Unit, and a National Synthesis was conducted with data from the Study Units. Workplans for Cycle I were developed at the study-unit scale and approved at the national level. In Cycle II, the decision was made to ensure that ground-water studies not only met study unit and national needs, but also adequately assessed principal regional aquifers. To that end, the NAWQA Implementation Team (NIT) selected 16 principal regional aquifer systems for study in Cycle II. A coordinator was assigned to each system and tasked with 1) analyzing all study unit activities with regard to the system, and 2) determining whether or not the planned activities for Cycle II study-unit investigation are adequate to characterize the ground-water resources in the aquifer system.

The Piedmont aquifer system (PAS) was selected as 1 of the 16 principal regional aquifers nationwide. The PAS is 1 of 7 systems selected in the heavily populated Eastern States. This workplan describes an analysis of the previous NAWQA Cycle I studies and work planned for Cycle II with regard to the PAS. The analysis was to answer the following questions:

Have aquifers serving most of the population been sampled?

(1) Have aquifers been sampled where they are the predominant source of drinking supply?

(2) Have the predominant land uses been sampled?

- (3) Have the different rock types that represent the regional aquifer been sampled?
- (4) Have the most susceptible settings been characterized and verified by sampling?
- (5) Have the most vulnerable settings been characterized and verified by sampling?
- (6) Can the most important regional water-quality issues be addressed with the data?

Several definitions of concepts are important as they relate to the understanding of this workplan:

Stratification: Establishing a framework to study the PAS. In the case of this study, strata are based on bedrock geology.

Susceptibility: Implies that an aquifer has characteristics that would allow movement of contaminants through the aquifer materials (without consideration of whether or not those contaminants are present). According to Focazio and others (2002),

“The intrinsic susceptibility of a ground-water system depends on the aquifer properties (hydraulic conductivity, porosity, hydraulic gradients) and the associated sources of water and stresses for the system (recharge, interactions with surface water, travel through the unsaturated zone, and well discharge). In this way, the intrinsic susceptibility assessments do not target specific natural or anthropogenic sources of contamination but instead

consider only the physical factors affecting the flow of water to, and through, the ground-water resource.”

Vulnerability: Implies both susceptibility of an aquifer and presence of a contaminant. According to Focazio and others (2002),

“The vulnerability of a ground-water resource to contamination depends on intrinsic susceptibility as well as the locations and types of sources of naturally occurring and anthropogenic contamination, relative locations of wells, and the fate and transport of the contaminant(s). Water-resource decision makers are often faced with a choice of deciding whether to manage a resource based on knowledge of intrinsic susceptibility or to target more comprehensive and contaminant-specific assessments of vulnerability.”

Regional Assessment: The aquifers in the Piedmont tend to have relatively short, localized flowpaths rather than large regional flow patterns. In the PAS, the regional approach for water-quality assessment is a cumulative summary of ground-water studies in areas with similar rock types with local flow systems and local land uses.

Purpose of Workplan

The purpose of this workplan is to present a plan of study for assessing ground-water quality in Cycle II, including consideration of three primary characteristics that, based on current knowledge, might help account for differences or similarities in water quality at a regional scale among each stratum that makes up the proposed framework. The three primary characteristics are:

1. The physical framework of the principal aquifer;
2. A measure of the relative susceptibility of each stratum of the principal aquifer to contamination; and
3. A relative measure of the potential vulnerability of each stratum of the principal aquifer to contamination.

The aquifer coordinators are also tasked with reviewing Cycle II plans with respect to their aquifer system to:

1. Review Cycle I accomplishments to determine whether the extent of characterization of the aquifer system is adequate;
2. Recommend and prioritize updates to Cycle II plans, if necessary, to meet program goals;
3. Update water use information if available to allow proper prioritization of planned activities;
4. Compare and contrast recommendations with most recent NIT guidance.

PIEDMONT AQUIFERS

The PAS covers an area of about 78,000 square miles in the Piedmont Physiographic Province. The Piedmont is bounded on the south and east by the fall line and the Atlantic Coastal Plain. The Piedmont is bounded on the north and west by the Blue Ridge or the Ridge and Valley Physiographic Province and the New England Physiographic Province (Fenneman, 1938). The Piedmont is a transitional area between the unconsolidated sedimentary deposits in the coastal plain and the more mountainous regions inland, and is generally characterized by low, rolling hills. The Piedmont extends almost 1,000 miles from the southern part of New York State in the north to eastern Alabama in the south and has a maximum width of about 125 miles (Hunt, 1967) (fig.1).

The PAS includes parts of 9 NAWQA study units. These study units are Long Island and New Jersey Coastal Drainages (LINJ), Delaware River Basin (DELR), Lower Susquehanna River Basin (LSUS – now discontinued), Potomac River Basin and Delmarva Peninsula (PODL), Albemarle-Pamlico Drainages (ALBE), Santee Basin and Coastal Drainages (SANT), Georgia-Florida Coastal Plain (GAFL), Apalachicola-Chattahoochee-Flint River Basins (ACFB), and Mobile River and Tributaries (MOBL) (fig. 1, table 1). The PODL study unit is a Cycle II study that was made by combining the Cycle I Potomac River Basin (POTO) and the Delmarva Peninsula (DLMV) pilot studies, however; only the POTO study unit included any part of the PAS. Discussions of Cycle I activities will refer to the POTO study unit and discussions of Cycle II activities will refer to the PODL study unit.

Framework of the Piedmont Aquifer System

The Piedmont is topographically divided into uplands and lowlands. The uplands are primarily igneous and metamorphic rocks, hereafter termed crystalline aquifers, that are resistant to erosion and form the hilly terrain. The lowlands are made up of clastic sedimentary rocks and carbonate rocks. The Mesozoic Lowlands, hereafter termed siliciclastic aquifers, are made up of sandstones and shales and formed in a rift basin. The sandstones and shales are locally intruded by diabase. Limestone, dolomite, and marble of Paleozoic age form the carbonate aquifers. These three basic rock types (crystalline, siliciclastic, and carbonate) form the three basic units used to stratify the Piedmont. The crystalline rocks make up 92 percent of the land within the Piedmont (fig. 1). Siliciclastic and carbonate rocks are 7 and 1 percent of the Piedmont Physiographic Province, respectively. For the purposes of this report, the following abbreviations will be used to refer to these areas: Piedmont Crystalline, PCRY; Piedmont Carbonate, PCAR; Piedmont Siliciclastic, PSIL.

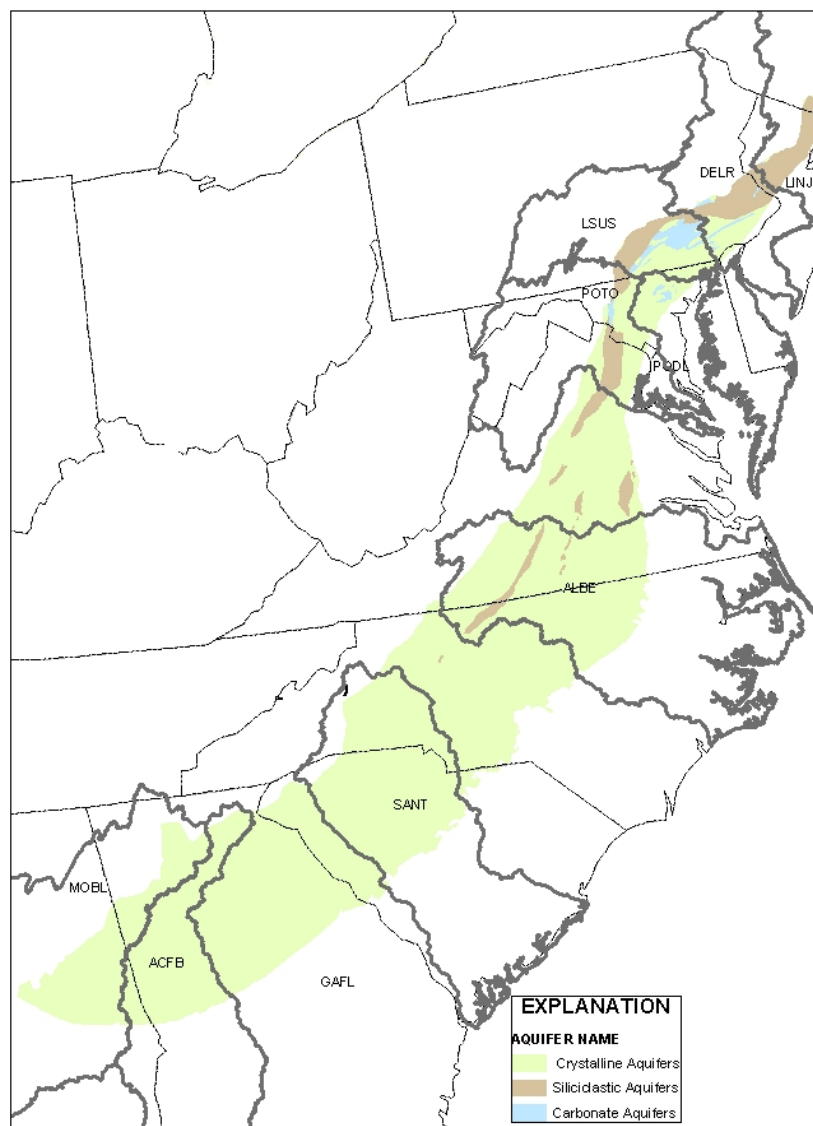
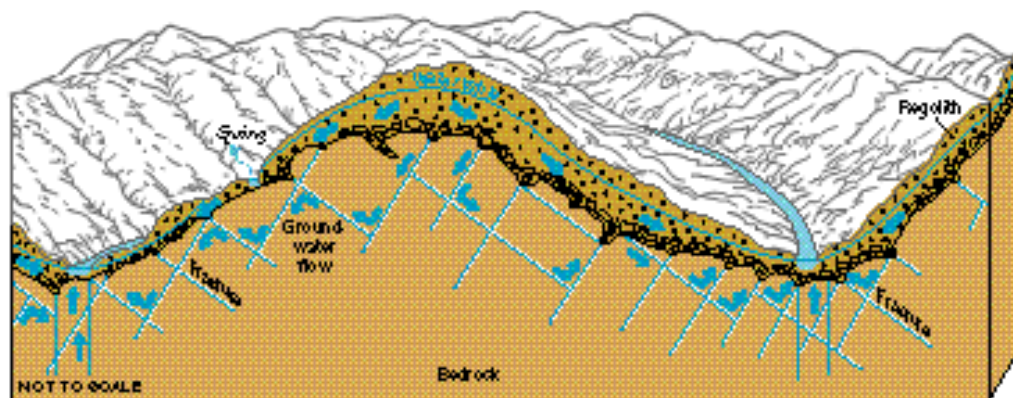


Figure 1. Piedmont aquifers and NAWQA study units: Long Island and New Jersey Coastal Drainages (LINJ), Delaware River Basin (DELR), Lower Susquehanna River Basin (LSUS), Potomac River Basin and Delmarva Peninsula (PODL), Albemarle-Pamlico Drainages (ALBE), Santee Basin and Coastal Drainages (SANT), Georgia-Florida Coastal Plain (GAFL), Apalachicola-Chattahoochee-Flint River Basins (ACFB), and Mobile River and Tributaries (MOBL).

Crystalline Aquifers

The PCRY aquifers are made up of igneous and metamorphic bedrock predominantly composed of silicate minerals. These rocks range from coarse-grained gneisses and schists to fine-grained phyllites and metamorphosed volcanic rocks. The primary porosity of these formations is extremely small, and most ground water flow is in fractures in the bedrock (Trapp and Horn, 1997). A covering of weathered bedrock referred to as regolith overlies most of the PCRY aquifers and, because it commonly has a larger porosity than the crystalline bedrock, it is often an important factor in storage and movement of ground water (fig.2). Bedrock that has weathered in place but maintains the structure of the original rock is referred to as saprolite. Saprolite develops in warm, humid conditions and therefore tends to be more significant in the southern part of the Piedmont.



Modified from Heath, R.C., 1980, Basic elements of ground-water hydrology with reference to conditions in North Carolina: U.S. Geological Survey Water-Resources Investigations Open-File Report 80-44, 86 p.

Figure 2. Ground water movement in crystalline aquifers (From Trapp and Horn, 1997).

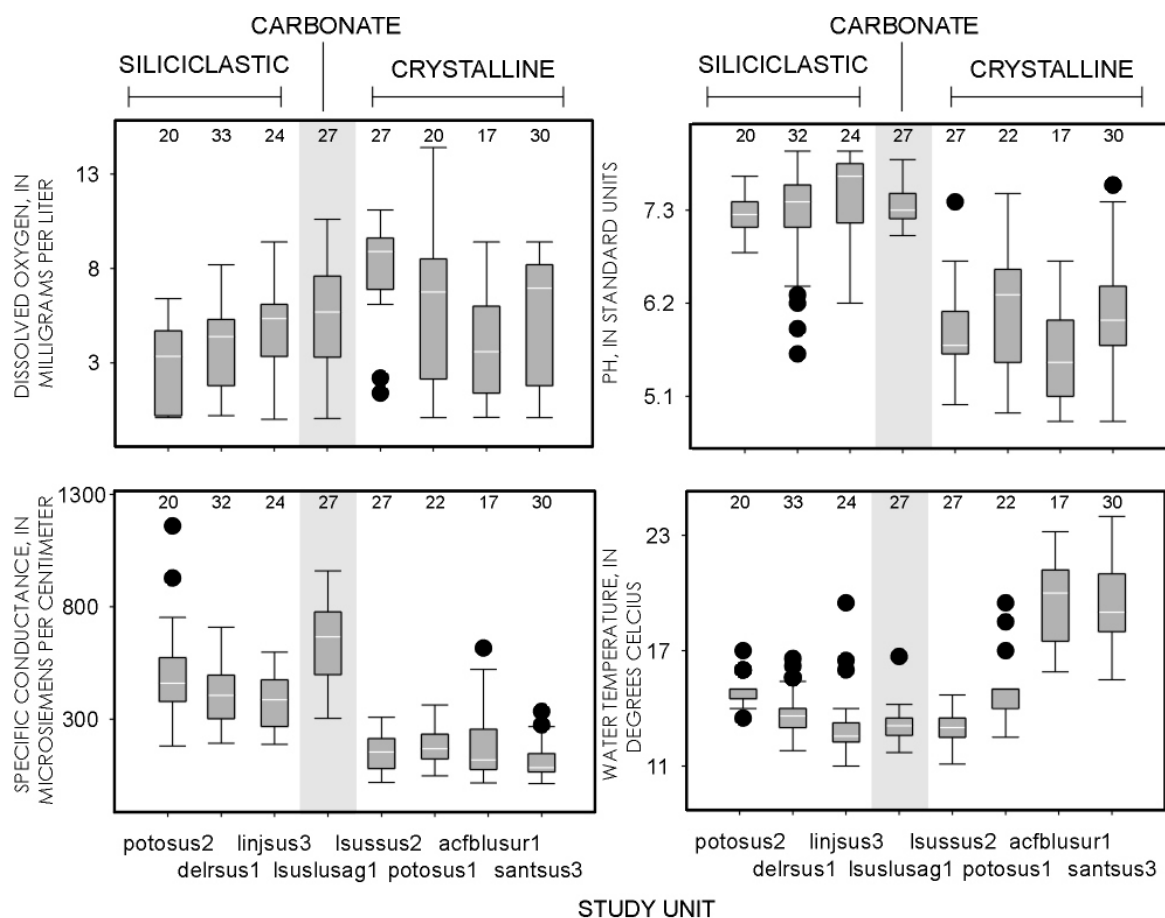
The PCRY aquifers are dominated by silicate weathering (Risser and Siwiec, 1996), which leads to lower specific conductance and low concentrations of dissolved solids, poorly buffered conditions with low pH, and low bicarbonate alkalinity (fig. 3 and fig. 4) The pattern of silica concentrations in results from Cycle I sampling differs from the other major ions. Silica concentrations are lowest in PCAR aquifers and higher in both PSIL and PCRY aquifers (fig. 4).

Population and Water Use – The population of the area underlain by the PCRY aquifers is approximately 16 million (all population and water use statistics cited are prorated based on percentage of county within the study area for border counties). Population and land use are closely related. The population density (fig. 5) follows an expected pattern, with the most densely populated areas being in the vicinity of New York, Philadelphia, Baltimore, Washington, D.C., and Atlanta. These cities are generally not in the Piedmont, however the rapidly growing counties around these cities are located in the Piedmont. Other cities in or near the fringe of the Piedmont include Richmond, Virginia, the Winston-Salem, Charlotte, and Raleigh-Durham areas of North Carolina, as well as Greenville and Columbia, South Carolina. The overall population density of the PCRY aquifers area is the lowest of all of the areas, with about 200 persons per square mile.

Water used for public supply is primarily from surface water in the PCRY area, with only about 1 million residents (6 percent) relying on ground water for public supply. An additional 3.7 million (22 percent) rely on ground water for domestic self -supply. Overall, about 4.7 million people, or 28 percent of the

population, rely on ground water in the PCRY aquifers. The total withdrawals from the PCRY aquifers are approximately 451 million gallons per day. The PCRY area has the lowest percentage of the population relying on ground water for public supply of the 3 aquifers in the Piedmont; however, an analysis of the percentage of the population relying on ground water shows the converse is true. Those rural areas that have a low population and low consumption rate for ground water typically are dependent on ground water for a high percentage of the water use (fig.6). Ground water from public water supply dominates the usage statistics in urban areas and ground water from domestic self-supply dominates the usage in rural areas. Therefore, although ground water use is greatest in the more urban, northeastern, part of the Piedmont, ground water is an essential resource for the more rural parts of the Piedmont as well.

Land Use – Land use in the area underlain by the PCRY aquifers is variable. The region is characterized by a highly populated area (predominantly agricultural and urban land uses) in the northeast, with more rural and forested land use to the south (fig 7). Generally, the population density increases from rural forested to rural agricultural to suburban to urban. The most intense agricultural activity is in Pennsylvania, Maryland and Virginia, although agricultural activity is important throughout the Piedmont. The southern Piedmont includes more evergreen forests than the northern Piedmont.



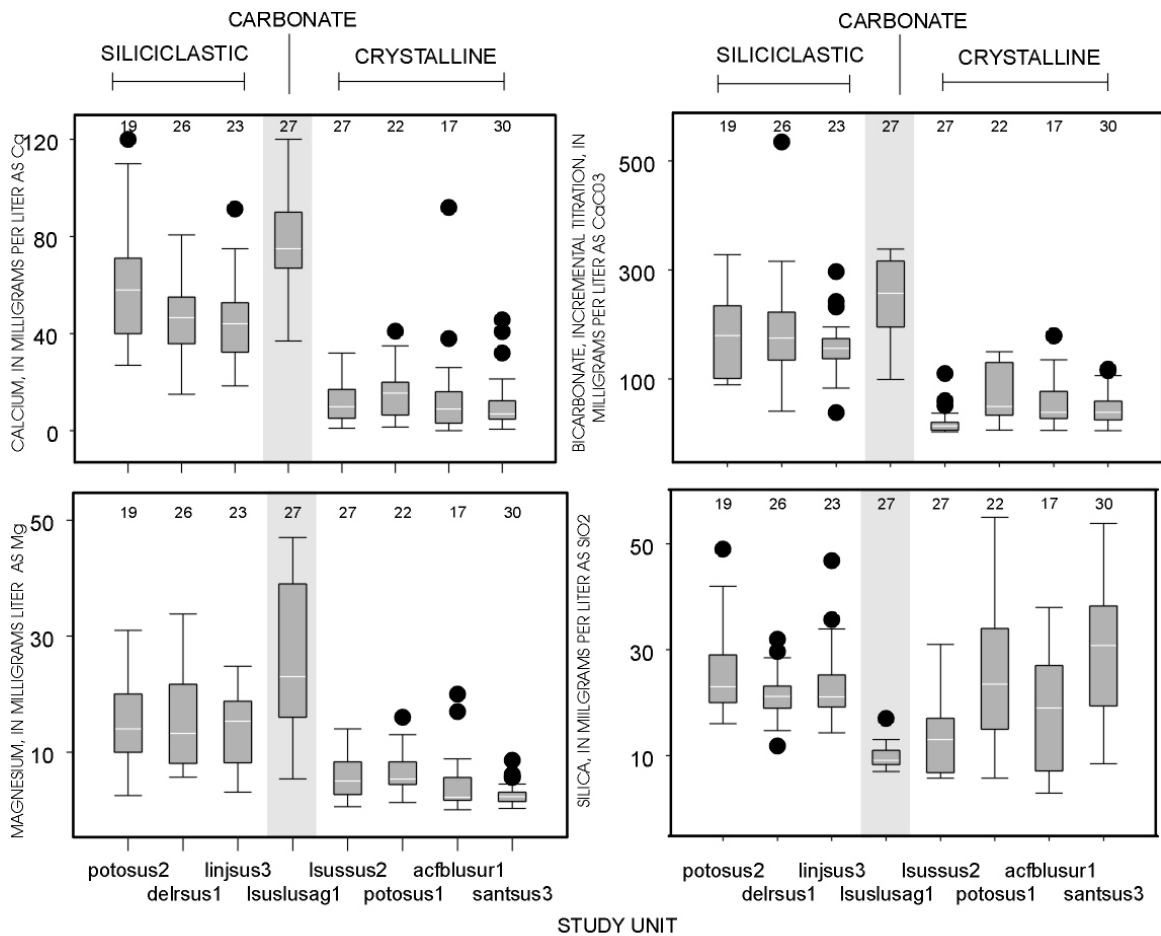
EXPLANATION

STUDY-UNIT ABBREVIATION

potosus2 - Potomac River Basin Piedmont Mesozoic Lowlands subunit survey
delrsus1 - Delaware River Basin Piedmont Mesozoic Lowlands subunit survey
linjsus3 - Long Island - New Jersey Coastal Drainages Piedmont Mesozoic Lowlands subunit survey
lsuslusag1 - Lower Susquehanna River Basin Piedmont carbonate agricultural land use study
lsussus2 - Lower Susquehanna River Basin Piedmont crystalline subunit survey
potosus1 - Potomac River Basin Piedmont crystalline subunit survey
acfblusur1 - Apalachicola-Chattahoochee-Flint River Basin Piedmont crystalline urban land use study
santsus3 - Santee River Basin and Coastal Drainages Piedmont crystalline subunit survey

N Number of samples
 ● Outlier data value greater than 3 times the interquartile range
 Data value less than or equal to 1.5 times the interquartile range
 75th percentile
 Median
 25th percentile
 Data value less than or equal to 1.5 times the interquartile range

Figure 3. Field parameter values in the Piedmont Aquifer System from Cycle I Study Units.



EXPLANATION

STUDY-UNIT ABBREVIATION

potosus2 - Potomac River Basin Piedmont Mesozoic Lowlands subunit survey
delrsus1 - Delaware River Basin Piedmont Mesozoic Lowlands subunit survey
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potosus1 - Potomac River Basin Piedmont crystalline subunit survey
acflblusur1 - Apalachicola-Chattahoochee-Flint River Basin Piedmont crystalline urban land use study
santsus3 - Santee River Basin and Coastal Drainages Piedmont crystalline subunit survey

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 75th percentile
 Median
 25th percentile
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Figure 4. Major ion chemistry in the Piedmont Aquifer System from Cycle I Study Units.

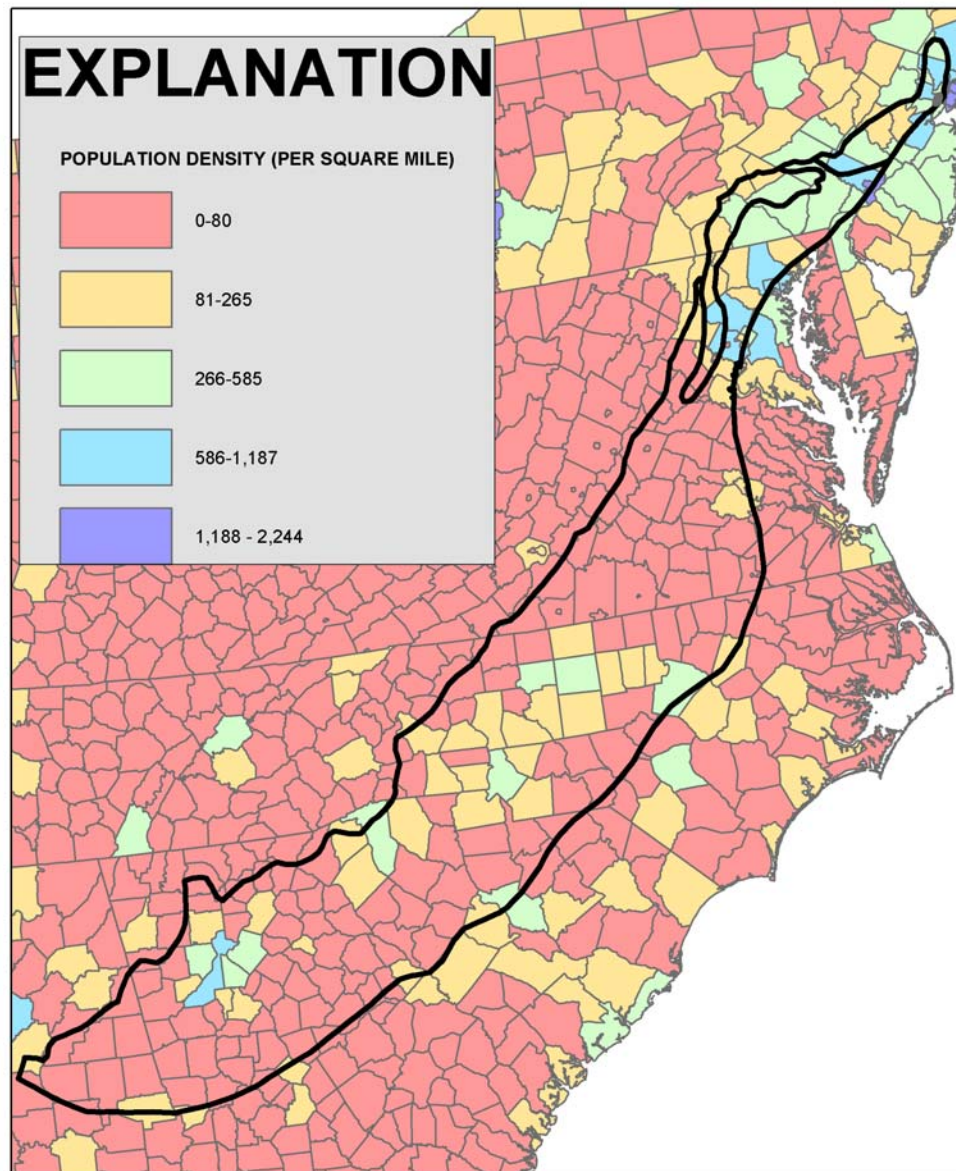


Figure 5. Population density by county in the Piedmont Aquifer System, dark line indicates the extent of the Piedmont Province and Sections.

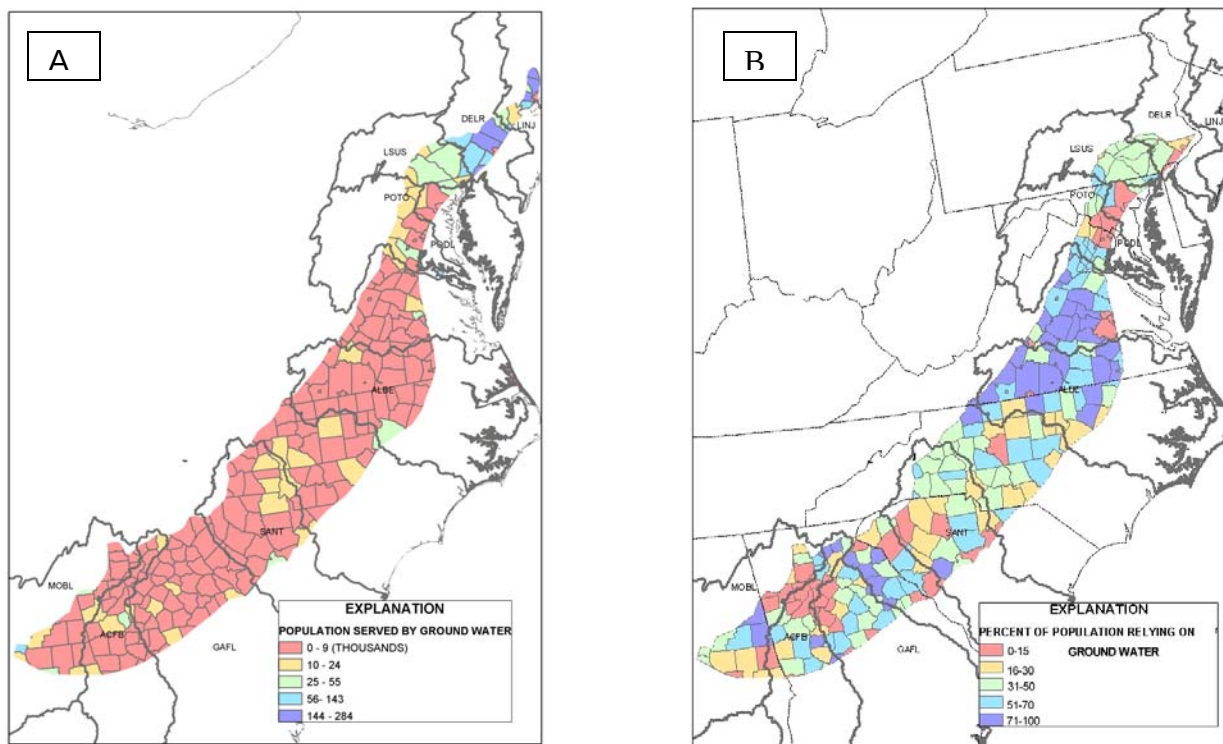


Figure 6. Population served by ground water (A) and percentage of population relying on ground water (B).

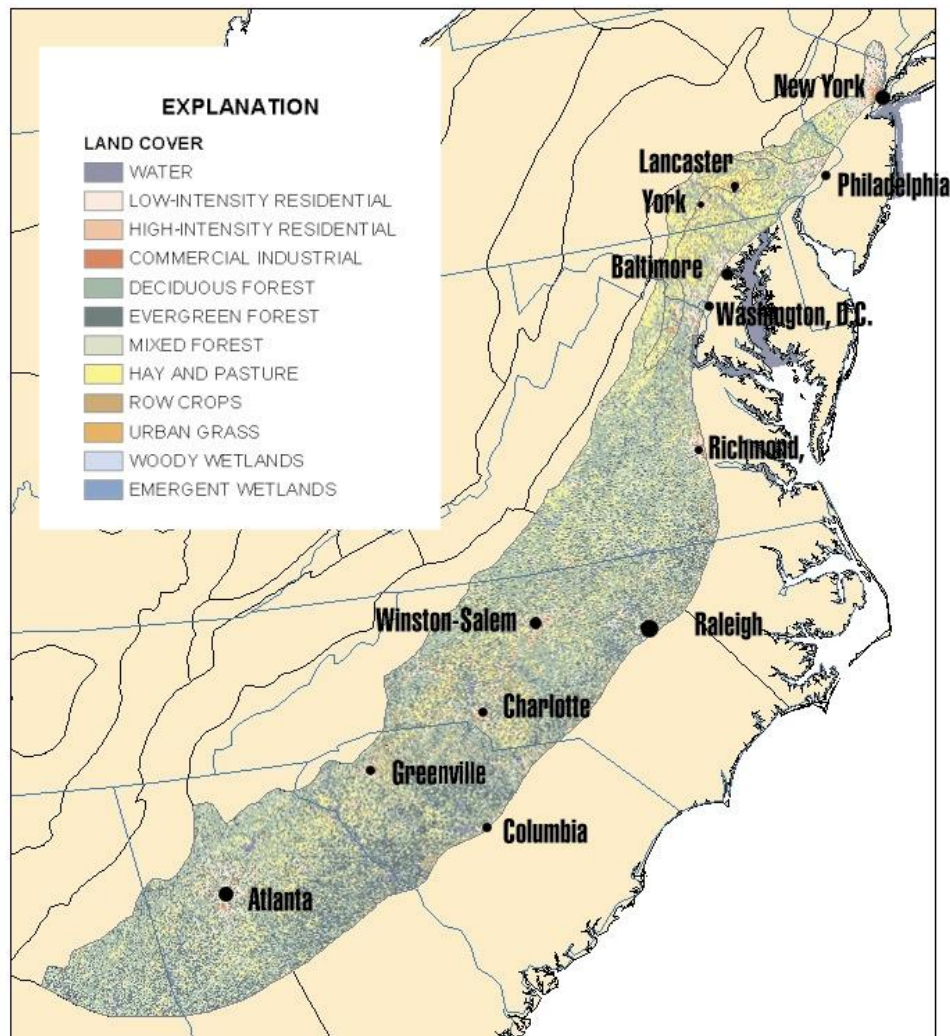


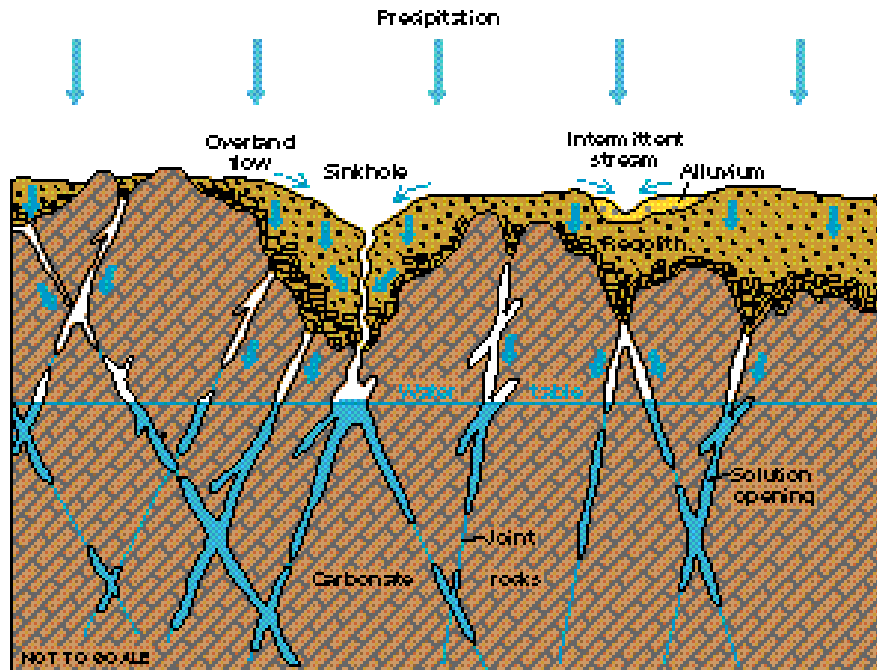
Figure 7. Land cover and major cities in the Piedmont Aquifer System.

Carbonate Aquifers

The PCAR aquifers of the PAS are located in the Piedmont Lowlands of Pennsylvania and Maryland. The limestone bedrock has typically weathered to an area of low relief. These aquifers are made up of mostly limestone and dolomite bedrock and are the most productive of the Piedmont aquifers (Trapp

and Horn, 1997). Karst features can be a controlling factor in the movement of ground water and contaminants. Dissolution of limestone and dolomite bedrock can form sinkholes that channel surface water directly into the ground water system. Well-developed fractures, conduits, and even caves develop in the limestone and transport ground water and contaminants over long distances (fig. 8). Springs may develop as outlets to the ground-water systems.

The PCAR aquifers are significantly affected by carbonate weathering. This tends to lead to high specific conductance values and large concentrations of dissolved solids, high, well-buffered pH, and high bicarbonate alkalinity (fig. 3 and fig. 4). Because the carbonate aquifers are predominantly made up of limestone (calcium carbonate) and dolomite (calcium magnesium carbonate) water from these aquifers commonly do not have high dissolved silica concentrations. Calcium concentrations were typically highest in ground water from carbonate aquifers and lowest in all crystalline aquifers with the concentrations in the siliciclastic aquifers falling between the other two (fig.4). This pattern is indicative of the relative amounts of calcium carbonate available for weathering in these respective rock types. Magnesium is another major ion that shows this same pattern, for essentially the same reason (fig. 4).



Modified from Nutter, L.J., 1973, Hydrogeology of the carbonate rocks, Frederick and Hagerstown Valleys: Maryland Geological Survey Report of Investigations 9, 70 p.

Figure 8. Ground water movement in carbonate aquifers (From Trapp and Horn, 1997).

Population and Water Use - The population of the area underlain by the PCAR aquifers is approximately 500,000. Population density is greater than in the PCRY area, with about 500 persons per square mile. The most densely populated areas are the cities of York and Lancaster in Pennsylvania. Water use for public supply is primarily from surface water in this area, with about 57,000 (12 percent) relying on ground water for public supply. An additional 155,000 (32 percent) rely on ground water for domestic self-supply. Overall, about 212,000 people, or 44 percent of the population, rely on ground water in the PCAR

aquifer. Withdrawals of ground water from the PCAR aquifers total 24 million gallons per day.

Land Use - Agricultural land use is particularly high in areas underlain by the PCAR aquifers. The PCAR area is mantled by residual soil that supports some of the most intense agricultural activity in Pennsylvania (U.S. Department of Commerce, 1990). In some parts of the PCAR area, agricultural activity is being displaced by urban and suburban development.

Siliciclastic Aquifers

Siliciclastic aquifers are primarily in three major basins—the Newark Basin in New Jersey and Pennsylvania, the Gettysburg Basin of Pennsylvania and Maryland, and the Culpeper Basin of Virginia. The PSIL aquifers underlie the Piedmont Lowlands, which is relatively flat, undulating terrain. The siliciclastic aquifers are bounded by faults that formed basins that were filled with thick sequences of sedimentary rocks (thicknesses of Triassic and Jurassic rocks greater than 20,000 feet in the larger basins) of fluvial and alluvial origin (fig. 9)(Trapp and Horn, 1997). The aquifers are made up of mostly sandstone and shale bedrock formed from silica sands and silicate clay minerals, respectively. The bedrock is often red or reddish-brown in color. The presence or absence of carbonate cement in the PSIL aquifers has a large affect on the concentrations of calcium and magnesium. Because the siliciclastic aquifers tend to contain both silicate minerals and carbonate minerals, they fall between the other two aquifer types (carbonate and crystalline) with regard to dissolved solids, specific conductance, pH, and bicarbonate alkalinity (fig.3 and fig. 4).

Population and Water Use - The population of the area underlain by the PSIL aquifers is approximately 5.5 million. The most densely populated parts of the PSIL are Central New Jersey, Southeastern Pennsylvania, Maryland, and Northern Virginia (fig. 5). Ground-water use from PSIL aquifers for public supply is more significant than that of the other two aquifers, with about 1.1 million (21 percent) relying on ground water for public supply. An additional 723,000 (13 percent) rely on ground water for domestic self -supply. Overall, nearly 2 million people, or 35 percent of the population, rely on the PSIL aquifer. Withdrawals of ground water from the PSIL aquifer total 218 million gallons per day. Ground-water pumping rates are highest in the PSIL aquifers, with about 7 times greater withdrawal rate in million gallons per day per square mile than the PCRY aquifers.

Land Use - Because much of this area is in the northern part of the Piedmont, the issue of urban and suburban development is significant. Agricultural land use is also significant in this area.

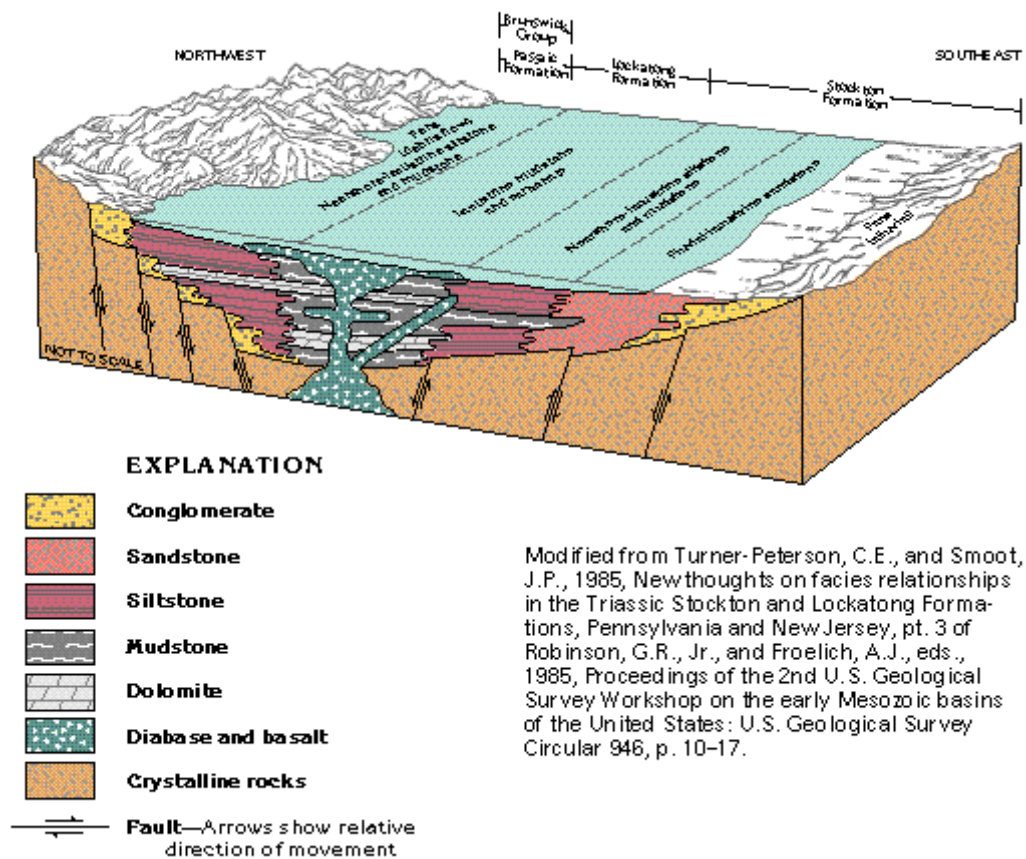


Figure 9. Ground water movement in siliciclastic aquifers (From Trapp and Horn, 1997).

CYCLE I STUDY RESULTS AND WATER-QUALITY ISSUES

In Cycle I, eight ground-water studies were completed in the PAS. These included six major aquifer studies and two land use studies (figs. 11 and 12)(table 1). In spatial coverage, the northern part of the Piedmont was sampled more densely than the southern part of the Piedmont. With regard to the proposed stratification, the two smaller sections of the PAS (carbonate and siliciclastic aquifers) were sampled intensely, and the crystalline aquifers had a much lower density of sampling. However, 3 major aquifer studies and 1 land use study were completed in the crystalline aquifers. There were 3 study units (ALBE, GAFL, and MOBL) that had no ground water sampling in the PAS in Cycle I. The intent of the analysis of data from Cycle I is to determine whether or not the sampling that took place during Cycle I was adequate to characterize this resource. In addition to assessing the spatial distribution of sampling, the results of Cycle I sampling will also be used to determine whether spatial gaps are significant.

Table 1. *Summary of Cycle I activities in Piedmont Aquifers System*

Aquifer	Study Unit	Study Name	Study type	Predominant Land Use	Number of samples
Siliciclastic	DELR	Delrsus1	Subunit Survey (Major Aquifer Study)	Mixed	26
	POTO (PODL in cycle II)	Potosus2		Mixed	20
	LINJ	Linjsus3		Mixed	24
Crystalline	LSUS	Lsussus2	Subunit Survey (Major Aquifer Study)	Mixed	27
	POTO	Potosus1		Mixed	22
	SANT	Santsus3		Mixed	30
	ACFB	Acfblusur1	Urban Land Use Study	Urban	17
Carbonate	LSUS	Lsuslusag1	Agricultural Land Use Study	Agricultural	27

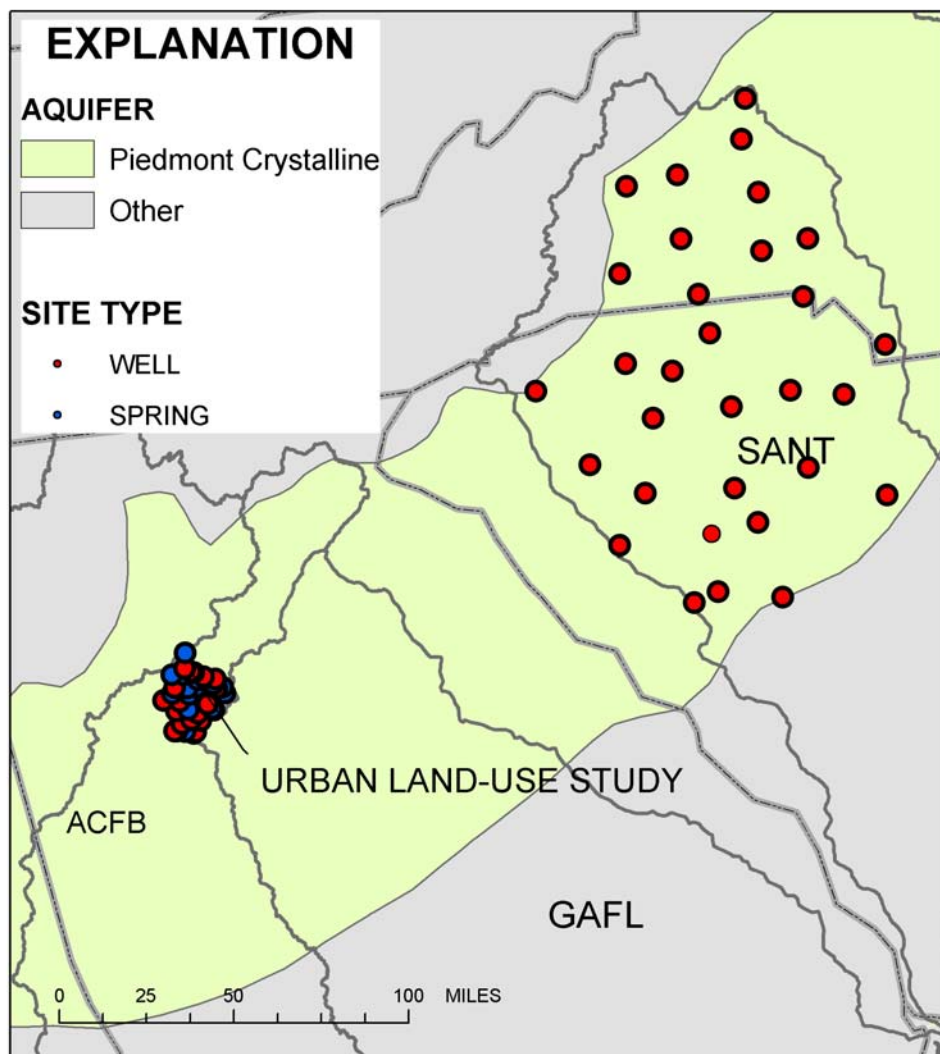


Figure 10. Samples collected in the southern section of the PAS during Cycle I of the National Water-Quality Assessment program, 1993 – 2000. Unless otherwise noted on figure, samples represent Major Aquifer Studies. [Santee Basin and Coastal Drainages (SANT), Georgia-Florida Coastal Plain (GAFL), Apalachicola-Chattahoochee-Flint River Basins (ACFB)]

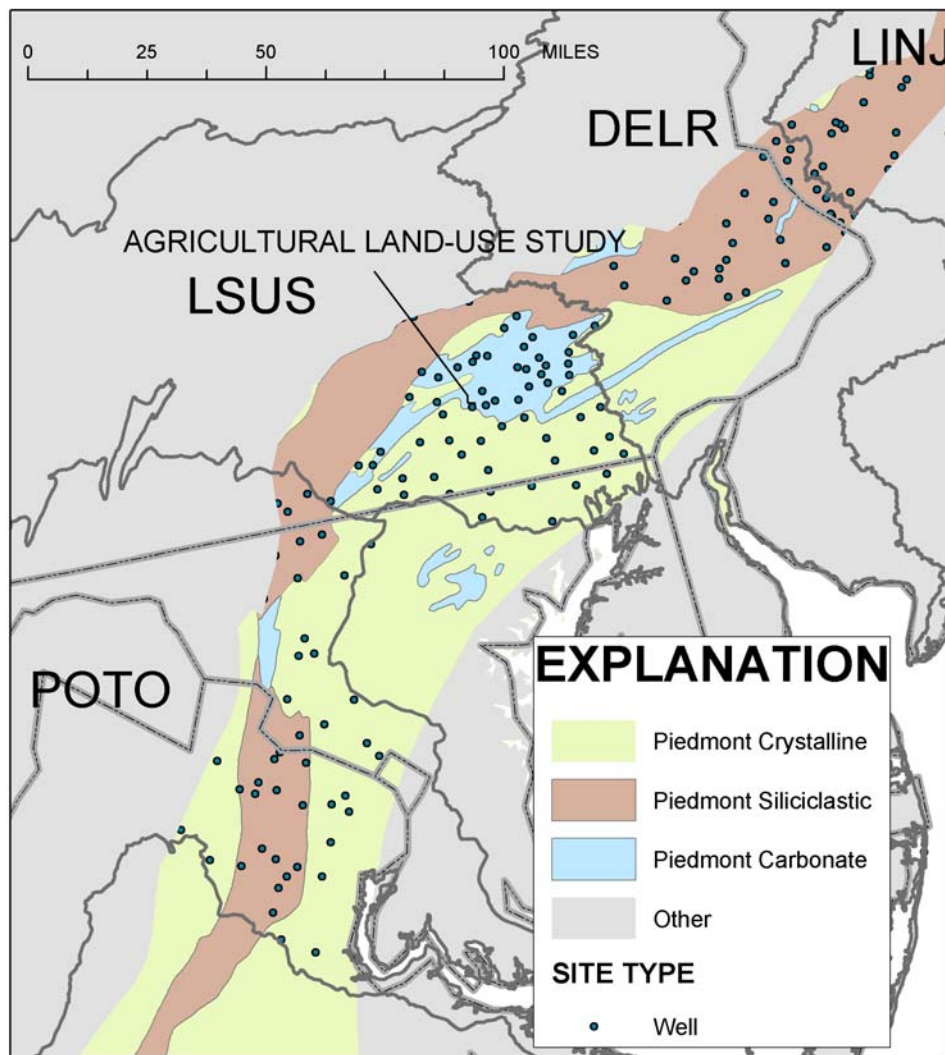


Figure 11. Samples collected in the northern section of the PAS during Cycle I of the National Water-Quality Assessment program, 1993 – 2000. Unless otherwise noted on figure, samples represent Major Aquifer Studies.

Anthropogenic Contaminants in Ground Water

The discussion of anthropogenic contaminants in water will focus on similarities among and differences between the aquifer types. For this analysis, however, variations in land use overlying the aquifer in general and at each well are a factor that makes this analysis difficult. *The difficulty arises in trying to conclude whether a given aquifer is actually less susceptible to contamination or the contaminant source is simply not present near a well sampling location.* The approach will be to discuss aquifer type and land use in general, and attempt to draw conclusions from the information available. Of the eight studies conducted (Table 1), only two were land-use studies. The ACFB conducted an urban land use study and the LSUS conducted an agricultural land use study. The remaining six studies were subunit surveys that had a mixture of land use types. In general, these are rural and suburban areas; however, the land uses surrounding each well was not considered in this analysis.

Nitrate

One of the major anthropogenic contaminants analyzed by all of the studies was nitrate. Nitrate is commonly the dominant form of nitrogen found in ground water. Concentrations of nitrate above 3 mg/L are considered an indicator of anthropogenic activity. The results of the nitrate analysis illustrated in figure 12 shows several themes. One is the susceptibility of the carbonate aquifer to nitrate contamination (fig 12. Isuslusag1). Carbonate aquifers have numerous features that allow direct contamination of the aquifer, and this area also has significant inputs of fertilizer and manure (Lindsey and others, 1997).

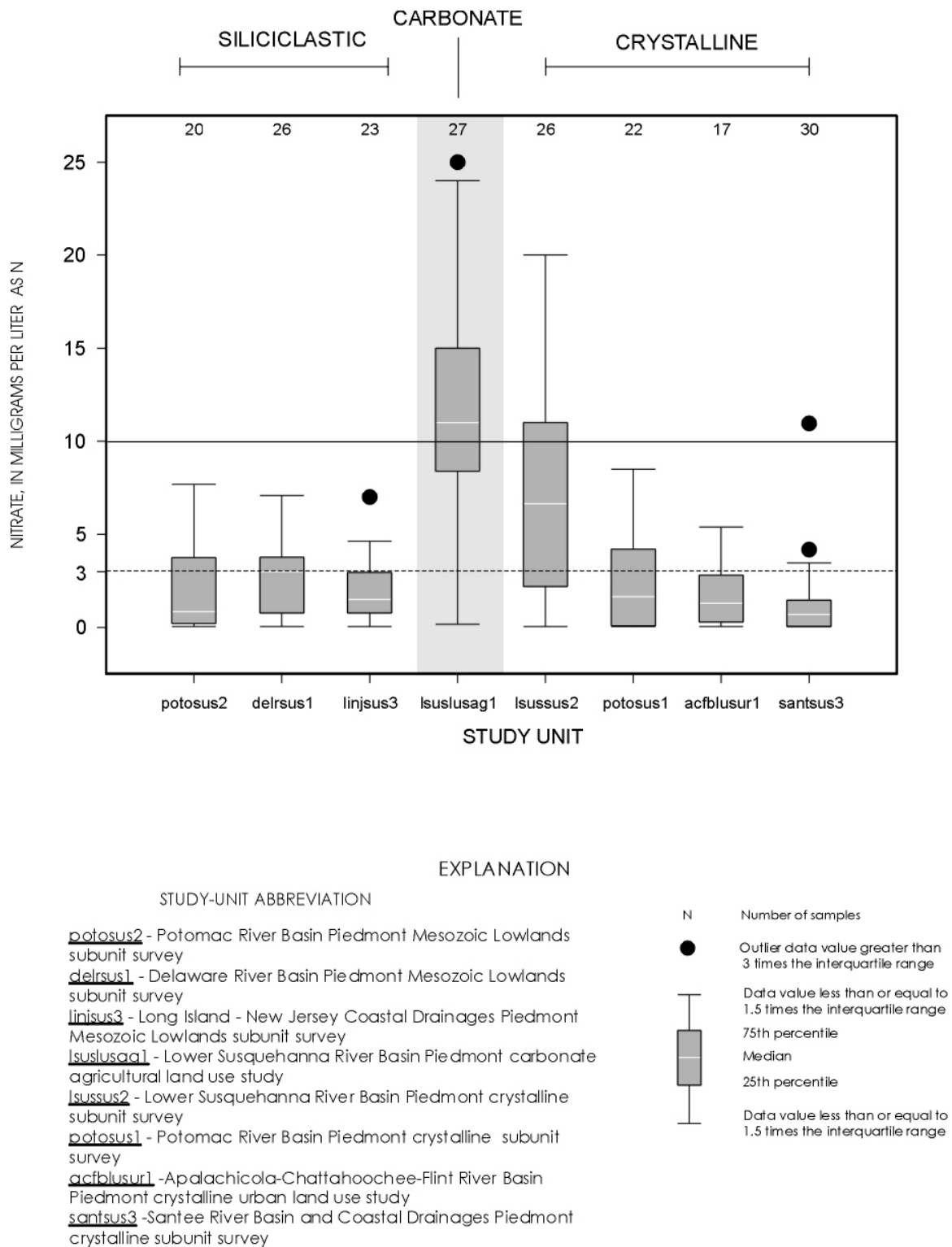


Figure 12. Nitrate concentrations in ground water in the Piedmont Aquifer System as determined from samples collected and analyzed for Cycle I Study Units, 1993-99.

The study that documented the second highest median nitrate concentration was the Isussus2 subunit survey of a crystalline aquifer, in an area with high inputs of fertilizer and manure (Lindsey and others, 1997). This shows that crystalline aquifers with high inputs of nitrogen have potential for high nitrate concentrations. The statistics from the land use/land cover within a 500 m radius of the wells in the delrsus1 study indicated the land use to be 46 percent agricultural, 33 percent forested, and 18 percent urban. Samples from wells in this study had the third highest median nitrate concentration. The samples from wells in the urban land use study had the next highest median nitrate concentration. Samples from wells in the remaining studies had low median nitrate concentrations, and interpretations of these data would probably show that land use surrounding the well was a significant factor affecting nitrate concentrations. Only the Isuslus1 and lussus2 studies had median concentrations greater than 3 mg/L; however, all of the studies had at least one sample with concentrations greater than 3 mg/L (fig. 12).

Pesticides

Pesticides are another set of major anthropogenic compounds analyzed by all NAWQA studies. The analysis of pesticide concentrations for this assessment of the PAS was based on atrazine, the most frequently detected pesticide in ground water samples collected by the NAWQA program, and metolachlor, a pesticide that ranks high in use, but has a lower detection frequency in ground water (Pesticide National Synthesis Project, 1997). The pattern observed for atrazine and metolachlor was similar to the pattern for

nitrate, with higher concentrations and frequent detections in the carbonate aquifer and the crystalline aquifer with a high percentage of agricultural land use (Isuslusag1 and Isussus2, fig. 13). The delrsus1 study had a higher detection rate of these pesticides than the linjsus3 study. Although both are Siliciclastic aquifers, the agricultural land use in the two areas may have been more in the delrsus1 study and the use of both metolachlor and atrazine are much less in the LINJ overall than in the DELR study unit. Several studies had a small number of detections of the two pesticides. This would be expected for the urban study (acfbelusur1) where agricultural pesticides are not commonly used. In the other areas it is difficult to determine whether the result is because the aquifer is not susceptible or the chemicals are not used in significant amounts. Table 2 summarizes study-unit pesticide use, which may be helpful in interpreting these patterns.

Table 2. *Use of Metolachlor and Atrazine in PAS Study Units.*
[--, data not available]

Study Unit	Pesticide Use Rank and Name	Treated Area (acres)	Active Ingredient Applied (lbs)	Treated Area (%)
ACFB	7 METOLACHLOR	179,486	341,562	0.57
	8 ATRAZINE	201,177	310,675	.35
ALBE	4 ATRAZINE	365,598	408,153	.64
	10 METOLACHLOR	470,712	913,047	1.51
DELR	2 METOLACHLOR	--	487,514	--
	3 ATRAZINE	--	287,781	--
GAFL	10 ATRAZINE	422,385	656,774	.74
	18 METOLACHLOR	192,873	345,996	.62
LINJ	2 METOLACHLOR	50,510	96,001	.16
	6 ATRAZINE	33,361	47,856	.06
LSUS	1 METOLACHLOR	425,705	758,897	1.36
	2 ATRAZINE	464,013	518,145	.81
MOBL	4 ATRAZINE	138,022	221,061	.24
	11 METOLACHLOR	62,324	92,357	.20
POTO	3 METOLACHLOR	220,810	417,337	.71
	4 ATRAZINE	279,096	377,881	.49
SANT	4 ATRAZINE	172,335	225,912	.30
	12 METOLACHLOR	81,309	114,275	.26

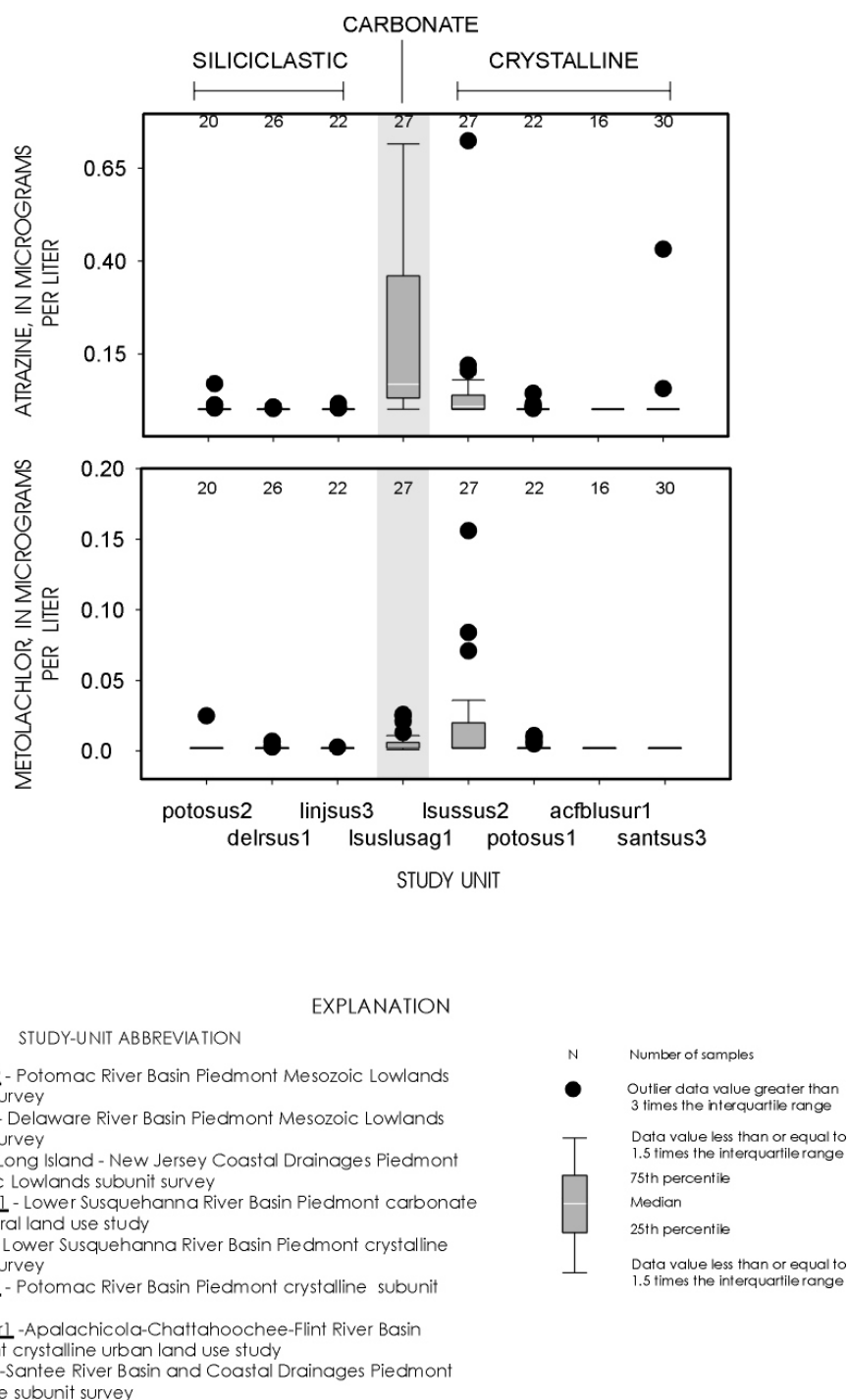


Figure 13. Atrazine and metolachlor concentrations in ground water from the Piedmont Aquifer System as determined from samples collected and analyzed for Cycle I Study Units, 1993-99.

VOC's

The interpretation of volatile organic compounds (VOC's) occurrence for this assessment of the PAS is based on the analyses for chloroform and methyl-tert butyl ether (MTBE) in six of the eight studies. Samples from the POTO study unit were not analyzed for VOC's. Detections of chloroform were highest in the delrsus1, linjsus3, and santsus3 studies. Detections of MTBE were highest in the delrsus1 and linjsus3 studies. The significance of these findings may be masked by the lowering of detection limits from the 1991 study units to the 1994 study units. The detection limits for chloroform for the 1991 and 1994 study units were <0.20ug/L and <0.0520ug/L, respectively. The detection limits for MTBE for the 1991 and 1994 study units were 0.20ug/L and 0.170ug/L, respectively. It is difficult to make an accurate comparison of the low number of detections of chloroform and MTBE in the urban land use study (acfblusur1--a 1991 study unit) to the DELR, LINJ, and SANT studies which have data reported at a lower detection limit (fig. 14) A reanalysis of the data at a common detection limit would be useful in determining the differences caused by the change in detection limit.

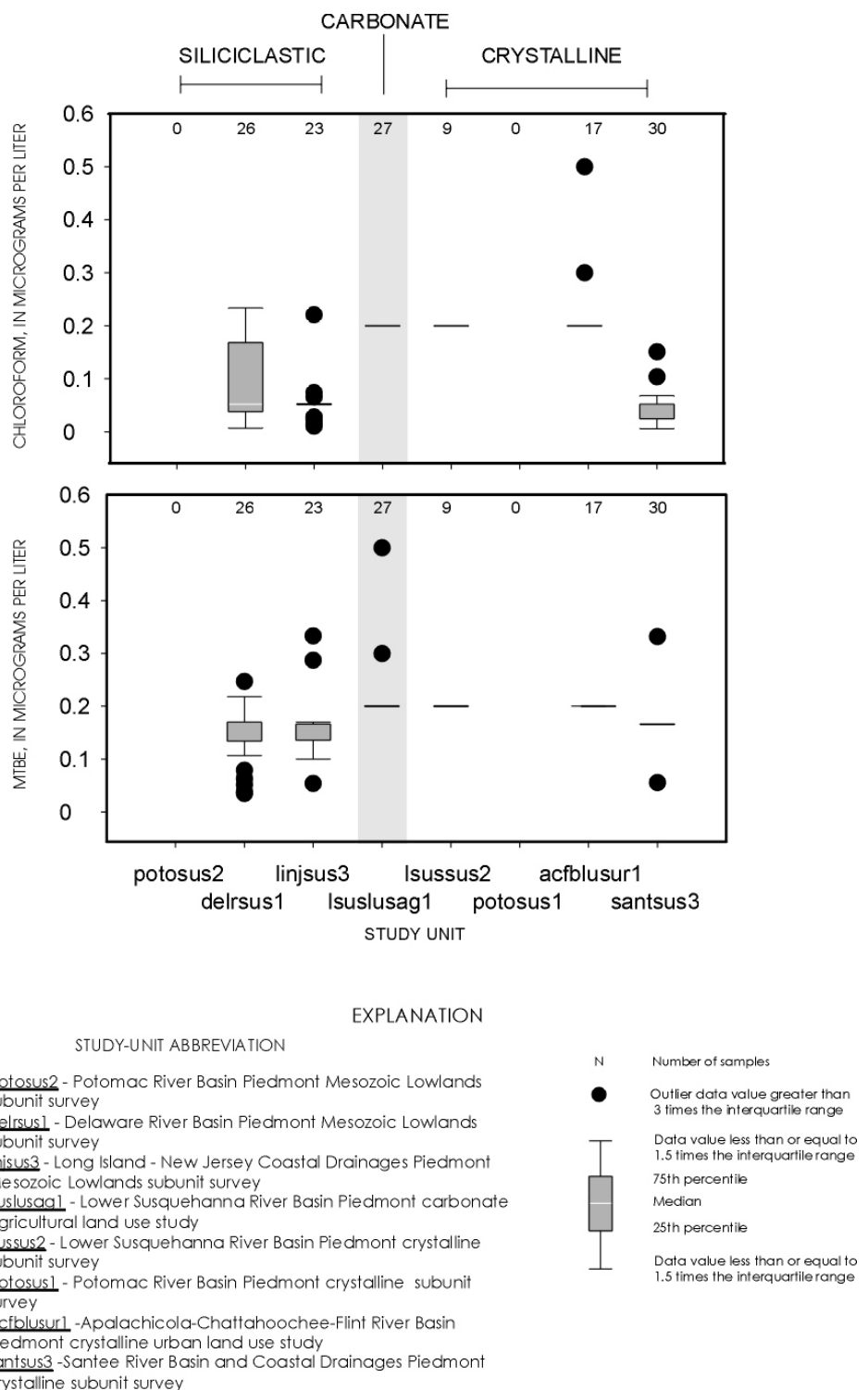


Figure 14. Chloroform and methyl-tert butyl ether concentrations in ground water from the Piedmont Aquifer System as determined from samples collected and analyzed for Cycle I Study Units, 1993-99.

In general, the aquifers studied in the Piedmont in Cycle I follow a predictable pattern with respect to anthropogenic contaminants when the sources are known, but a pattern that cannot be interpreted when the sources are not known. Anthropogenic contaminants were generally detected more frequently in the PCAR aquifers than in the PSIL and PCRY aquifers.

***Weaknesses of the available data from individual study units
for NAWQA Regional Synthesis of Ground Water in the
Piedmont Aquifer System***

Spatial coverage

A major weakness of the assessment of ground water quality in the PAS is the inadequacy of coverage and spatial distribution of samples. The Cycle I sampling provides a minimal assessment. The carbonate (about 1 samples every 30 square miles--1,000 square mile area and 27 samples collected) and siliciclastic (about 1 samples every 80 square miles--5,400 square mile area and 70 samples collected) areas have been sampled with a density that may be adequate to categorize the water quality in those areas; however, the crystalline aquifer has a very low sampling density of about 1 samples for every 770 square miles (71,500 square mile area, 96 samples collected). With regard to spatial distribution of that sampling, the large area south of the Potomac River Basin has had only 47 samples collected to characterize water quality (30 samples for the SANT and 17 wells and springs sampled in the Atlanta area for an urban land use study by the ACFB study unit). Agricultural activity is a significant land use factor affecting ground water quality in the PCRY area and, due to the broad area

underlain by this aquifer, the type and intensity of agricultural land use is likely to vary from one part of the PCRY area to another. Indications from the LSUS study of the crystalline aquifer indicate that intense agricultural activity may result in elevated concentrations of agricultural contaminants in ground water.

Categories of Contaminants

A major weakness of interpreting various contaminants in the PAS is that sampling for the various NAWQA schedules was not complete even within the areas that were sampled. The gaps in spatial coverage are even more dramatic when individual constituents are considered. VOC samples were collected in only 132 of the 193 ground-water samples. The samples from the siliciclastic aquifers and carbonate aquifers had VOCs analyzed in all studies with the exception of the POTO study unit. In the PCRY aquifer, only 56 samples are available to characterize water quality in the major aquifer, with 30 of those being in the SANT study unit. An additional 17 samples were collected in the ACFB urban area. This information, coupled with the change in detection limits in Cycle I, make the ability to conclude anything about the vulnerability of the Piedmont Crystalline Aquifer to VOC contamination very limited.

Another category of contaminants that has not been sampled throughout the PAS is trace elements. Trace element contamination can be from naturally occurring materials in the aquifer or anthropogenic activity. There were 17 samples collected in the PCRY urban study in the ACFB, 30 in the SANT PCRY major aquifer study, and 24 samples collected in the LINJ PSIL major aquifer study. The lack of data on trace elements makes it difficult to draw conclusions

about the natural variability in occurrence and if occurrence indicates vulnerability of the PAS to trace element contamination.

Land use

The lack of sampling in all of the agricultural land use types is also a major weakness of the study. Land use within the PAS is not uniform. This is particularly important for understanding agricultural contaminants. The dominant crops in the northern Piedmont (POTO, LSUS, DELR, LINJH) are corn and soybeans, however, the dominant crops in the southern Piedmont study units (ALBE, SANT, GAFL, ACFB, MOBL) are cotton, peanuts, corn, tobacco, and soybeans. Dairy farms are the predominant form of animal agriculture in the northern Piedmont study units, whereas combinations of dairy, hogs, and poultry are the norm to the south. These variations in agricultural land use, especially crop production, indicate that pesticide use is variable throughout this region as well (table 2). The ability to determine vulnerability within an aquifer with this level of diversity of agricultural activity is difficult with the number of samples collected. *This is particularly important because the aquifer tends to be dominated by short, local flowpaths.* To assess water quality in a specific land use area, samples would need to be collected in the direct vicinity of those land uses.

Land use change is an important issue as well. The PSIL area within the PAS is experiencing rapid growth and is an area of significant reliance on ground water withdrawals (DELR/LINJ study units). The PSIL area also has one of the higher densities of Superfund sites in the nation. Some sampling has been

conducted in this area; however, the population density, growth rate, and water use make this an important area for further study.

PLANNED CYCLE II STUDIES

Cycle II of NAWQA ground water studies include components of resampling, new assessments, and special studies. The special studies include Agricultural Chemicals Transport (ACT) studies and Transport of Anthropogenic and Natural Contaminants to Public Supply Wells (TANC) studies. In the proposed workplan for Cycle II in the PAS, the proposed work is an urban land use study and a source water assessment (SWA) (table 3). Both of these activities are proposed for the PODL study unit, in the crystalline aquifer of the Piedmont. These activities are in an area assessed as part of a subunit survey in Cycle I (potosus1). There is, however, no additional spatial coverage planned in Cycle II for any of the PAS aquifers.

Table 3. Summary of proposed work for Cycle II in Piedmont Aquifer System.

[NMAS, New Major Aquifer Study; NLUS, New Land Use Study; PODL, Potomac Delmarva; SWA, Source Water Assessment; RMAS, Resampled Major Aquifer Study; RLUS, Resampled Land Use Study; RFPS, Resampled Flow Path Study; RSWA, Resampled Source Water Assessment; TANC, Transport of Anthropogenic and Natural Contaminants to Supply Wells; ACT, Agricultural Chemicals: Sources, Transport, and Fate]

Aquifer System	Cycle II								
	New Status			Trends				TANC	ACT
	NMAS	NLUS	SWA	RMAS	RLUS	RFPS	RSWA		
Crystalline	--	PODL 32	PODL 15	--	--	--	--	--	--
Carbonate	--	--	--	--	--	--	--	--	--
Siliciclastic	--	--	--	--	--	--	--	--	--

RECOMMENDATIONS FOR CYCLE II STUDIES

Two stated purposes of this workplan were to assess the adequacy of the sampling in Cycle I, and recommend priorities for Cycle II sampling. The answers to both questions are subjective. As an overall answer, the sampling in Cycle I provided a minimal assessment of the resource. The recommended sampling in Cycle II is ultimately dependent on resources available, and therefore, the answer is contingent upon those resources. The sampling in Cycle I is a minimal assessment and not an ideal assessment. Although the data show that all three types of aquifers in the Piedmont have been sampled, the PCRY aquifer in particular has a much lower density of sampling than the PSIL and PCAR areas. The four studies in the crystalline aquifers showed similar characteristics, which, with a careful analysis relating land use to contaminants, may provide the data to show that the spatial distribution of sampling sites is adequate.

One recommendation for additional study in Cycle II will be to carefully analyze the Cycle I data with all of the ancillary data available on a site-by-site basis. This analysis should also bring in water-quality data from other studies such as the Appalachian Valleys-Piedmont Regional Aquifer Systems Analysis studies. The PCAR and PSIL aquifers have been sampled with a fairly high sampling density, and would be a lower priority for any additional sampling. Additional sampling in those areas where no sampling has occurred would be necessary to make the determination that water-quality in the Piedmont has been adequately assessed.

The potential for additional sampling is greatest in the central area of the Piedmont, in the ALBE study unit. The gap between existing samples in the POTO and the SANT studies is approximately 300 miles. Additionally, there is a span of about 250 miles between the SANT and the southern end of the PAS, with only the ACFB urban land use study to characterize ground water quality in the Piedmont. The significance of these spatial gaps should be assessed in order to make a substantial case that the PAS has been adequately studied. The areas of the GAFL, ACFB, or MOBL studies would be candidates for additional sampling as well.

The analysis was to determine answers to the following questions:

1. Have aquifers serving most of the population been sampled?

The siliciclastic aquifers in the Piedmont supply the largest population on a use per land area basis. This is the most densely sampled area as well.

2. Have aquifers been sampled where they are the predominant source of drinking supply?

Large areas of the Piedmont have a low overall use of ground water, but are the only source of water for domestic supply. Most of this area has not been assessed.

3. Have the various rock types and land used been sampled?

Samples have been collected in each of the strata identified, however, differences over such a large area are difficult to assess without a broader sampling network.

4. Have the most susceptible settings been characterized and verified by sampling?

The most susceptible settings are the carbonate aquifers, which are probably the most well-characterized aquifer in the Piedmont. However, the carbonate rock aquifers are only 1 percent of the Piedmont area.

5. Can the most important regional water-quality issues be addressed with the data?

There are many issues that can be addressed with the data available, however, it is difficult to draw conclusions about the overall importance of water- quality issues with the data available.

Issues and proposed workplan updates:

The following are summaries of outstanding issues in the Piedmont Aquifer System and recommendations to address those issues:

1. Spatial coverage – because of the size of the PAS and the distribution of the existing sampling network, two additional Major Aquifer Studies are recommended. At a minimum, an additional MAS in the ALBE, and one in either the MOBL, ACFB, or GAFL would provide the minimum coverage of the PAS. A cooperative study of ground water in the Piedmont that is being conducted by the North Carolina District may provide an opportunity to obtain the additional samples needed in this area without the expense

of a full MAS. Similar opportunities may be available in other parts of the Piedmont.

2. Categories of contaminants – because of the fact that not all contaminants have been analyzed in each area, it is recommended that a full suite of analyses—including VOCs and trace elements—be included in any future sampling.
3. Land use in the Southern Piedmont – because of the lack of sampling in agricultural areas of the Southern Piedmont, a minimum of one additional agricultural land use study in one of the southern study units is recommended.
4. Population growth and water use in the siliciclastic aquifer – because of the pressure of growth in the Philadelphia, New Jersey, New York, corridor, an additional urban/suburban land use study is recommended in the DELR/LINJ area. Although this aquifer has the most dense sampling network from Cycle I, these additional samples are important to further characterize the resource.

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