**Hydrogeologic Setting of A/M Area: Framework for
Groundwater Transport (U)**

by

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HYDROGEOLOGIC SETTINGS OF A/M AREA: FRAMEWORK FOR GROUNDWATER TRANSPORT

BOOK 1 OF 7

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LIST OF BOOKS

- 1 Report Text**
- 2 Hydrogeological Plates**
- 3 Geophysical Logs ABP-3C to MSB-17BB (Appendix A)**
- 4 Geophysical Logs MSB-18A to MSB-55C (Appendix A)**
- 5 Geophysical Logs MSB-55TA to RWM-16 (Appendix A)**
- 6 Time/Concentration Graphs (Appendix B)**
- 7 Potentiometric and Isoconcentration Maps with Structural Interpretation (Appendix C)**

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CONTENTS

TABLE OF CONTENTS	v
LIST OF TABLES	viii
LIST OF FIGURES	ix
LIST OF PLATES	x
LIST OF APPENDICES	xi
LIST OF ACRONYMS	xii
EXECUTIVE SUMMARY	ES-1
 1.0 INTRODUCTION	 1-1
1.1 Purpose and Scope of Work	1-1
1.2 Background History of the A/M Area	1-1
 2.0 REGIONAL AND SITE GEOLOGY	 2-1
2.1 Physiography	2-1
2.2 Geologic History	2-5
2.3 Atlantic Coastal Plain Stratigraphy, Lithology, and Structure	2-10
2.3.1 Late Cretaceous Sediments	2-15
2.3.2 Paleocene-Eocene Black Mingo Group	2-19
2.3.3 Middle Eocene Orangeburg Group	2-21
2.3.4 Late Eocene Barnwell Group	2-23
2.3.5 "Upland Unit"	2-24
2.3.6 Quaternary Deposits	2-25
2.3.7 SRS Area Structure	2-25
 3.0 GEOLOGY OF THE A/M AREA	 3-1
3.1 Crystalline Paleozoic Basement	3-1
3.2 Atlantic Coastal Plain Sequence	3-2
3.2.1 Cretaceous Stratigraphy	3-2
3.2.1.1 Cape Fear Formation	3-2
3.2.1.2 Lumbee Group	3-2
3.2.1.2.1 Middendorf Formation	3-2
3.2.1.2.2 Black Creek Formation	3-3
3.2.1.2.3 Peedee Formation	3-3
3.2.2 Tertiary Stratigraphy	3-5
3.2.2.1 Ellenton Formation	3-6
3.2.2.2 Congaree/Fishburne Formations	3-6
3.2.2.3 Warley Hill Formation	3-7
3.2.2.4 Santee Formation	3-8
3.2.2.5 Middle Eocene-Late Eocene Undifferentiated	3-8
3.2.2.6 Dry Branch Formation	3-8
3.2.2.7 Tobacco Road Formation	3-8
3.2.2.8 "Upland Unit"	3-9
3.2.2.9 A/M Area Structure	3-9

4.0	HYDROGEOLOGY	4-1
4.1	Regional Hydrogeology and Hydrostratigraphy	4-1
4.1.1	<i>Regional Hydrostratigraphic Classification</i>	4-1
4.1.2	<i>Regional Hydrogeology</i>	4-4
4.2	A/M Area Hydrogeology and Hydrostratigraphy	4-6
4.2.1	<i>A/M Area Hydrogeologic and Hydrostratigraphic Setting</i>	4-6
4.2.2	<i>Summary of A/M Area Hydrogeologic Data</i>	4-9
4.3	A/M Area Aquifer Units/Zones and Confining Units/Zones	4-12
4.3.1	<i>Crouch Branch Aquifer</i>	4-12
4.3.1.1	<u>Horizontal and Vertical Extent</u>	4-12
4.3.1.2	<u>Hydraulic Gradients and Groundwater Movement</u>	4-13
4.3.1.3	<u>Hydraulic Properties</u>	4-13
4.3.2	<i>Crouch Branch Confining Unit</i>	4-14
4.3.2.1	<u>Horizontal and Vertical Extent</u>	4-14
4.3.2.2	<u>Hydraulic Gradients and Groundwater Movement</u>	4-15
4.3.2.3	<u>Hydraulic Properties</u>	4-16
4.3.3	<i>"Lost Lake" Aquifer Zone</i>	4-17
4.3.3.1	<u>Horizontal and Vertical Extent</u>	4-17
4.3.3.2	<u>Hydraulic Gradients and Groundwater Movement</u>	4-18
4.3.3.3	<u>Hydraulic Properties</u>	4-19
4.3.4	<i>"Green Clay" Confining Zone</i>	4-19
4.3.4.1	<u>Horizontal and Vertical Extent</u>	4-19
4.3.4.2	<u>Hydraulic Gradients and Groundwater Movement</u>	4-20
4.3.4.3	<u>Hydraulic Properties</u>	4-20
4.3.5	<i>Steed Pond Aquifer and the "M-Area" Aquifer Zone</i>	4-21
4.3.5.1	<u>Horizontal and Vertical Extent</u>	4-21
4.3.5.2	<u>Hydraulic Gradients and Groundwater Movement</u>	4-22
4.3.5.3	<u>Hydraulic Properties</u>	4-22
4.4	Summary of Hydrogeologic Conditions of the A/M Area	4-23
5.0	CONTAMINANT PLUME DESCRIPTIONS FOR TRICHLOROETHYLENE AND TETRACHLOROETHYLENE	5-1
5.1	General Information	5-1
5.2	Sources of Groundwater Contamination in the A/M Area	5-2
5.2.1	<i>Known Sources of Contamination</i>	5-3
5.2.2	<i>Potential Sources of Contamination</i>	5-6
5.2.3	<i>Distant Sources of Contamination</i>	5-9
5.2.4	<i>Savannah River Laboratory Seepage Basins</i>	5-9
5.2.5	<i>Metallurgical Laboratory Basin</i>	5-9
5.3	Trichloroethylene	5-9
5.3.1	<i>Horizontal Distribution</i>	5-9
5.3.1.1	<u>"M-Area" Aquifer Zone</u>	5-10
5.3.1.2	<u>Upper "Lost Lake" Aquifer Zone</u>	5-10
5.3.1.3	<u>Lower "Lost Lake" Aquifer Zone</u>	5-11

	<u>5.3.1.4 "Middle Sand" Aquifer Zone</u>	5-11
	<u>5.3.1.5 Crouch Branch Aquifer</u>	5-11
5.3.2	<i>Vertical Distribution</i>	5-11
	<u>5.3.2.1 Cross Section A-A'</u>	5-12
	<u>5.3.2.2 Cross Section B-B'</u>	5-21
	<u>5.3.2.3 Cross Section C-C'</u>	5-21
	<u>5.3.2.4 Cross Section D-D'</u>	5-22
	<u>5.3.2.5 Cross Section E-E'</u>	5-23
5.4	Tetrachloroethylene	5-24
5.4.1	<i>Horizontal Distribution</i>	5-24
	<u>5.4.1.1 "M-Area" Aquifer Zone</u>	5-24
	<u>5.4.1.2 Upper "Lost Lake" Aquifer Zone</u>	5-25
	<u>5.4.1.3 Lower "Lost Lake" Aquifer Zone</u>	5-25
	<u>5.4.1.4 "Middle Sand" Aquifer Zone</u>	5-25
	<u>5.4.1.5 Crouch Branch Aquifer</u>	5-25
5.4.2	<i>Vertical Distribution</i>	5-26
	<u>5.4.2.1 Cross Section A-A'</u>	5-26
	<u>5.4.2.2 Cross Section B-B'</u>	5-35
	<u>5.4.2.3 Cross Section C-C'</u>	5-35
	<u>5.4.2.4 Cross Section D-D'</u>	5-36
	<u>5.4.2.5 Cross Section E-E'</u>	5-37
5.5	Time/Concentration Graphs	5-37
6.0	SUMMARY	6-1
	REFERENCES	6-3

LIST OF TABLES

4-1	Summary of Final Hydrogeologic Parameters Used in Flow Model	4-10
4-2	A/M Area Master Well List	4-26
4-3	Summary of Hydrostratigraphic Data from Monitoring Wells in the A/M Area . . .	4-33
4-4	Cross Section A-A' Monitoring Wells Showing Potentiometric Elevations	4-34
4-5	Cross Section B-B' Monitoring Wells Showing Potentiometric Elevations	4-36
4-6	Cross Section C-C' Monitoring Wells Showing Potentiometric Elevations	4-37
4-7	Cross Section D-D' Monitoring Wells Showing Potentiometric Elevations	4-38
4-8	Cross Section E-E' Monitoring Wells Showing Potentiometric Elevations	4-40
5-1	Estimated Amount of Solvent Use at M-Area	5-4
5-2	Cross Section A-A' Monitoring Wells Showing Trichloroethylene Concentrations	5-13
5-3	Cross Section B-B' Monitoring Wells Showing Trichloroethylene Concentrations	5-15
5-4	Cross Section C-C' Monitoring Wells Showing Trichloroethylene Concentrations	5-16
5-5	Cross Section D-D' Monitoring Wells Showing Trichloroethylene Concentrations	5-17
5-6	Cross Section E-E' Monitoring Wells Showing Trichloroethylene Concentrations	5-19
5-7	Cross Section A-A' Monitoring Wells Showing Tetrachloroethylene Concentrations	5-27
5-8	Cross Section B-B' Monitoring Wells Showing Tetrachloroethylene Concentrations	5-29
5-9	Cross Section C-C' Monitoring Wells Showing Tetrachloroethylene Concentrations	5-30
5-10	Cross Section D-D' Monitoring Wells Showing Tetrachloroethylene Concentrations	5-31
5-11	Cross Section E-E' Monitoring Wells Showing Tetrachloroethylene Concentrations	5-33

LIST OF FIGURES

1-1	Location of the SRS in South Carolina	1-2
1-2	Known or Suspected Sources of Groundwater Contamination within the A/M Area	1-4
2-1	Physiographic Provinces of the Eastern United States	2-2
2-2	Physiographic Subprovinces of the South Carolina Coastal Plain	2-3
2-3	Processes Occurring at a Convergent Plate Boundary	2-6
2-4	Tectonic Setting of Eastern United States	2-8
2-5	Triassic-Jurassic Rift Basins of Eastern North America	2-9
2-6	Geologic Map of South Carolina	2-11
2-7	Geologic Cross Section of the Coastal Plain of South Carolina	2-13
2-8	Generalized Stratigraphic Cross Section Across the SRS	2-14
2-9	Stratigraphic Column for the SRS	2-16
2-10	Depositional Environments of Coastal Plain Sediments	2-17
2-11	Location Map of the Pen Branch Fault and Other Basement Faults Identified in the Conoco, 1989, Seismic Reflection Survey Data	2-26
3-1	Comparison of Chronostratigraphic, Lithostratigraphic, and Hydrostratigraphic Units at the SRS	3-4
4-1	Hydrogeologic Nomenclature for the SRS Region	4-3
4-2	Limits of Aquifer Systems Within the SRS	4-5
4-3	Hydrostratigraphic Chart for the A/M Area	4-7
4-4	Schematic Diagram of Horizontal and Vertical Groundwater Velocities in the A/M Area	4-11
4-5	Vectorial Representation of Seepage Velocities	4-25
5-1	Time Period of Solvent Use	5-5
5-2	Degreaser Solvent Discharges to Process Sewers	5-7
C-1	Potentiometric Map 3Q91, Crouch Branch Aquifer with Structural Interpretations	
C-2	Potentiometric Map 3Q91; "Middle Sand" Aquifer Zone within the Crouch Branch Confining Unit with Structural Interpretations	
C-3	Potentiometric Map 3Q91, Lower "Lost Lake" Aquifer Zone of the Steed Pond Aquifer with Structural Interpretations	
C-4	Isoconcentration Map – Trichloroethylene 4Q91, Upper "Lost Lake" Aquifer Zone of the Steed Pond Aquifer with Structural Interpretations	
C-5	Isoconcentration Map – Trichloroethylene 4Q91, Lower "Lost Lake" Aquifer Zone of the Steed Pond Aquifer with Structural Interpretations	
C-6	Isoconcentration Map – Trichloroethylene 4Q91, Crouch Branch Aquifer with Structural Interpretations	

LIST OF PLATES

- 3-1 Cross-Section Location Map
- 3-2 A/M Area Hydrogeologic Cross Section A-A'
- 3-3 A/M Area Hydrogeologic Cross Section B-B'
- 3-4 A/M Area Hydrogeologic Cross Section C-C'
- 3-5 A/M Area Hydrogeologic Cross Section D-D'
- 3-6 A/M Area Hydrogeologic Cross Section E-E'
- 4-1 Cross Section A-A', Potentiometric Map
- 4-2 Cross Section B-B', Potentiometric Map
- 4-3 Cross Section C-C', Potentiometric Map
- 4-4 Cross Section D-D', Potentiometric Map
- 4-5 Cross Section E-E', Potentiometric Map
- 4-6 Potentiometric Map 3Q91, Crouch Branch Aquifer
- 4-7 Isopach Map, Thickness of Crouch Branch Confining Unit
- 4-8 Altitude Contour on Top of Crouch Branch Confining Unit
- 4-9 Potentiometric Map 3Q91, "Middle Sand" Aquifer Zone within the Crouch Branch Confining Unit
- 4-10 Isopach Map, Thickness of "Lost Lake" Aquifer Zone of the Steed Pond Aquifer
- 4-11 Potentiometric Map 3Q91, Upper "Lost Lake" Aquifer Zone of the Steed Pond Aquifer
- 4-12 Potentiometric Map 3Q91, Lower "Lost Lake" Aquifer Zone of the Steed Pond Aquifer
- 4-13 Isopach Map, Thickness of "Green Clay" Confining Zone of the Steed Pond Aquifer
- 4-14 Altitude Contour on Top of "Green Clay" Confining Zone of the Steed Pond Aquifer
- 4-15 Isopach Map, Thickness of "M-Area" Aquifer Zone of the Steed Pond Aquifer
- 4-16 Isopach Map, Thickness of Steed Pond Aquifer
- 4-17 Potentiometric Map 3Q91, "M-Area" Aquifer Zone of the Steed Pond Aquifer
- 5-1 Location Map of A/M Area Showing Areas of Known or Suspected Sources of Contamination
- 5-2 Isoconcentration Map – Trichloroethylene 4Q91, "M-Area" Aquifer Zone of the Steed Pond Aquifer
- 5-3 Isoconcentration Map – Trichloroethylene 4Q91, Upper "Lost Lake" Aquifer Zone of the Steed Pond Aquifer
- 5-4 Isoconcentration Map – Trichloroethylene 4Q91, Lower "Lost Lake" Aquifer Zone of the Steed Pond Aquifer
- 5-5 Isoconcentration Map – Trichloroethylene 4Q91, "Middle Sand" Aquifer Zone within the Crouch Branch Confining Unit
- 5-6 Isoconcentration Map – Trichloroethylene 4Q91, Crouch Branch Aquifer
- 5-7 Isoconcentration Contour Map, Trichloroethylene A-A'
- 5-8 Isoconcentration Contour Map, Trichloroethylene B-B'
- 5-9 Isoconcentration Contour Map, Trichloroethylene C-C'
- 5-10 Isoconcentration Contour Map, Trichloroethylene D-D'
- 5-11 Isoconcentration Contour Map, Trichloroethylene E-E'
- 5-12 Isoconcentration Map – Tetrachloroethylene 4Q91, "M-Area" Aquifer Zone of the Steed Pond Aquifer
- 5-13 Isoconcentration Map – Tetrachloroethylene 4Q91, Upper "Lost Lake" Aquifer Zone of the Steed Pond Aquifer

LIST OF PLATES (CONT'D)

- 5-14 Isoconcentration Map – Tetrachloroethylene 4Q91, Lower "Lost Lake" Aquifer Zone of the Steed Pond Aquifer
- 5-15 Isoconcentration Map – Tetrachloroethylene 4Q91, "Middle Sand" Aquifer Zone within the Crouch Branch Confining Unit
- 5-16 Isoconcentration Map – Tetrachloroethylene 4Q91, Crouch Branch Aquifer
- 5-17 Isoconcentration Contour Map, Tetrachloroethylene A-A'
- 5-18 Isoconcentration Contour Map, Tetrachloroethylene B-B'
- 5-19 Isoconcentration Contour Map, Tetrachloroethylene C-C'
- 5-20 Isoconcentration Contour Map, Tetrachloroethylene D-D'
- 5-21 Isoconcentration Contour Map, Tetrachloroethylene E-E'

LIST OF APPENDICES

- A Geophysical Logs, A/M Area Monitoring Wells (Books 3-5)
- B Time Concentration Graphs, A/M Area Monitoring Wells (Book 6)
- C Potentiometric and Isoconcentration Maps with Structural Interpretations (Book 7)

LIST OF ACRONYMS

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DNAPL	Dense Nonaqueous Phase Liquid
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
FSAR	Final Safety Analysis Report
gpd/ft ³	gallons per day per cubic foot
gpm	gallons per minute
GSA	General Separations Area
HWMF	Hazardous Waste Management Facility
in/yr	inches per year
Met Lab	Metallurgical Laboratory
msl	mean sea level
NASC	North American Stratigraphic Commission
NPDES	National Pollutant Discharge Elimination System
ppb	parts per billion
RCRA	Resource Conservation and Recovery Act
RFI/RI	RCRA Facility Investigation/Remedial Investigation
RM	Reactor Materials
RMET	Reactor Materials Engineering and Technology
SCDHEC	South Carolina Department of Health and Environmental Control
sq mi	square mile(s)
SRL	Savannah River Laboratory
SRS	Savannah River Site
SRTC	Savannah River Technology Center (formerly SRL)
SVE	Soil-Vapor Extraction
TCLP	Toxicity Characteristic Leaching Procedure
USGS	United States Geological Survey
VOC	Volatile Organic Compound
WLBS	Water Level Below Standpipe
WSRC	Westinghouse Savannah River Company

EXECUTIVE SUMMARY

This document includes a brief summary of the regional geology within a 200-mile radius of the A/M Area, a summary of stratigraphy and hydrostratigraphic nomenclature as it applies to the A/M Area, and a summary of stratigraphy and hydrostratigraphy specific to the A/M Area. Five different stratigraphic cross sections show site-specific geology of the Tertiary section of the Upper Atlantic Coastal Plain geologic province within the A/M Area. The Cretaceous section lacks detail because the deepest wells penetrate only the uppermost part of the Upper Cretaceous sediments. Most of the wells are confined to the Tertiary section.

The A/M Area is located in the northwestern corner of the Savannah River Site (SRS). The A-Area serves as a main administrative hub for the site. The M-Area includes several production facilities that are being investigated or have been closed under the regulatory requirements of either the Resource Conservation and Recovery Act (RCRA) or the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

Between 1958 and 1985, approximately 2,000,000 pounds of volatile organic solvents (metal degreasers, primarily trichloroethylene and tetrachloroethylene) were routed to the M-Area Settling Basin. Between 1954 and 1958, effluent also was discharged to Tim's Branch via the A-014 Outfall. In the main M-Area Solvent Handling/Storage Area, a significant amount of leakage occurred from drums stored during this time period. Extensive quantities of solvents were transported, via the Process Sewer Line, to the M-Area Settling Basin, and leaks occurred along this line as well. A smaller source area has been identified and is centered around the Savannah River Laboratory (SRL) (now called the Savannah River Technology Center [SRTC]) Complex. All of these source areas are represented by solvent contamination in the groundwater system.

In order to understand the distribution and migration of contaminants in the groundwater system, the nature and horizontal and vertical distribution of sediments must be characterized. Potential fluid migration pathways and directions of the sedimentary units must be delineated. Because the A/M Area is in close proximity to the present-day erosional boundary of the Upper Atlantic Coastal Plain, the sedimentary units are thinner, are locally bounded by unconformities, and are laterally discontinuous.

The Tertiary sedimentary section is represented by a sequence of alternating sand and clay above the relatively thick Ellenton Formation (locally greater than 50 feet of clay) near the Tertiary-Cretaceous boundary. The Ellenton Formation thins significantly to the north in the A/M Area and consists of thin clay stringers beneath the SRTC Complex. In most of the section, the clay beds are significantly thinner than sand beds, and the clay beds are laterally discontinuous. Locally, however, thin clay beds control migration of contaminants in the subsurface. Clayey sand beds also occur within the upper part of the section (i.e., in the Tobacco Road Formation and "Upland unit").

The sedimentary section in the A/M Area is divided into aquifer units and zones and confining units and zones based on relative permeabilities. The names of the units and zones follow the recent nomenclature developed by Aadland et al. (1992). The lowermost aquifer unit

penetrated by monitoring wells is the Crouch Branch Aquifer, which is overlain by the Crouch Branch Confining Unit. The Crouch Branch Confining Unit is further subdivided into two confining zones, which enclose the "middle sand" aquifer zone. The "Lost Lake" aquifer zone overlies the Crouch Branch Confining Unit, which, in turn, is overlain by the "green clay" confining zone. The "M-Area" aquifer zone is generally the water table aquifer in the A/M Area. Locally, however, the intervening confining zone has minimal thickness, resulting in the unconfined Steed Pond Aquifer which encompasses the entire Tertiary sequence.

Potentiometric maps, constructed using third quarter 1991 data, show predominantly downward flow potentials, although lateral flow is also significant in the "Lost Lake" aquifer zone/Steed Pond Aquifer. Local head differences exist both across the "green clay" confining zone and between similar elevation screens between individual wells. Local areas of recharge and areas of restricted flow are represented within the A/M Area.

The greatest concentration of trichloroethylene and tetrachloroethylene is associated with the M-Area Settling Basin. Another significant source of trichloroethylene and tetrachloroethylene is due to past leaks in the old Process Sewer Line along which solvents were transferred to the M-Area Settling Basin. Two other large contaminant source areas are the M-Area Solvent Handling/Storage Area, where leaks occurred during past storage and handling, and discharge along the A-014 Outfall related to both the M-Area Settling Basin and pre-settling basin discharge.

The hydrostratigraphic units in the A/M Area are interpreted specifically in the context of the A/M Area, as well as in relationship to the entire Atlantic Coastal Plain section and the stratigraphy specific to the SRS. The stratigraphic section thins and undergoes facies changes from the south and east toward the northwest and north across the SRS region. In the A/M Area, the section contains a higher percentage of clastic sediment and very little carbonate; elsewhere at the SRS, carbonate-rich units play a significant role in controlling hydraulic characteristics. The Crouch Branch Confining Unit also thickens to the east and south, and confining zones, which are minimal in the A/M Area, become more laterally continuous and thicken to the south. Because of facies changes and the thinning of important units, local controls are especially important in the A/M Area.

1.0 INTRODUCTION

1.1 Purpose and Scope of Work

A multiple aquifer system underlies the A/M Area, and understanding particle and transport potentials for constituents in that system necessitates refinement of boundary control conditions in this complex environment. As new subsurface data becomes available, updating of geologic and hydrostratigraphic interpretations and continued definition of contaminant plume is requisite. The site-specific hydrogeologic characteristics of the A/M Area relative to the regional SRS will continue to be an important aspect of future remediation activities.

Regionally, the SRS is underlain by sediments of the Atlantic Coastal Plain. Cretaceous to Tertiary strata consisting of unconsolidated to indurated sediments nonconformably overlie metamorphic, igneous, or sedimentary rocks ranging from ?Early Paleozoic to Triassic in age. Although these older rocks are overlain by several hundred to around one thousand feet of less consolidated sediments, their condition as basement to the coastal plain sediments is important for an understanding of regional stress relationships and existing fracture and joint systems in the SRS region. This report deals with the regional Atlantic Coastal Plain geology and hydrogeology including a discussion of regional stratigraphy and regional hydrostratigraphy as well as the most recent changes to hydrostratigraphic nomenclature.

Specific topics addressed for the A/M Area are an update of hydrostratigraphy and hydrostratigraphic nomenclature and vertical and horizontal distributions of contaminant plumes of trichloroethylene and tetrachloroethylene. The alphanumeric hydrostratigraphic system (Bledsoe and Aadland, 1991) nomenclature is generally included for comparative purposes with the newer A/M specific nomenclature of Aadland and others (1992); the alphanumeric system is being replaced by a regionally compatible nomenclature using geographical names. At the SRS, regional aquifer systems and confining systems are subdivided into site-wide aquifers and confining units. Subdivision into aquifer and confining zones is made on a site-specific basis. Contaminant distribution is outlined for a specific quarter (3Q91) or in some instances quarters (3Q91 and 4Q91) with each aquifer. Published aquifer properties are compiled along with general hydrogeologic characteristics of the Tertiary stratigraphic section.

1.2 Background History of the A/M Area

Construction of the Savannah River Site (SRS) was initiated by the United States Government in 1950. The main function of the SRS has been to produce nuclear materials for national defense. The SRS is part of the United States Department of Energy (DOE) Nuclear Weapons Complex. It is owned and operated by the DOE.

The SRS is located in south-central South Carolina and occupies an area of approximately 300 square miles (192,000 acres) (Fig. 1-1). The major physiographic feature is the Savannah River, which forms the southwestern boundary of the site and is also the South Carolina-Georgia border. The SRS includes portions of Aiken, Barnwell, and Allendale Counties in

Source: SAR, 1991

Figure 1-1. Location of the SRS in South Carolina

South Carolina. The site is located 25 miles southeast of Augusta, Georgia; 22 miles south of Aiken, South Carolina; and 100 miles northwest of the Atlantic Coast.

Eighteen production, service, and research and development areas are scattered across the 300-square-mile SRS site. The production facilities occupy less than 10 percent of the SRS area. The remainder of the site is forest or wetlands.

The A/M Area is an approximately 10-square-mile area in the northwestern section of the SRS (Fig. 1-1). It is located atop a wide, flat ridge in the drainage basin of the Savannah River and its tributaries (Upper Three Runs and Tim's Branch). The M-Area production facility was designed to process raw materials, such as uranium and lithium, into fuel and target assemblies for the SRS production reactors. The A Area has served as administrative and research center.

Within the A/M Area are various facilities that are known or suspected sources of groundwater contamination (Fig. 1-2). These areas include the M-Area Settling Basin, the Savannah River Laboratory (SRL) recently renamed the Savannah River Technology Center (SRTC), M-Area Solvent Handling/Storage Area, Process Sewer Line, A-001 Outfall, A-014 Outfall, and others. Due to the close proximity of these areas to one another, a comprehensive A/M Area Corrective Action Program was instituted. This collaborative approach allows for effective remediation of A/M Area groundwater contamination, regardless of source.

Installation of monitoring wells began in November 1979 in order to assess suspected contamination. In June 1981, groundwater contamination, mainly degreaser solvents (i.e., trichloroethylene and tetrachloroethylene), was discovered. Since that time over 300 monitoring wells, at more than 80 locations, have been installed to assess the vertical and horizontal extent of the contaminant plumes in the A/M Area.

The Corrective Action Program for the A/M Area began in February 1983 with the startup of a pilot air stripper. Air stripping of volatile organic contaminants from the groundwater was found to be an effective remediation technology and a full-scale system of groundwater recovery and air stripping was instituted in 1985. In 1987, a soil vacuum extraction process was tested and found to be an effective technology for removal of volatile organic compounds from the unsaturated (vadose) zone. A full-scale soil vacuum extraction system is currently being developed. Additionally, innovative technologies, such as horizontal well drilling and in-situ air stripping, have been evaluated for remediation of A/M Area contamination.

Figure 1-2. Known or Suspected Sources of Groundwater Contamination within the A/M Area

2.0 REGIONAL AND SITE GEOLOGY

2.1 Physiography

The Savannah River Site (SRS) region, defined as the area within a 200-mile radius of the center of the site, includes parts of the Atlantic Coastal Plain, Piedmont, Blue Ridge, and Valley and Ridge physiographic provinces (Fig. 2-1). The SRS is located on the Upper Atlantic Coastal Plain, about 30 miles southeast of the Fall Line (Figs. 2-1 and 2-2).

The Atlantic Coastal Plain extends southwest from Cape Cod, Massachusetts, to south-central Georgia where it merges with the Gulf Coastal Plain. The province is distinguished by a seaward-dipping wedge of unconsolidated and semiconsolidated sediments that extends from the contact with the crystalline Piedmont province at the Fall Line to the edge of the continental shelf. Sediment thickness increases from 0 feet at the Fall Line to more than 4000 feet at the South Carolina coastline. More than 30,000 feet of sediment occurs in the Carolina Trough beneath the South Carolina continental shelf (Klitgord and Behrendt, 1979). Coastal Plain strata in South Carolina range from early Late Cretaceous (Cenomanian) to Recent age (Hazel et al., 1977); sediments as old as Early Jurassic occur in the Carolina Trough (Klitgord and Behrendt, 1979).

Colquhoun and Johnson (1968) divided the South Carolina Coastal Plain into three physiographic belts: Upper, Middle, and Lower Coastal Plain (Fig. 2-2). The Upper Coastal Plain slopes from a maximum elevation of 650 feet above mean sea level (msl) at the Fall Line to about 250 feet above msl on its southeastern boundary. Primary depositional topography of the Upper Coastal Plain has been obliterated by fluvial erosion. The Upper Coastal Plain is separated from the Middle Coastal Plain by the Orangeburg Scarp, which has a topographical relief of approximately 100 feet over a distance of a few miles. The Orangeburg Scarp is the site of Eocene, Upper Miocene, and Pliocene (?) shorelines (Colquhoun and Johnson, 1968). The Middle Coastal Plain, separated from the Lower Coastal Plain by the Surry Scarp (Fig. 2-2), is characterized by lower elevations and subtle depositional topography that has been significantly modified by fluvial erosion (Rankin, 1977). The Lower Coastal Plain is dominated by primary depositional topography that has been modified slightly by fluvial erosion.

Siple (1967) and Cooke (1936) previously divided the Upper Coastal Plain of South Carolina into the Aiken Plateau and Congaree Sand Hills (Fig. 2-2). The Aiken Plateau, where the SRS is located, is bounded by the Savannah River and Congaree River (shown as Broad River on Fig. 2-2) and extends from the Fall Line to the Orangeburg Scarp. Its highly dissected surface is characterized by broad interfluvial areas with narrow, steep-sided valleys. Local relief in the dissected areas is as much as 300 feet (Siple, 1967). The plateau is generally well drained, although many poorly drained sinks and depressions exist, especially on the topographically high (250 feet above msl) "Upland unit". Some depressions may represent original depositional topography, whereas others are related to dissolution of either underlying calcareous sediment (Siple, 1967; and USACE, 1952) or other sediment (Smith, 1931).

Source: SAR, 1991

Figure 2-1. Physiographic Provinces of the Eastern United States

PHYSIOGRAPHIC SUBPROVINCES OF THE SOUTH CAROLINA COASTAL PLAIN

Fig. 2-2. Physiographic Subprovinces of the South Carolina Coastal Plain

The site region contains elliptical depressions called Carolina Bays. These features, common throughout the Atlantic Coastal Plain, are most numerous in North and South Carolina. Some of the depressions within the SRS have axes up to 6000 feet long (Siple, 1967). Because the Carolina Bays are closed depressions, surface water tends to locally recharge the groundwater at faster rates. This can result in a localized groundwater mounding effect associated with the Carolina Bays.

The Congaree Sand Hills trend along the Fall Line northeast and north of the Aiken Plateau (Fig. 2-2). The Congaree Sand Hills are characterized by gentle slopes and rounded summits that are interrupted by valleys with southeasterly flowing streams (Siple, 1967).

The Piedmont province is the easternmost physiographic and geologic province of the Appalachian Mountains. It extends southwest from New York to Alabama and is adjacent to the Atlantic Coastal Plain (Fig. 2-1). The Piedmont province is a seaward-sloping plateau, whose width varies from about 10 miles in southeastern New York to almost 125 miles in North Carolina; it has the least rugged topography of the Appalachian physiographic provinces. The elevation of the inland boundary ranges from about 200 feet above msl in New Jersey to over 1800 feet above msl on isolated mountain peaks in Georgia. In the southeastern portion of the province, bedrock is poorly exposed because it is generally covered by deep residual soil and saprolite. In North Carolina, South Carolina, and Georgia, the Piedmont province consists of a metamorphic suite of gneiss, schist, phyllite, and slate which are intruded by plutonic rocks of alkalic to calcalkalic to ultramafic composition. The Paleozoic metamorphic grade of the province generally increases from east to west.

The Blue Ridge province extends southwest from Pennsylvania to northern Georgia (Fig. 2-1). It is about 30 miles wide in its northern half and up to 75 miles wide in the southern section. Elevations are highest in North Carolina and Georgia, where several peaks exceed 6000 feet above msl, including Mount Mitchell, North Carolina, the highest point (6684 feet above msl) in the Appalachian Mountains. The Blue Ridge front, with a maximum elevation of 4000 feet above msl in North Carolina, is an east-facing escarpment that forms the border between the Blue Ridge and Piedmont physiographic provinces in the southern Appalachians. The Blue Ridge geologic province, which extends approximately 10 miles eastward beyond the Blue Ridge front, is a metamorphosed basement/cover sequence with complex folds and faults.

The Valley and Ridge province extends southwest from the northeastern corner of the United States to central Alabama (Fig. 2-1). The province is a thrust-faulted and folded sedimentary section consisting of sandstone, shale, limestone, and conglomerate. The parallel ridge and valley topography, which is the result of differential erosion of the sedimentary layers, is characterized by large amplitude folds in the northern part of the Valley and Ridge province. In the southern section, an elongate zone of thrust systems is the dominant structural control of the ridge and valley topography. The eastern boundary with the Blue Ridge province is topographically distinct and marked by the Alleghenian Blue Ridge thrust system. The western boundary with the Appalachian Plateau is typically a thrust or overturned fold.

2.2 Geologic History

The eastern continental margin of the North American, or Laurentian, craton has evolved to its present state over geologic time through a series of plate collision and rifting episodes. Collision events generally are correlative with mountain building because they may result in folded mountain ranges, such as the Alps or the Appalachians. These folded mountain chains are supported by thickened continental crust "floating" in the underlying, denser mantle.

Rifting, or "pull-apart", events initially produce fault-bounded basins in which sediments accumulate. Thinning of the upper mantle (mantle lid) allows increased heat flow from deeper levels within the earth, and consequent thermal expansion of the continental crust produces local uplift due to isostatic adjustment. Subsequent erosion may result in thinning of the continental crust and deposition of the eroded sediments into rift basins. The Atlantic continental margin has been a site of coastal sediment accumulation since Middle Jurassic time, about 175 million years ago.

Collisional events occur when continental masses collide. As two continents approach one another, adjacent oceanic crust is destroyed in subduction zones, and continental margin sediments are either compressed, folded, and thrust onto the colliding continents and/or metamorphosed beneath the edge of a continental mass (Fig. 2-3). The Appalachians, Alps, and Himalayas are examples of such folded mountain chains. The overriding of one continental mass by another results in thickening of the continental crust, producing mountain chains that were not in isostatic equilibrium following cessation of contractional tectonics. Negative Bouguer gravity anomalies associated with mountain belts are evidence for the overthickened crust. Because collisions are accompanied by metamorphism and production of igneous intrusive rocks, radiometric "clocks" may be reset during orogenesis, and the timing of the events may be dated.

The oldest rocks routinely encountered in the southern Appalachian area are approximately 1.2 billion years old and are attributed to metamorphic and igneous activity during the Grenville orogeny (Davis et al., 1962; Hatcher, 1972; Odom et al., 1973; and Bartholomew and Lewis, 1984). Grenville-age rocks form the crystalline basement beneath the Valley and Ridge province (SAR, 1991). Seismic data suggest that the Valley and Ridge province extends southeastward beneath the allochthonous Blue Ridge and western Piedmont provinces as well. The Grenville orogeny was followed by rifting events that began about 760 million years ago. This early (760-700 million years ago) rifting is recorded by the rocks of the Ocoee Supergroup (preserved in the Blue Ridge province), which were deposited in rift basins, and by intrusion of rift-related gabbros and granites. A passive continental margin had developed along the east coast of North America in Early Cambrian time following the second phase of rifting about 600 to 570 million years ago. Basaltic volcanism occurred during this phase. The rift-to-drift transition is recorded in sediments of the Chilhowee Group, named for exposures on Chilhowee Mountain in eastern Tennessee, which accumulated in the miogeocline. The timing of collisional events along the eastern margin of North America is reflected by the source of coeval sediments deposited in the miogeocline. Sediments deposited during the Early Cambrian (600-550 million years ago) indicate a western sediment source. By Early

Source: SAR, 1991

Figure 2-3. Processes Occurring at a Convergent Plate Boundary

Ordovician time (about 485 million years ago), the source of sediments now preserved in eastern Tennessee was clearly from the east.

Much of the material now in the Piedmont physiographic province (Inner Piedmont, Kings Mountain belt, Charlotte belt, Carolina Slate belt, Kiokee belt, Belair belt) consists of exotic lithostratigraphic terranes, which were involved in a collisional event about 600 million years ago (Harris and Glover, 1988). These terranes are similar in age to the igneous rocks in Africa that were affected by the pan-African II event, suggesting that exotic blocks of the Avalonian, or Carolina, terrane originated in Late Precambrian to Early Paleozoic (655-525 million years ago) settings far from North America, probably as island arcs (Avalon platform) adjacent to Africa (Fig. 2-4) (Harris and Glover, 1988; Secor et al., 1983; Secor et al., 1986a; and Secor et al., 1986b).

By Middle Ordovician time (475 million years ago), these exotic terranes were near North America, and their accretion to the Laurentian margin began as a collisional event (the Taconic orogeny), which continued into the Silurian period (Fig. 2-4). Continued accretion of exotic terranes of the Piedmont province to North America was concomitant with a regional metamorphic event and associated igneous activity in the Silurian, Devonian, and Early Carboniferous (430-355 million years ago), (the Acadian orogeny) (Fullagar, 1971) (Fig. 2-4). The convergence of the Laurentian and African cratons continued until the African plate overrode the edge of the North American plate during Late Carboniferous and Permian time (325-265 million years ago), causing the deformation and plutonism of the Alleghenian orogeny (Fig. 2-4). Granites dated at about 300 to 275 million years may record melting of the lower edge of the North American crustal plate associated with this collision. The mountains of each of these Paleozoic orogenies downwarped the adjacent crust of North America, forming the foreland Appalachian basin, which received sediments shed from the highlands to the east. The youngest sediments deposited in the Appalachian basin are Carboniferous and Permian in age. By the mid-Permian period (about 250 million years ago), isostatic uplift of the Appalachian Mountain chain eliminated the sea in which sediments had been accumulating.

Early in the Mesozoic Era (about 240 million years ago), the supercontinent Pangea, formed during the Paleozoic collisions, began to break up. The present Atlantic Ocean was created by diachronous rifting between North and South America on the west and Africa and Eurasia on the east, beginning in the north and progressing southward. Rift basins formed along the east coast of North America (Fig. 2-5) were the locale of accumulation of thick (1-3 miles) sequences of sediments in the Late Triassic (about 225 million years ago). In Virginia and North Carolina, a western belt of basins ends in Davie County, North Carolina; an eastern belt extends beneath the Coastal Plain sediments into South Carolina and is approximately aligned with the Dunbarton basin, which underlies Coastal Plain sediments in the southeastern part of the SRS. Rifting of the continental crust ceased in Early Jurassic time (190 million years ago). Since then the Atlantic Coast of North America has been a passive continental margin characterized mostly by subsidence and sediment accumulation. Some differential subsidence, or uplift, has occurred, causing broad features such as the Cape Fear Arch and the South Georgia Embayment.

TECTONIC SETTING OF EASTERN UNITED STATES

LATE PRECAMBRIAN EXTENSION

LATE PRECAMBRIAN SPREADING

LATE PRECAMBRIAN - EARLY CAMBRIAN

MIDDLE ORDOVICIAN - SILURIAN (TACONIC OROGENY)

DEVONIAN - EARLY CARBONIFEROUS (ACADIAN OROGENY)

LATE CARBONIFEROUS - PERMIAN (ALLEGHENIAN OROGENY)

SOURCE: URANIUM SOLDIFICATION FACILITY SITE CHARACTERISTICS, APPENDICES 3A, 3B, 3C, OCTOBER, 1989.

DWG NO.
 G00125

Source: SAR, 1991

Figure 2-4. Tectonic Setting of Eastern United States

Source: SAR, 1991

Figure 2-5. Triassic-Jurassic Rift Basins of Eastern North America

Metasedimentary and metaigneous rocks of pre-Triassic age beneath the SRS are folded and faulted, and intruded by predominantly granitic plutons. This deformation and metamorphism was associated with accretion of exotic terranes to Laurentia. Accretion occurred during the Taconic, Acadian, and Alleghanian orogenies, which culminated about 265 million years ago at the close of the Paleozoic Era. At that time, Africa collided with North America, and the crystalline basement rocks beneath the SRS were emplaced in their present position.

At the SRS, a Mesozoic rift basin (Dunbarton basin) (Fig. 2-5) is faulted against the crystalline basement, filled with a thick, terrigenous clastics, sedimentary sequence, and intruded by diabase sills and dikes. Subsequently, as the drifting phase of sea floor spreading began in the Atlantic Ocean, rifting in the Dunbarton basin ceased, and a gently undulating erosional surface formed across both the basement complex and Mesozoic rift sediments. The continental margin has since been a passive margin and is characterized by general subsidence and gradual accumulation of a shelf sequence of sediments.

The Coastal Plain at the SRS was formed during Late Cretaceous (Turonian-Cenomanian) time with the deposition of fluvial and deltaic sediments. Coastal Plain sediments began to accumulate at this time because sea level rose 650 to 980 feet above its present level, and the basement complex was downwarped to the southeast to compensate for sediment loading on the more seaward portions of the continental margin (SAR, 1991). Deposition of sediments in fluvial and deltaic environments continued into the Early Eocene. During Middle and Late Eocene time, deposition of Coastal Plain sediments at the SRS occurred in shallow marine environments. Deposition was interrupted several times during this epoch during sea level falls.

Sea level fell following deposition of the Eocene sediments, and, except for the deposition of the "Upland unit", erosion subsequently prevailed on the Coastal Plain. The "Upland unit" was deposited by streams as they cut down into the underlying strata. The only present-day sedimentation on the Coastal Plain occurs mainly in floodplains and swamps.

2.3 Atlantic Coastal Plain Stratigraphy, Lithology, and Structure

The SRS is located on the Upper Atlantic Coastal Plain. In South Carolina, the Atlantic Coastal Plain extends southwest from Massachusetts to south-central Georgia and consists of stratified sand, clay, limestone, and gravel. The province dips gently seaward and ranges from Late Cretaceous age to Recent age (Figs. 2-6, 2-7, and 2-8). Thickness of the sedimentary sequence increases from 0 feet at the Fall Line to more than 4000 feet at the coast. Regional dip is to the southeast, at 35 feet/mile (Klitgord and Behrendt, 1979) although beds dip and thicken locally in other directions because of locally variable depositional regimes and differential subsidence of basement features, such as the Cape Fear Arch and the South Georgia Embayment.

The province is divided into several formations and groups based principally on age and lithology. Siple (1967) provided the basic geologic framework for the SRS. Although the regional nomenclature is still evolving, much of Siple's nomenclature is currently used at

Source: SAR, 1991

Figure 2-6. Geologic Map of South Carolina

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PLATE 19. REGIONAL HYDROST

PREPARED BY: ROLF K. AADLAND, 1989

DRAWN BY: ROD A. BOLT

MODIFIED FROM D. COLQUHOUN ETAL. 1983

HYDROSTRATIGRAPHIC CROSS-SECTION

REV. NO.	DATE	REVISION	GEIS	DRIFT
1	11/15/91	REVISED CLAYS GROUPS & FH		TLH

DOC NO. R00017	REV. NO. 1	REV. DATE 3-24-94	AREA SITE
SAVANNAH RIVER SITE		ENVIRONMENTAL RESTORATION "Restoring the Environment Today for a Cleaner Tomorrow"	
TITLE PLATE 19. REGIONAL HYDROSTRATIGRAPHIC CROSS-SECTION			
CREATED BY R.BOLT	DATE 3-24-94	APPROVED BY NA	DATE 93
PREPARED BY R.AADLAND	DATE 3-24-94	APPROVED BY NA	DATE 93
APPROVED BY NA	DATE 93	APPROVED BY NA	DATE 93
APPROVED BY NA	DATE 93	APPROVED BY NA	DATE 93

PREPARED BY: ROLF K. AADLAND, 1989
DRAWN BY: ROD A. BOLT
MODIFIED FROM D. COLOUHOON ETAL. 1983

[illegible]

SCALE

MILES 0 10 20 30

KILOMETERS 0 10 20 30 40 50

KEY PLAN

STRATIGRAPHIC CROSS-SECTION

SOUTHEAST

AL. CO. — HAMPTON CO.

13.4 MI

AL IND.
PARK
AL-22

WESTINGHOUSE
HAM
46
(38)

REV. NO.	DATE	REVISION	GELS	DWFT
1	12/18/91	REVISED CLAYS & GROUP/FORMATIONS		

DWG. NO. R00016	REV. NO. 1	REV. DATE 3-24-94	AREA SITE
SAFETY • RESPONSIBILITY • SECURITY SRS SAVANNAH RIVER SITE		ENVIRONMENTAL RESTORATION EAR Restoring the Environment Today for a Cleaner Tomorrow	
TITLE PLATE 2. REGIONAL STRATIGRAPHIC CROSS-SECTION			
CREATED BY R.BOLT	DATE 3-24-94	APPROVED BY NA	DATE 93
PREPARED BY R.AADLAND	DATE 3-24-94	APPROVED BY NA	DATE 93
APPROVED BY NA	DATE 93	APPROVED BY NA	DATE 93
APPROVED BY NA	DATE 93	APPROVED BY NA	DATE 93

the SRS. Current formation names and groups are listed below and discussed in the following sections:

- Late Cretaceous sediments
- Paleocene-Eocene Black Mingo Group
- Middle Eocene Orangeburg Group
- Late Eocene Barnwell Group
- "Upland unit"
- Quaternary deposits

2.3.1 Late Cretaceous Sediments

The Cape Fear Formation, the basal unit of the Coastal Plain stratigraphic section at the SRS (Fig. 2-9), is not observed at the surface in the vicinity of the SRS. A lithofacies of this formation may be included in the undifferentiated Late Cretaceous sediments (Nystrom and Willoughby, 1982a,b) updip from the SRS. The Cape Fear Formation is about 30 feet thick at the northwestern boundary of the SRS and thickens to more than 180 feet near the southeastern boundary. Correlation of the basal Cretaceous sediments at the SRS with the type Cape Fear Formation is uncertain. The type locality is in southern North Carolina, and the unit is not extensively traced in the subsurface to the south. Furthermore, reported ages vary from Santonian to Coniacian (Prowell et al., 1985a; Nystrom and Willoughby, 1982a,b; Gohn et al., 1977; Christopher et al., 1979; and Carter, 1983). Pollen dated as possibly Turonian or Coniacian has been recovered from a Cape Fear Formation sample at the SRS. Future correlation studies may reveal that the lowest Cretaceous unit found at the SRS is inappropriately named; therefore, the term "Cape Fear Formation" is used provisionally.

The Cape Fear Formation is composed of poorly sorted, silty to clayey quartz sand and interbedded clay. The sand is locally arkosic. Mica (muscovite) and iron sulfides (pyrite) also characterize the sediments. Pebbly quartz zones are present in many parts of the section. Cape Fear Formation sediments are more indurated than the other Cretaceous formations because of their high clay content and abundance of cristobalite in the matrix. The quartz sand is typically medium-grained but ranges from very fine- to coarse-grained. In general, bedding thickness varies from about 5 to 20 feet and sand units are thicker than clay units. The environment of deposition is interpreted as upper delta plain (Fig. 2-10) (Prowell et al., 1985a).

The Lumbee Group overlies the Cape Fear Formation and consists, from oldest to youngest, of the Middendorf, the Black Creek, and the Peedee Formations. Lumbee Group strata crop out between the Fall Line and the SRS, and time-equivalent units of these three Cretaceous formations are present at the SRS (Fig. 2-9). The Middendorf and Black Creek Formation lithologies at SRS are comparable to the type localities in northern South Carolina and southern North Carolina. However, the Peedee Formation equivalent at the SRS is dissimilar to the type Peedee Formation.

Within the SRS, Cretaceous strata (Lumbee Group) were previously referred to as the Tuscaloosa Formation (Siple, 1967; Swift and Heron, 1969). The type Tuscaloosa Formation

Figure 2-9. Stratigraphic Column for the SRS

Source: SAR, 1991

Figure 2-10. Depositional Environments of Coastal Plain Sediments

is Santonian in age, but all fossil dates obtained from the Cretaceous sediments in the southwestern South Carolina Coastal Plain are younger than Santonian. Much of what Siple (1967) mapped as the Tuscaloosa Formation in outcrops to the north of the SRS is now assigned, using new paleontological data (Scrudato and Bond, 1972; Abbott and Zupan, 1975; Inden and Zupan, 1975; and Tschudy and Patterson, 1975), to Eocene formations.

In the central Savannah River area it is difficult to distinguish among some of the exposures of Cretaceous formations, and they are mapped as undifferentiated Upper Cretaceous (Nystrom and Willoughby, 1982a,b). The dip of the upper surface of the Lumbee Group is to the southeast at approximately 21 feet/mile across the SRS. Thickness varies across the site from 380 feet in the northwestern part of the SRS to more than 740 feet near the southeastern boundary. In general, the Lumbee Group consists of variably colored sand and clay, although calcareous strata occur downdip from the SRS. At the coast this group is more than 1500 feet thick (Colquhoun et al., 1983).

The Middendorf Formation unconformably overlies the Cape Fear Formation along a sharp, distinct contact. The Middendorf Formation is correlated by outcrop tracing from its type locality in northern South Carolina to outcrops northwest of the SRS (Nystrom and Willoughby, 1982a,b). In the subsurface, the formation is approximately 130 feet thick near the northwestern boundary of the SRS; it thickens to more than 180 feet near the southeastern boundary. The Middendorf Formation has been assigned a Late Santonian age in the SRS area (Prowell et al., 1985a).

Quartz sand, especially in the northern part of the SRS, is the dominant lithotype of the Middendorf Formation, and sand-rich units of the Middendorf Formation are much cleaner and less indurated than Cape Fear Formation sediments. The Middendorf Formation is dominantly medium and coarse sand, but grain size is locally variable. Sorting is generally moderate to good. Pebbly zones are common within the sand, and clay clasts occur locally. Some parts of the unit are feldspathic; micaceous and lignitic zones also occur. Cross-bedding is well developed in the lower part of the formation.

In the northern part of the SRS, clay beds are only about 2 feet thick but thicken considerably downdip to form distinct units near the middle and at the top of the Middendorf Formation in the south and southeastern areas of the SRS. Kaolinite clay lenses occur interspersed throughout the formation. The upper clay zone, locally, is 80 feet thick. The upper unit varies from clay to interbedded clay and sand, and is increasingly micaceous and lignitic to the southeast. Fining-upward sequences are typical of the interlayered sandy beds. In older SRS geologic reports (e.g., Siple, 1967), the upper clay-rich unit was termed the "Middle Tuscaloosa Clay".

Within the area of occurrence of the Black Creek Formation, percentages of quartz sand, silt, and clay vary downdip. Compared to other Late Cretaceous units in the region, the Black Creek Formation is distinguished by darker color and a higher percentage of mica and lignite. Sandy layers are fine- to coarse-grained and moderately to poorly sorted. Zones of pebble conglomerate and clay intraclasts commonly occur associated with the sand units, which may locally contain feldspar. According to Logan et al. (1989), the environment of deposition of

most of the Black Creek Formation was a lower delta plain, although they considered the light-colored sand of the northwestern SRS as a derivative of an upper delta plain environment (Fig. 2-10).

At the SRS, the Black Creek Formation lithofacies change from northwest to southeast. In the northwestern SRS area, the lower part of the formation is mostly light-colored fissile clay and is separated from an upper clayey, silty unit by a sandy zone. The clay-rich part of the uppermost unit may be 20 to 40 feet thick and contain local orange-brown oxidized zones (Fallaw, 1991) and root traces. In the central and southwestern SRS area, the dominant lithotype is micaceous, lignitic, silty sand with thin interbeds of clay. To the southeast, the uppermost lithofacies is generally fine-grained and is predominantly dark gray clay. Fining-upward sequences of dark, fine- to medium-grained sand also occur. Iron sulfides occur within both the clay and sand beds.

The Peedee Formation at its type area in northeastern South Carolina is dark, glauconite-bearing, fine-grained sandstone and siltstone. Marine fossils indicate a shallow shelf environment of deposition. The formation was traced in the subsurface into southwestern South Carolina (Colquhoun et al., 1983) where light-colored sand and distinctively colored clay are the typical lithologies. In South Carolina, the Peedee Formation is Middle to Late Maastrichtian age (Prowell et al., 1985a). Dinoflagellates and pollen of Maastrichtian age were recovered from the Steel Creek member at the SRS.

Because of lithologic disparities between the type Peedee Formation and laterally equivalent sediments in southwestern South Carolina, the deposits in the vicinity of the SRS are referred to as the Steel Creek Member of the Peedee Formation. The Steel Creek Member was defined using the sequence in well P-21 near Steel Creek. Surface outcrops of the Steel Creek Member, as recognized in the P-21 well, have not been recognized near the SRS. However, northwest of the SRS, a lithofacies, identified by Nystrom and Willoughby (1982a,b) in an undifferentiated Upper Cretaceous sequence, may be a lateral equivalent. In the subsurface, the Steel Creek Member is approximately 110 feet thick near the northwestern SRS boundary and about 130 feet thick at the southeastern boundary.

The lower part of the Steel Creek Member is sandy, and a pebble-rich zone at its base suggests a basal unconformity. This lower deposit consists of poorly to well-sorted, fine- to coarse-grained quartz sand and silty sand and in places is very micaceous. Concentrations of feldspar and lignite also occur. Pebbly zones are common, as are layers with clay clasts. The upper part of the Steel Creek Member is a clay that varies from more than 50 feet to less than 3 feet in thickness at the SRS. Fining-upward sand is interbedded with the clay in some areas. The Steel Creek Member probably formed in an upper delta plain environment (Fig. 2-10) in the southwest and in a lower delta plain in the northeast. Marine microplankton (dinoflagellates) indicate some marine influence in parts of the Steel Creek Member.

2.3.2 Paleocene-Eocene Black Mingo Group

In southwestern South Carolina, the Black Mingo Group consists of the Danian (Early Paleocene) Ellenton Formation, the Early and Middle Thanetian (Late Paleocene) Williamsburg

Formation (Abbott and Zupan, 1975), and the Late Ypresian (Early Eocene) Fishburne Formation (Gohn et al., 1983). These formations, with the possible exception of the Fishburne Formation, have been traced updip in the subsurface from their type localities in the Lower Coastal Plain of South Carolina to the SRS (Fig. 2-6). One Late Sabinian (Thanetian) fossil assemblage was found at the SRS, but the distribution of any Fishburne Formation equivalent is not known at this time. Late Paleocene deposits crop out in a few places northwest of the SRS. The upper surface dips to the southeast at about 16 feet/mile across the SRS. The Black Mingo Group is about 70 feet thick at the northwestern SRS boundary, thickens to about 150 feet near the southeastern boundary, and is about 700 feet thick at the coast (Colquhoun et al., 1983).

The Ellenton Formation was defined and described from well cuttings at the SRS by Siple (1967). At that time, he thought that the age of the formation was either Cretaceous or Paleocene. The formation was later dated as Midwayan (Paleocene) (Prowell et al., 1985b) and found to be laterally equivalent to the Rhems Formation. Because it is lithologically different from the type Rhems Formation, the "Ellenton" was considered to be a member of the Rhems Formation (Colquhoun et al., 1983). The Ellenton Formation crops out about 4 miles northwest of the SRS in the valley of Hollow Creek. The Ellenton Formation is approximately 40 feet thick at the northwestern boundary of the SRS and thickens to about 100 feet near the southeastern boundary. The Midwayan (Danian) section, at the coast, is about 250 feet thick and is calcareous in nature (Colquhoun et al., 1983). Dinoflagellate and pollen samples of Midwayan (Danian) age have been obtained from Ellenton Formation samples at the SRS.

The Ellenton Formation lies unconformably above the Upper Cretaceous sediments and consists mostly of gray, micaceous, lignitic, poorly sorted, silty and clayey quartz sand interbedded with gray clay. Iron sulfide minerals and cristobalite are common in the darker parts of the lignitic clay section. Moderately to well-sorted, glauconitic, fine-grained quartz sand also occurs. Upper delta plain deposits (Fig. 2-10) composed of light-colored, moderately to poorly sorted, micaceous quartz sand are common in the northwestern part of the SRS. Darker, poorly sorted, micaceous, lignitic lower delta plain facies (Fig. 2-10) become dominant in the southeastern part.

The Williamsburg Formation is about 350 feet thick and calcareous near the coast (Colquhoun et al., 1983). The deposits near the SRS that are time-equivalent to the Sabinian (Ypresian/Thanetian) age Williamsburg Formation differ from the type Williamsburg Formation and are designated as the Snapp Member of the Williamsburg Formation. The unit is represented in well P-22 in the southeastern part of the SRS near Snapp Station. Snapp Member sediments have not been identified in outcrop northwest of the SRS. The Snapp Member is about 30 feet thick at the northwestern SRS boundary and thickens to about 50 feet near the southeastern boundary. A few dinoflagellate and pollen samples indicating a Sabinian (Ypresian/Thanetian) age have been found at the SRS.

Snapp Member sediments are typically medium- to coarse-grained, silty, quartz sand interbedded with clay. Dark, micaceous, lignitic sand also occurs. In the northwestern part of the SRS, the Snapp Member is less silty and better sorted and has thinner clay interbeds. The Snapp Member changes from an upper delta plain facies in the northwestern part to a lower

delta plain facies (Fig. 2-10) in the southeastern part of the SRS. The basal contact is probably unconformable with the underlying Ellenton Formation.

The Four Mile Member of the Fishburne Formation crops out northwest of the SRS where it has been mapped as part of the Huber Formation. The Four Mile Member of the Fishburne Formation has been traced in the subsurface into the northwestern area of the SRS (Fallaw, 1991). Four Mile Member sand beds are variable in color, fine- to coarse-grained, moderately to well sorted, and loose. A few pebbly zones occur near the base of the unit. A clayey zone of varying thickness may be interbedded with the sand sequence. Based on lithologic characteristics the Four Mile Member sand probably was deposited in a shallow marine environment and the clay probably formed in bays or lagoons (Fallaw, 1991).

2.3.3 Middle Eocene Orangeburg Group

The Claibornian (Bartonian/Lutetian) Orangeburg Group in the southwestern Coastal Plain of South Carolina consists of the lower Middle Eocene Congaree Formation, the middle Middle Eocene Warley Hill Formation, and the upper Middle Eocene Santee Formation (Lisbon equivalent) (Fig. 2-9). The Orangeburg Group crops out at lower elevations along drainage in many places at the SRS and in its vicinity. A pisolitic clay zone that is present at the base of the Claibornian (Bartonian/Lutetian) sediments in South Carolina is similar to the clay zone at the base of Claibornian (Bartonian/Lutetian) deposits in the Gulf Coastal Plain. The sediments thicken from approximately 100 feet at the northwestern SRS boundary to about 160 feet near the southeastern boundary. The upper surface dips about 12 feet/mile to the southeast across the SRS. Downdip at the coast, the Orangeburg Group is about 325 feet thick (Colquhoun et al., 1983).

The lower Middle Eocene age Congaree Formation has been traced from the Congaree valley in central-eastern South Carolina into the SRS area; many different stratigraphic names have been applied to these deposits in the southwestern South Carolina Coastal Plain (Colquhoun et al., 1983). The Congaree Formation equivalent northwest of the SRS was mapped as the Huber Formation (Nystrom and Willoughby, 1982a,b). The Huber Formation is more micaceous than the Congaree Formation and is poorly sorted and indicates deposition in fluvial and deltaic environments (Fig. 2-10). Lower Middle Eocene deposits are increasingly calcareous between the SRS and the coast (Colquhoun et al., 1983).

The Congaree Formation is about 60 feet thick at the northwestern boundary of the SRS and about 85 feet thick near the southeastern boundary. At the SRS, the Congaree Formation consists of yellow, orange, tan, gray and greenish gray, well-sorted, fine- to coarse-grained quartz sand. Thin clay laminae occur throughout the section, and pebbly layers, clay clasts, and glauconite are locally present. Quartz grains tend to be better rounded than those in the rest of the stratigraphic column. A glauconitic clay encountered in some wells at SRS may be at or near the base of the formation, which is unconformable. In many localities at the SRS, the upper part of the Congaree Formation is silica-cemented, and in other places it is slightly calcareous. The well-sorted sand and high permeability of the Congaree Formation are indicative of a shallow marine depositional environment (Fallaw, 1991) (Fig. 2-10).

Upper Middle Eocene age deposits in the vicinity of the SRS consist of carbonate, calcareous quartz sand, quartz sand, glauconitic sand, and clay and are included in the Santee Formation. The names "McBean Formation" and "Lisbon Formation" have been applied in the past to sediments in this sequence. The McBean Formation at its type locality in Georgia, across the Savannah River from the SRS, consists of limestone overlain by quartz sand. Most of the overlying sand is apparently of Late Eocene age (Huddleston and Hetrick, 1985), and the typical McBean Formation carbonate lithology is limited to a small area near the type locality. The Georgia Power Company Plant Vogtle Final Safety Analysis Report (FSAR) uses "McBean" as a member of the Lisbon Formation (Carter, 1983). "McBean Member" of the Santee Formation has been used, at the SRS, because the type locality of the Santee Formation in South Carolina is geographically closer than the type Lisbon Formation in Alabama and because "Santee" has priority (Connell, 1968). Sloan (1908) used the "Santee", "Warley Hill", and "Caw Caw" nomenclature at the SRS before the McBean Formation was proposed by Veatch and Stevenson (1911). The "McBean Formation" of previous SRS reports consists largely of sediments that are now known to be Late Eocene (Dry Branch Formation). All members of the Santee Formation are exposed at the surface within the SRS boundaries. The formation is approximately 40 feet thick at the northwestern boundary of the SRS and thickens to more than 80 feet near the southeastern boundary. Many fossils of Middle Eocene age have been recovered from the Santee Formation at the SRS.

A fine-grained, often glauconitic sandstone occurs at the base of the Santee Formation at many locations throughout the SRS. Sloan (1908) assigned outcrops of this sandstone along Tinker Creek to his "Warley Hill phase" and correlated it to his type Santee Formation locality in Calhoun County in the central-eastern South Carolina Coastal Plain. These sediments are referred to as "Warley Hill Formation" (Aadland et al., 1992). Sloan (1908) also referred to outcrops of green clay along Tinker Creek as the "Caw Caw phase", for which the type locality also is in central-eastern South Carolina. These deposits are assigned to the "Caw Caw Member" of the Santee Formation in this report. Both the Warley Hill and the Caw Caw lithologies occur at, or near, the base of the Santee Formation at the SRS and are referred to collectively as the "green clay" in many SRS reports. Clay beds in this interval are laterally discontinuous in the northernmost SRS area. This unit has more lateral continuity south of Upper Three Runs Creek. The remainder of the Santee Formation, assigned to the McBean Member, is made up of micritic, calcarenitic, and bioclastic limestone suggestive of shallow marine depositional environments (Fig. 2-10), calcareous quartz sand, and noncalcareous, generally fine-grained quartz sand. Calcareous components of the McBean Member are rare in the northwestern area of the SRS and somewhat abundant in the central area, but they become widespread and thick in the southeastern areas of the SRS. Siple (1967) speculates that dissolution of calcareous material in the Santee Formation occurred locally at the SRS and caused subsidence of overlying beds and formation of depressions. Siple (1967) noted that voids and loosely compacted sediments were encountered during well drilling and mentioned that large amounts of cement grout were required to stabilize the subsurface before construction of heavy structures.

2.3.4 Late Eocene Barnwell Group

Late Eocene age deposits unconformably overlie the Santee Formation. Huddleston and Hetrick (1985) revised the Upper Eocene stratigraphy of the Georgia Coastal Plain, and their interpretation was extended into South Carolina (Nystrom and Willoughby, 1982a,b; and Nystrom et al., 1986). These authors elevated the Eocene (Priabonian) "Barnwell Formation" to "Barnwell Group", the type locality of which is located in Burke County, Georgia, and includes (from oldest to youngest) the Clinchfield, Dry Branch, and Tobacco Road Formations (Fig. 2-9). The Clinchfield Formation is sandy in Georgia and contains some clay and siliceous sponge spicules. It thins markedly and grades into sandy limestone downdip and to the east. The Dry Branch Formation includes the Twiggs Clay Member, which predominates west of the Ocmulgee River in Georgia; the Irwinton Sand Member, which predominates from the Savannah River eastward; and the Griffins Landing Member, which contains beds of calcareous sand, clay, and carbonate. The Tobacco Road Formation, the youngest unit of the Barnwell Group, is probably the typical "Barnwell" of older literature.

Quartz sand of the Clinchfield Formation has been distinguished only when contrasting carbonates of the Griffins Landing Member of the Dry Branch Formation and the McBean Member of the Santee Formation occur, with the sand sandwiched between them. This quartz sand was identified at three localities within the SRS, where it is up to 25 feet thick, but it is not generally mappable.

The Dry Branch Formation, which crops out in many places around and within the SRS, is about 50 feet thick near the northwestern boundary and about 80 feet thick near the southeastern boundary. Most of the upper, noncalcareous part of the "McBean Formation" of previous SRS reports is the Irwinton Sand Member. The Late Eocene age of the Dry Branch Formation was established in Georgia (Huddleston and Hetrick, 1985).

The carbonate portion of the Griffins Landing Member of the Dry Branch Formation is up to 45 feet thick in the southeastern part of the SRS. Several fossil samples of Late Eocene age have been taken from the Griffins Landing Member at the SRS. Previous SRS geology reports assigned all carbonate to the Middle Eocene "McBean Formation". The Griffins Landing carbonate occurs locally at the SRS and is not known to be present northwest of Tinker Creek and Upper Three Runs Creek within the SRS boundaries. Sloan (1908) reported the occurrence of the oyster *Crassostrea gigantissima* above Middle Eocene deposits on Tinker Creek; it appears to be restricted to the Late Eocene at the SRS. The Griffins Landing Member formed in a shallow marine or lagoon environment (Fig. 2-10). The remainder of the Dry Branch Formation within the SRS is made up of the Irwinton Sand Member, which is composed of tan, yellow, and orange, moderately sorted quartz sand, with interlaminated, locally abundant clay. Pebbly layers and zones rich in clay clasts also occur. The Twiggs Clay Member is not mappable within the A/M Area, but clay that is lithologically similar to the Twiggs Clay Member is present at various stratigraphic intervals within the Dry Branch Formation. This clay lithofacies, which is tan, light gray, and brown, is up to 12 feet thick in the SRS wells but is not laterally continuous. It was referred to as the "tan clay" in many SRS reports.

The Late Eocene Tobacco Road Formation conformably overlies the Dry Branch Formation. The Tobacco Road Formation crops out over much of the southwestern South Carolina Coastal Plain and is widely exposed at the SRS. Its upper surface is irregular because of the incision that is associated with deposition of the overlying "Upland unit" as well as younger erosion. The thickness varies considerably because of the eroded upper surface, but it is locally at least 50 feet thick. The combined thickness of the Dry Branch and Tobacco Road Formations at the coast is almost 400 feet (Colquhoun et al., 1983). These two formations correspond to the Eg unit of Prowell (Prowell et al., 1985a). The Late Eocene age of the Tobacco Road Formation is established in Georgia (Huddleston and Hetrick, 1985), but parts of the formation may be younger (Prowell et al., 1985a,b; and Colquhoun et al., 1983).

The base of the unit is marked by a coarse layer that in many localities contains flattened quartz pebbles. The formation consists of moderately to poorly sorted, fine- to coarse-grained, red, brown, tan, purple, and orange quartz sand. A higher silt and clay content results in a lower permeability, as compared to the underlying Dry Branch Formation. *Ophiomorpha* burrows, produced by shrimp organisms, are abundant in parts of the formation, and pebble layers are fairly common. The sediments have the characteristics of a shallow marine deposit (Fallaw, 1991) (Fig. 2-10).

2.3.5 "Upland Unit"

The "Upland unit" is an informal stratigraphic term applied to deposits that occur locally at higher elevations in the southwestern South Carolina Upper Coastal Plain (Nystrom and Willoughby, 1982a,b; and Nystrom et al., 1986). The "Upland unit" is generally not fossiliferous, and the age is equivocal. Previous works included the "Upland unit" with older Tobacco Road Formation sediments, and lateral equivalents are still indeterminate. Huddleston (1988) includes the "Upland unit" with his reintroduced, redefined Altamaha Formation of Early to Middle Miocene age. Nystrom and Willoughby (1992) consider "Upland unit" equivalents to overlie Middle Miocene age beds. Prowell et al. (1985a) and Nystrom et al. (1986) also interpreted "Upland unit" sediments to be of Miocene age. The coarse and sandy deposits of the "Upland unit" are interpreted to be fluvial in origin (Siple, 1967; Kite and Nystrom, 1983; and Huddleston, 1988). Much of the "Upland unit" corresponds to the Hawthorn Formation of Siple (1967). The "Upland unit" is observed at higher elevations in many localities around and within the SRS. In the central part of the SRS, the "Upland unit" is better preserved across broad areas than to the northwest where incisive erosion of the topography is more widespread. It extends downdip only as far as the Orangeburg Scarp and may be up to 70 feet thick in parts of the SRS (Colquhoun et al., 1983).

According to Nystrom et al. (1986), typical "Upland unit" lithologies in the SRS area consist of pink to orange, poorly sorted, angular to subangular, coarse-grained sand. Cross bedding is common, and clay may either be interstitial or form a matrix for sand grains. Local conglomerate lenses are distinctive and may contain pebbles and cobbles of quartz as well as pale purple to light gray clay clasts. Scouring of underlying sediments is apparent in some outcrops within the SRS.

2.3.6 Quaternary Deposits

Quaternary deposits include irregularly distributed, laterally discontinuous surficial deposits occurring in isolated outcrops geographically associated with major stream channels. Cooke (1936) identified seven different terraces, interpreted to be of marine origin in the site region, although the highest three are extensively eroded and are not easily recognized (Siple, 1967). The terrace deposits are locally fluvial (Nystrom et al., 1986) and 20 to 30 feet thick. Their age is undetermined. Quaternary to Recent alluvium occurs in the main and tributary channels of the Savannah River and other streams within and near the SRS.

2.3.7 SRS Area Structure

The crystalline rocks which are the basement of the Atlantic Coastal Plain at the SRS are cut by faults that range from ?Paleozoic to Tertiary age. The Augusta fault is mapped within 10 miles northwest of the SRS and dips approximately 45° southeast. Amphibolite-facies rocks of the Kiokee belt on the southeast are juxtaposed over greenschist facies rocks of the Belair belt on the northwest. A planar structure delineated by seismic reflectors (Stieve et al., 1991) in crystalline rocks beneath the SRS has a relatively shallow dip and may be an extension of the Augusta fault. The Augusta fault has been interpreted by various workers as a dextral strike slip fault, a thrust fault (Maher et al., 1979; Snoke et al., 1980), and a reactivated low-angle extensional fault (Dennis, 1991). Prowell and O'Connor (1978) suggest that the nearby north-northeast trending Belair fault shows movement as young as Early Eocene.

The fault-bounded Dunbarton basin is delineated on seismic profiles (Stieve et al., 1991) in the southeastern part of the SRS. Samples obtained from core drilling indicate the Dunbarton basin contains unmetamorphosed sedimentary rocks of Triassic to ?Jurassic age. Similar basins, formed in extensional tectonic environments during the Mesozoic age, occur in the Coastal Plain from Georgia to New York. The general trend of the long axis of the Dunbarton basin is more northeasterly than the axes of the basins farther to the north in North Carolina and Virginia.

Some high-angle faults delineated on seismic profiles (Stieve et al., 1991) cut the crystalline rocks in the basement beneath the SRS upward into the Coastal Plain sediments. Near Langley, South Carolina, within 17 miles of the SRS, small high-angle faults have about 4 feet of apparent normal displacement in a section of interbedded kaolin and sand of Early Eocene age. These faults form a small graben and have a north 30° to 40° west orientation.

A number of faults previously identified (Stieve et al., 1991) are currently under investigation by researchers at SRTC. North-northeast trending faults are, from north to south of the SRS, the Crackerneck fault, the Upper Three Runs fault, the Pen Branch fault, and the Steel Creek fault (Fig. 2-11). The Atta fault is a northwest trending fault in the northeastern area of the SRS. With the exception of the Upper Three Runs fault, these faults delineated on seismic sections (Stieve et al., 1991) cut from the crystalline basement upward into the Tertiary Atlantic Coastal Plain sediments. All of these faults show steep dips, and some are interpreted to have apparent normal and reverse displacement.

Figure 2-11. Location Map of the Pen Branch Fault and Other Basement Faults Identified in the Conoco, 1989, Seismic Reflection Survey Data

3.0 GEOLOGY OF THE A/M AREA

The geology and hydrostratigraphy of the sedimentary sequence in the A/M Area was delineated using lithologic data from the extensive core data inventory at the Savannah River Site (SRS), along with geophysical data from 60 A/M Area wells. All available geophysical logs for monitoring wells within the A/M Area are included in Appendix A. Five hydrostratigraphic cross sections (refer to Plate 3-1 for locations) traverse the A/M Area from north to south (A-A' and E-E') and east to west (B-B', C-C', and D-D'). Refer to Plates 3-2 through 3-6. Hydrostratigraphic units for the A/M Area were interpreted using these cross sections, as well as data from aquifer tests, measured potentiometric surfaces, slug tests, and laboratory sediment analyses.

The deepest wells in the A/M Area penetrate only the uppermost part of the Late Cretaceous age Peedee Formation. A detailed hydrostratigraphic interpretation in the A/M Area is feasible for only the uppermost Late Cretaceous and Tertiary (Peedee Formation, Black Mingo Group, Orangeburg Group, Barnwell Group, and "Upland unit") of the stratigraphic section (Plates 3-2 through 3-6). A sitewide hydrostratigraphic framework, which includes the Cretaceous stratigraphic section, can be found in Aadland (1992, in preparation). Correlation of these units with others in the Gulf and Atlantic Coastal Plains is based mostly on the work of Carter (1983), Colquhoun et al. (1983), Gorday (1985), Hazel et al. (1977), Huddleston and Hetrick (1985), and Prowell et al. (1985a).

Geographic compass directions are given with respect to SRS plant north, which is 36°22' west of true north, and topographic elevations are given in feet above mean sea level (msl). Stratigraphic and hydrostratigraphic tops were picked using both the lithologic and geophysical logs when both were available. On the hydrogeologic cross sections (Plates 3-2 through 3-6), it is indicated at the base of the lithologic columns whether or not the lithologic column for individual wells is based on core plus geophysical data, or on geophysical data alone.

3.1 Crystalline Paleozoic Basement

Crystalline basement rocks of the Kiokee belt beneath the Atlantic Coastal Plain in the A/M Area are probably orthogneisses of Late Proterozoic to Early Paleozoic age, metamorphosed to amphibolite-facies during the Early Paleozoic time. Mafic and ultramafic rocks are associated with the orthogneisses, especially within the Savannah River terrane of Maher et al. (1991). Granitic rocks (about 300 million years old) intrude parts of the Kiokee belt and are generally undeformed.

Lithologies specific to the A/M Area must be inferred from geologic data derived from the surrounding region. Regional stratigraphic data indicate that the crystalline basement is at an elevation of approximately 400 feet below msl (approximately 750 feet below land surface). South of Upper Three Runs, three deep core holes (WSRC, 1989b) in wells SSW-1, SSW-2, and SSW-3 were drilled into a hornblende gneiss below the saprolite zone. Primary minerals consist of hornblende, quartz, feldspar, chlorite, and biotite. Secondary or accessory minerals are reported as muscovite, calcite, pyrite, epidote, garnet, and zeolite.

3.2 Atlantic Coastal Plain Sequence

3.2.1 *Cretaceous Stratigraphy*

3.2.1.1 Cape Fear Formation

The Cape Fear Formation, the lowermost Coastal Plain unit (Fig. 2-9), was not penetrated by wells in the A/M Area. Two deep wells, PT-1 and P-30, which are located about 2 miles southeast of the center of the A/M Area, provide some information. There, the Cape Fear Formation is composed mostly of gray, medium to very coarse, pebbly, clayey quartz sand, which is feldspathic in the lower part of the unit. The sand tends to fine upward, and sorting is poor to moderate. Clay beds up to 3 feet thick are interbedded with sand containing small amounts of mica and heavy minerals. The sediments are moderately to well indurated. The top of the Cape Fear Formation is picked where cleaner, looser sand of the Middendorf Formation overlies clayey sand of the Cape Fear Formation. The Cape Fear Formation, on geophysical logs, shows a much lower resistivity. The upper contact is probably unconformable. The top of the formation in these wells is at an elevation of approximately 350 feet below msl, and the formation is about 40 feet thick. The Cape Fear Formation is not known to crop out in the South Carolina Coastal Plain. It is probably an upper delta plain or estuarine deposit, and its high clay content indicates low permeability (Aadland et al., 1992).

3.2.1.2 Lumbee Group

The Lumbee Group is approximately 400 feet thick in the A/M Area, and based on regional mapping, consists of fluvial and deltaic quartz sand, pebbly sand, and clay (Logan et al., 1989). The Lumbee Group includes the Middendorf, Black Creek, and Peedee Formations; all are similar lithologically. The top of each formation is identified at the top of the clay or clayey zones within the mostly sandy section. The clay tends to be color-variegated. The colors probably developed from oxidation during periods of nondeposition and exposure.

3.2.1.2.1 Middendorf Formation. In wells PT-1 and P-30, located about 2 miles southeast of the center of the A/M Area, the Middendorf Formation is about 100 feet thick. The top is at a depth of about 590 feet below land surface. The formation crops out northwest of the SRS. The two deepest wells in the A/M Area, MSB-12 and MSB-34, are cored into, but not through, the Middendorf Formation. The top of the formation is identified by an interbedded clay and sand interval, which is overlain by massive tan-colored sand. Muscovite is common and scattered throughout the unit but is not as abundant as in the overlying Black Creek Formation. Tan, purple, and gray clay beds are about 10 feet thick. The quartz sand of the Middendorf Formation is medium- to very coarse-grained, very poorly to moderately sorted, and slightly to moderately indurated. Pebbly zones are interspersed throughout. The interbedded clay layers show higher gamma ray counts on geophysical logs than the overlying massive sand.

The cross-bedding and variation in sorting suggest a fluvial environment of deposition. The upper clay layers, which are oxidized in places, suggest close proximity to an unconformity.

The Middendorf Formation is not definitively dated at the SRS, but regional studies suggest a Santonian age (early Late Cretaceous) (Prowell et al., 1985b).

3.2.1.2.2 Black Creek Formation. Black Creek Formation sediments from downdip SRS wells have yielded Campanian (middle Late Cretaceous) and Maastrichtian (late Late Cretaceous) paleontological ages at the SRS. The formation was traced into the A/M Area by correlation of lithologic and geophysical logs. Only two boreholes (well clusters MSB-12 and MSB-34) were cored into the Black Creek Formation in the A/M Area. The Black Creek Formation is 211 feet thick in MSB-12 and 224 feet thick in MSB-34. It crops out northwest of the SRS (Fallaw, 1991). The upper contact is identified at the top of a clay unit about 15 feet thick. The top is 38 feet below msl in MSB-12 and 1 foot below msl in MSB-34. The Black Creek Formation in the A/M Area appears to be composed of two thick, fining-upward sequences. In MSB-12 (the well with the better core recovery in the Black Creek Formation), the lower sequence consists of a sandy zone about 120 feet thick topped by a clay about 8 feet thick. The lower section of the upper sequence contains a sandy zone about 65 feet thick, overlain by a clay about 15 feet thick. In MSB-34, the clay in the lower sequence is about 35 feet thick.

Most of the formation consists of medium- and coarse-grained quartz sand. Sand beds are generally more micaceous than in the underlying Middendorf Formation. Feldspar and pyrite are rare. Clay clasts are common, and clay laminae are fairly common. The sand beds are slightly indurated and are mostly tan, but some beds are white, gray, and yellow. Sorting varies from very poorly to well sorted. Pebbly beds occur throughout. Clay at the top of the lower sequence is locally oxidized, suggesting that deposition of the Black Creek Formation may have been interrupted by a period of weathering. The clay bed that caps the lower fining-upward sequence forms the McQueen Branch Confining Unit that separates the McQueen Branch Aquifer from the overlying Crouch Branch Aquifer (Fig. 3-1). The oxidized upper clay bed may represent an unconformity (Fallaw, 1991). The clay is distinguished on geophysical logs by a higher gamma ray count and lower resistivity on geophysical logs than the adjacent sands. The sediments of the Black Creek Formation have the characteristics of fluvial deposits, with the clays at the tops of the two sequences representing deposition in a lower delta plain environment (Fallaw, 1991).

3.2.1.2.3 Peedee Formation. The top of the Steel Creek Member of the Peedee Formation (Fig. 3-1) is identified at the uppermost contact of a massive clay bed below the sand and clay that were dated as Paleocene (Ellenton Formation) (Prowell et al., 1985b) in the A/M Area and above the sand and clay that yield Cretaceous ages in the downdip direction at the SRS. A few Maastrichtian (Late Cretaceous) paleontological samples have been recovered from the Steel Creek Member in downdip SRS wells, and the unit was correlated into the A/M Area using lithologic and geophysical logs. Samples from the clay in well P-19, located about 8 miles downdip from the A/M Area, yielded Late Cretaceous dates. Correlation using lithologic and geophysical logs indicates that this is the same clay identified as being at the top of the Peedee Formation in the A/M Area. Assignment of the clay above the uppermost "clean" Cretaceous sand to the Steel Creek Member of the Peedee Formation is in accord with the fining-upward (regression) sequences which are prevalent in the Lumbee Group. In downdip wells for which core recovery in the Cretaceous section was better than those in the A/M Area,

the contact between the clay and the underlying sand is more gradational than the contact with the overlying sand. However, the contact with the overlying Ellenton Formation may occur within the upper clay unit. Additional palynological data are required in order to accurately place the Cretaceous-Tertiary contact.

The sand beds of the Peedee Formation have the characteristics of fluvial deposits (Fallaw, 1991) (i.e., upward-coarsening quartz-rich sand interbedded with layers of clay and silt). The massive clay that caps the formation may be a lower deltaic plain sediment. The major sand beds in the Peedee Formation are highly permeable. Very low permeability in the massive clay bed at the top of the formation has a significant influence on vertical groundwater movement. This clay unit is thickest in the southern portion of the A/M Area (55 feet thick in well MSB-30), but it thins to less than 3 feet in the extreme northeastern portion of the A/M Area. The uppermost clay of the Peedee Formation constitutes the "lower clay" confining zone of the Crouch Branch Confining Unit (Fig. 3-1). The upper massive clay bed of the Peedee Formation and the underlying sand unit are 111 feet thick in the MSB-12 well cluster and 104 feet thick in the MSB-34 well cluster, respectively. The clay probably crops out northwest of the SRS but is difficult to distinguish on the basis of lithology from the underlying Black Creek Formation.

Tan, brown, white, gray, yellow, and orange are the most common sand bed colors, but in some wells the sand immediately below the upper clay is dark gray and black. The quartz sand underlying the massive clay is mostly medium- and coarse-grained and poorly to well sorted. The sand layers locally contain as much as 20% mica. Pebbly zones and clay balls are common. Feldspar is common in a few wells and sulfides are rare.

3.2.2 Tertiary Stratigraphy

The amount of core and geophysical log information is more substantial for the Tertiary stratigraphic section than for the Cretaceous stratigraphic section in the A/M Area (Plates 3-2 through 3-6), and thus the younger part of the section is described in more detail. Four unconformities of regional stratigraphic significance are apparent on the hydrostratigraphic sections of the A/M Area. The Cretaceous-Tertiary (Peedee-Ellenton) boundary is difficult to identify because it occurs only in the subsurface. The contact is generally interpreted as an unconformity (Aadland and Bledsoe, 1990b). Late Paleocene (locally called Snapp Member of the Williamsburg Formation) beds and possibly some Early Eocene sediments (locally called Four Mile Member of the Fishburne Formation) are either missing or indistinguishable along a regionally significant unconformity. The Warley Hill Formation may include lithologies informally known as the "green clay" in the SRS area and has a gradational contact with the overlying siliclastic updip equivalent units of the Middle Eocene age Santee Formation. However, the contact with the overlying Dry Branch Formation is an unconformity, which in turn is unconformably in contact with the Late Eocene age Tobacco Road Formation. The (?Miocene age) "Upland unit" is locally preserved along an erosional boundary with the Tobacco Road Formation.

3.2.2.1 Ellenton Formation

In the A/M Area, the upper clayey part of the Cretaceous age (Maastrichtian) Steel Creek Member beds (Peedee Formation equivalent) is difficult to distinguish from clay beds in the lower part of the clay-rich Paleocene age (Danian) Ellenton Formation on the basis of lithology. Although a regional unconformity is generally interpreted at the Cretaceous-Paleocene boundary (Aadland, 1991), both units are of deltaic origin according to Fallaw (1991), and thus the depositional environment masks lithologic distinction. Dinoflagellate assemblages from A/M Area sediments interpreted as Ellenton Formation yield both Danian and Thanetian dates.

Although local variation in total thickness of the Ellenton Formation occurs in the A/M Area, the overall trend is a regional thinning of the section from south to north (Plate 3-2), due generally to erosional truncation at the top of the unit, although depositional thinning may play a role in the north. The thickness of the total section decreases from about 100 feet in the southern area (well clusters MSB-40 and MSB-73) to less than 20 feet (well cluster MSB-85) in the northern section. (Refer to Plate 3-1 for locations.)

Clay is the dominant lithology within the Ellenton Formation in the A/M Area, although the thickness, both of total clay and of individual clay beds, decreases to the north and west relative to the south and east. The top of the Ellenton Formation is picked at the top of a clay unit that locally is 20 feet thick. Below the uppermost clay unit, a sandy clay to clayey sand unit is locally confined between clay layers above and below (i.e., in well clusters MSB-42, MSB-37, and MSB-47). The distinctive clay beds, including the sandy units of the Ellenton Formation, constitute a significant confining unit, the Crouch Branch Confining Unit, in the A/M Area.

Two distinctive depositional facies occur in the Ellenton Formation in the A/M Area. One facies consists of tan to light gray to yellow, brown, pale purple, and orange clay and interlayered sandy beds. Moderately to well-sorted sand and rare lignite and sulfide also distinguish this facies of the Ellenton Formation. Mica (muscovite) is locally common. The lithologies are similar to those in the underlying Late Cretaceous units. The other facies common to the central portion of the SRS consists of dark gray to black, fine- to coarse-grained, clayey, silty, quartz sand, kaolinitic clay, and clayey silt. Sorting is moderate to poor. Muscovite, iron sulfide, and feldspar are common. Induration is slight to moderate. The type Ellenton Formation (Siple, 1967) is similar to the darker facies. Pebble zones are common in both facies. Fallaw (1992) interprets the lighter facies as upper delta plain, channel-dominant environments and the darker facies as lower delta-plain, bay-dominant environments.

3.2.2.2 Congaree/Fishburne Formations

Part of the Fishburne Formation may be missing or is indistinguishable from Congaree Formation lithologies, along the unconformity with the underlying Ellenton Formation. Therefore, the Congaree and the Fishburne Formations are described as one unit. The generally thick, upper clay of the Ellenton Formation contrasts with the interlayered, thin (generally 2 feet or less) sand and clay beds of the lower Congaree Formation. Delineation of

the contact is usually distinct on both gamma ray (lower) and resistivity (higher) geophysical logs (Plates 3-2 through 3-6). On gamma ray logs, a marked deflection (to the right) occurs toward the clay baseline, and the resistivity curves sharply deflect (to the left) toward lower resistivity regions. Most of the Congaree Formation is dominated by clean, well-sorted quartz sand, but near the upper boundary, clayey sand or sandy clay beds are more common. A sample from the A/M Area yielded a paleontological age of Early to Middle? Eocene age. Outcrops of Congaree Formation sediments were noted along Upper Three Runs Creek by Fallaw (1991).

Sand beds in the Congaree Formation are tan, orange, yellow, brown, and white; the sand is fine- to coarse-grained, moderately to well sorted, and loose to slightly indurated. Scattered occurrences of pebbly zones are observed especially near the base. The presence of marine fossils (Fallaw, 1991) and well-sorted, clean, coarse-grained sand suggests a near shore, or intertidal depositional environment. The clean, well-sorted sand also allows high permeability. The average thickness is approximately 60 feet.

3.2.2.3 Warley Hill Formation

The Warley Hill Formation has a gradational contact with the underlying Congaree Formation; the contact is distinguished in part by an increase in clay thickness, content, and lateral continuity. The clay is distinctive enough that the informal designation of the "green clay" is commonly used at the SRS. Silty, clayey sand is interbedded with up to three clay beds. As many as three distinct clay beds have increasing silt and sand content to the north and northeast where they no longer are distinguishable or traceable as an effective aquitard. A zone of micritic, shelly fossil hash limestone was encountered at well cluster MSB-40 (Plate 3-2) within the Warley Hill Formation. To date, this is the only carbonate sediment encountered in the A/M Area or vicinity, although it is common in this interval south of Upper Three Runs. Because of the high percentage of very fine-grained sediment, permeability throughout most of the Warley Hill Formation is low. Even where clay beds are singularly indistinguishable, some confining characteristics are present (B. Looney, personal communication). The finer-grained and more clay-rich sediment of the Warley Hill Formation suggests a shallow marine bay or lagoonal depositional environment. Several paleontological samples collected from A/M Area wells yielded Bartonian (Middle Eocene) ages (Fallaw, 1991).

The Warley Hill Formation was delineated with geophysical logs where there is a marked deflection of the gamma ray curve towards the clay baseline (to the right) and a sharp deflection of the resistivity curves towards the low resistivity region (to the left). The top of the Warley Hill Formation is identified on geophysical logs where the sediments with lower resistivity are overlain by the higher resistivity sediments of the Santee Formation. In general, the gamma ray count of the Warley Hill Formation is higher than in the adjacent stratigraphic units. On most lithologic logs, the contact can be identified where the better-sorted sediments of the Santee Formation overlie the more argillaceous deposits of the Warley Hill Formation (Plates 3-2 through 3-6).

Sand beds in the Warley Hill Formation in the A/M Area contain mostly orange and yellow, fine- to coarse-grained, poorly to well-sorted quartz sand. Pebbles and clay clasts are locally

common, and muscovite is a common detrital mineral. Induration is slight to moderate. Locally, one to four, gray, grayish-green, and green clay and silt beds as much as 4 feet thick are present. Clay laminae are common throughout the formation. Thickness ranges from as little as 1 foot in the northeast to more than 30 feet in the south.

3.2.2.4 Santee Formation

The contact of the Santee Formation with the underlying Warley Hill Formation is gradational and is distinguished by an increase in the percentage of sand that is interbedded with clay. Due to the presence of a higher clay content in the Santee Formation interval, the gamma ray count on the geophysical logs is higher than in the overlying Dry Branch Formation (Plates 3-2 through 3-6). In the A/M Area, the Santee Formation is a clastic-dominated, updip equivalent to calcareous sediments farther to the southeast.

Sandy intervals contain brown, tan, and yellow, fine- to coarse-grained, poorly to well-sorted quartz sand, which is interbedded with green to yellow to brown clay beds. Clay beds are locally 8 feet thick. The overall thickness of the clastic sediments in this interval varies from 30 to 45 feet.

3.2.2.5 Middle Eocene-Late Eocene Undifferentiated

Stratigraphic units in the upper part of the Middle Eocene and lowermost Late Eocene are not separately distinguished in the A/M Area based on age.

3.2.2.6 Dry Branch Formation

A gradational increase in clean sand percentage occurs across the boundary between the Dry Branch Formation and underlying lithologies of Middle to Late Eocene age. Fossils of Bartonian age were found downdip in beds correlated with the Dry Branch Formation and the unit traced into the A/M Area by means of geophysical and lithologic logs. Gamma ray logs yield a low count in the relatively clean Dry Branch sandy beds. Dry Branch Formation beds also thin to the north in the A/M Area, and thickness varies from zero feet in some northernmost wells to 110 feet in wells in the south. Sand of the Dry Branch Formation is interpreted as shallow marine deposition (Fallaw, 1991).

The predominant lithology of the Dry Branch Formation consists of orange, brown, tan, and yellow, fine- to coarse-grained, poorly to well-sorted sand. Pebbly layers are common, and induration is slight to moderate. Light yellow-gray clay laminae are common, and tan, green, yellow, and brown individual clay beds, locally up to 8 feet thick, occur within the Dry Branch Formation.

3.2.2.7 Tobacco Road Formation

The Tobacco Road Formation is characterized by a gradational contact with the underlying Dry Branch Formation and by an increase in the percentage of silt and clay and lower gamma ray count on geophysical logs. A small quartz pebble zone typically marks the base of the Tobacco

Road Formation in the vicinity of the A/M Area. Huddleston and Hetrick (1985) dated (using paleontology) downdip beds in Georgia equivalent to the Tobacco Road Formation as Late Jacksonian (Priabonian) (late Late Eocene) age. Nystrom and Willoughby (1982a) correlated outcrops of similar sediment as Claibornian (Bartonian/Lutetian), into the A/M Area. Dry Branch Formation sediments crop out along stream drainages in the A/M Area.

Silty, clayey sand beds and sandy silt and clay beds of the Tobacco Road Formation are reddish-orange, yellow-brown to purplish-red. Sand units are fine- to coarse-grained and poorly to well sorted. Pebbly layers less than 1 foot thick are common. Clay intraclasts and mudballs are locally common.

3.2.2.8 "Upland Unit"

The "Upland unit" unconformably overlies the Tobacco Road Formation, typically along a channeled or scoured surface. Although pebble conglomerate beds are areally the most distinctive lithology, sand is the predominant lithology in the A/M Area. Within the site region, the "Upland unit" is locally distributed on isolated, preserved higher surfaces. Siple (1967) and subsequent workers interpret the "Upland unit" as the remnant of fluvial channel, point bar, floodplain, and abandoned channel deposits. The "Upland unit" has not been dated paleontologically, but it may correlate with the Miocene Altamaha Formation in Georgia (Nystrom et al, 1986).

Clayey to silty and clayey, quartz sand beds of the "Upland unit" in the A/M Area are yellow, orange, purple, red, brown, and tan. Grain size varies from fine to very coarse. Local pebble conglomerate beds are very poorly to poorly sorted and moderately indurated. Interbedded clay lenses are locally up to 50 feet thick. Weathered detrital feldspar grains are also locally abundant. Even in the very coarse beds, the poor sorting and plentiful clay matrix result in little interconnected pore space.

3.2.2.9 A/M Area Structure

Within the A/M Area, as in the surrounding Atlantic Coastal Plain outcrop area, faults are readily discernible from borehole and subsurface correlation information. Using currently available subsurface information, the most clearly apparent fault is in the northern section of the A/M Area and strikes north-northeast. Three hydrostratigraphic sections are oriented such that this fault is evident on them (Plates 3-2, 3-4, and 3-6). The youngest strata which clearly show displacement are Eocene in age. Because the sections do not generally show strata older than Paleocene, the lower extent of the fault plane was not determined. The dip angle is very steep, and the apparent movement as shown on the hydrostratigraphic sections is normal. The north-northeast strike is generally parallel to the trend of the Pen Branch and other subparallel faults. In all sections which show offset, unconformities which were determined from comparison of geophysical logs (Aadland et al., 1992) show offset comparable to stratigraphic offset. This fault shows as localized anomalies on the altitude contours drawn on top of the Crouch Branch Confining Unit and the "green clay" confining zone (Plates 4-8 and 4-14), on potentiometric surface contours, and on the isoconcentration maps of trichloroethylene (Plates C-4 through C-6).

Other faults probably exist in the A/M Area, notably the Crackerneck fault (Stieve et al., 1991). The Crackerneck fault strikes N75E and extends across the A/M Area (Fig. 2-11). The Crackerneck fault is not distinctly apparent on the A/M Area hydrostratigraphic sections, but this probably results from a combination of the orientation of the section relative to the fault and the lack of distinctive marker beds in the part of the A/M Area which the Crackerneck fault traverses. A slight thickness anomaly, which occurs in the area of the Crackerneck fault, is also observed on the isopach contour map of the Crouch Branch Confining Unit (Plate 4-7). The altitude contour map on top of the Crouch Branch Confining Unit (Plate 4-8) suggests an anomaly on top of that unit which may be related to the Crackerneck fault as well as a fault with a northwest trend possibly subsidiary to the Crackerneck fault. This fault is indicated also on hydrostratigraphic section A-A' (Plate 3-2). As interpreted from the hydrostratigraphic section, this fault does not appear to extend above the uppermost clay of the Ellenton Formation (Crouch Branch Confining Unit).

Effects of faults, especially the northernmost fault, are apparent not only on the hydrostratigraphic sections but also on sections and maps showing potentiometric surfaces and contaminant plumes. Head differences which show geometry of distribution compatible with apparent offset exist in wells on either side of the fault (Plate 4-3). Faults may serve either as loci of transport (via associated fractures or localized open space) or zones of sealing (fine-grained rock flour or fault gouge). Some evidence of plume migration control is suggested in the vicinity of MSB-77 (Plate 5-21). Both fabric orientation controls (including faults and fractures) and aquifer properties are important for understanding and modeling contaminant migration.

4.0 HYDROGEOLOGY

4.1 Regional Hydrogeology and Hydrostratigraphy

4.1.1 Regional Hydrostratigraphic Classification

The hydrostratigraphic classification (Aadland and Bledsoe, 1990a) used in this study is based largely on the recommended guidelines for the classification of hydrostratigraphic units, developed by the South Carolina Hydrostratigraphic Nomenclature Subcommittee. The preliminary draft classification scheme developed by the subcommittee (Burt, 1987a) combines guidelines published by Laney and Davidson (1986), who developed a preferred system for naming hydrogeologic units in United States Geological Survey (USGS) reports, and the draft of the proposed addition to the North American Stratigraphic Code (Seaber, 1986).

The hydrostratigraphic classification of the aquifers in this study utilizes a hierarchy of aquifer and confining units ranked at four levels. Level 1, hydrogeologic province, is comparable to the hydrologic systems described by Miller and Renken (1988). The hydrologic province consists of major regional-scale rock and/or sediment sequences that behave as a single unified hydrologic unit (Miller and Renken, 1988). An example of a hydrogeologic province is the fine- to coarse-grained clastic and carbonate sequence in the Atlantic and Gulf Coastal Plain sedimentary wedge, including the Savannah River Site (SRS), deposited between the Cape Fear Arch in North Carolina and the Mississippi Embayment in Mississippi. The wedge is referred to here as the Southeastern Coastal Plain hydrogeologic province.

Levels 2 through 4 correspond to the hydrostratigraphic units of Laney and Davidson (1986) and are similar to the ranking defined by Seaber (1986) for the North American Stratigraphic Commission (NASC):

Level	Proposed South Carolina Hydrostratigraphic Units (after Laney and Davidson, 1986)	Corresponding NASC units (Seaber, 1986)
1	Hydrogeologic Province	
2	Aquifer System, Confining System	Aquigroup
3	Aquifer, Confining Unit	Aquifformation
4	Zone (informal)	Aquimember, Aquibed

Ranked at level 2 are aquifer systems and confining systems. An aquifer system may be composed of two or more coalescing aquifers and confining units that transmit groundwater regionally. The aquifers may be separated at least locally by confining units that impede groundwater movement but that do not greatly affect the regional hydraulic conductivity of the system (modified from Poland et al., 1972). A confining system may be composed of two or more confining units with less significant aquifers that impede groundwater flow regionally.

Aquifers and confining units (level 3) are the fundamental units of the classification. As defined by the subcommittee (Burt, 1987a,b), an aquifer is a mappable (greater than 400

square miles [sq mi]) body of rock or sediments that is sufficiently permeable to conduct groundwater and to yield significant quantities of the water to wells and springs (modified from Bates and Jackson, 1980). A confining unit is a mappable (greater than 400 sq mi) body of rock or sediments of significantly lower hydraulic conductivity than an adjacent aquifer that impedes groundwater flow to or from an aquifer (modified from Lohman et al., 1972). In nature, the hydraulic conductivity of a confining unit may range from nearly zero to some value distinctly lower than that of the nearby aquifer. In this sense, the assignment of a level and unit name to a hydrostratigraphic unit is not quantitatively defined and does not imply hydraulic continuity or the lack thereof, but rather distinguishes relative differences in hydraulic properties.

Aquifers and confining units may be informally subdivided into zones (level 4), which are characterized by properties significantly different from the associated unit, such as hydraulic conductivity, water chemistry, lithology, and color. For example, an aquifer may contain a "low permeability zone", a "high salinity zone", or a "tan clay zone", or a confining unit may contain a "high permeability zone" or a "sandy zone". Miller (1986) described the "Fernandina permeable zone" in the Lower Floridan Aquifer where the permeability greatly exceeds that of the rest of the aquifer.

The systems, units, and zones discussed in this report were all defined at a type well or cluster of wells that penetrated strata representative of the geological and hydrogeological properties typical of the unit. The hydrostratigraphic units are defined on the basis of the hydraulic properties of the sediments, most significantly hydraulic conductivity, and also porosity and specific storage. These criteria eliminate any "formal" reliance of the classification system on lithology, genesis, age, geologic history, paleogeographic position, or other features that are not strictly hydraulic properties of the units. The reliance of the formal classification on hydraulic properties and the exclusion of lithic properties as classification criteria are not intended to deny the relationship between lithology and hydraulic properties. Lithology is certainly used as a tool for correlating hydrostratigraphic units as are other features of the subsurface, such as geophysical response, groundwater chemistry, and hydraulic continuity. However, these properties should be viewed only as indirect indications of the hydraulic characteristics of the units and not as specific criteria for the formal classification of the units.

Thus, aquifers that are described in this report are defined by the hydraulic properties (hydraulic conductivity and transmissivity measurements, specific storage, etc.) of the units relative to the hydraulic properties measured in the overlying and underlying confining units (Aadland and Bledsoe, 1990a,b; Bledsoe et al., 1990) at the type well or type well cluster location. The aquifers and confining units are mapped, on the basis of the thickness, areal distribution, and continuity of the attendant lithologies of the particular unit. Other properties used for mapping purposes include geophysical response, groundwater chemistry, and hydraulic continuity.

Aquifer systems, confining systems, and aquifers are named for a prominent geographic feature near the type well cluster where the hydrogeologic unit is defined. Confining units are named for the aquifers that they overlie. For example, the Gordon Aquifer of the Floridan Aquifer System is overlain by the Gordon Confining Unit (Fig. 4-1). Aquifers and confining

Figure 4-1. Hydrogeologic Nomenclature for the SRS Region

zones are informally named, and any unique feature that distinguishes the zone from the surrounding aquifer or confining unit is permissible.

The hydrostratigraphic code described in this report accounts for and accommodates the rapid thinning of the sediment wedge and lateral variation in lithofacies observed at the SRS. In addition, the hierarchical ranking of the hydrologic units into systems, units, and zones makes the classification scheme flexible. The rankings can be made as detailed as the complexity of the local hydrogeologic regime demands. Thus, the classification scheme is applicable to all locations in the region, resulting in a unified, consistent hydrostratigraphic classification amenable to all future hydrogeological studies and reports.

4.1.2 Regional Hydrogeology

Southeastern Coastal Plain Hydrogeologic Province

The Southeastern Coastal Plain hydrogeologic province underlies approximately 120,000 sq mi of the Coastal Plain of South Carolina, Georgia, Alabama, and Mississippi, and small contiguous areas of southeastern North Carolina and northern Florida. It extends from central Mississippi to southeastern North Carolina. The entire SRS lies within the Southeastern Coastal Plain hydrogeologic province.

The Southeastern Coastal Plain hydrogeologic province grades laterally to the northeast into the Northern Atlantic Coastal Plain Aquifer System (Meisler, 1980); it is partly overlain by, and partly grades laterally into, the Floridan Aquifer System (Miller, 1986) to the south and the Mississippi Embayment and Coastal Lowlands Aquifer Systems (Grubb, 1986) to the west. The northern and northwestern limit of the province is its contact with crystalline rocks at the Fall Line which marks the updip limit of coastal plain sediments.

The Southeastern Coastal Plain hydrogeologic province constitutes a multilayered hydraulic complex in which retarding beds composed of units of clay and marl are interspersed with beds of sand and limestone that transmit water more readily. Groundwater flow paths and flow velocities in each of these units are governed by the hydraulic properties of these sediments, the geometry of the particular unit, and the distribution of recharge and discharge areas.

The sediments that make up the Southeastern Coastal Plain hydrogeologic province in west-central South Carolina have been grouped into three aquifer systems divided by one confining unit and one confining system, all of which are underlain by the Appleton Confining System (Fig. 4-1). The Appleton Confining System separates the Southeastern Coastal Plain hydrogeologic province from the underlying Piedmont hydrogeologic province.

Overlying the Appleton Confining System is the Midville Aquifer System, the Dublin Aquifer System, and the Floridan Aquifer System separated by the Allendale Confining Unit and the Meyers Branch Confining System (Fig. 4-1). As the confining systems and units thin and become discontinuous in a northerly direction at the SRS, the three aquifer systems, as defined at the southern extent of the SRS, are combined to form a single aquifer system for the northern portions of the SRS (Fig. 4-2).

Figure 4-2. Limits of Aquifer Systems Within the SRS

Locally, individual aquifer and confining units are delineated within each of the aquifer systems. These units may be further divided into aquifer and confining zones. The subdivision of these units into zones is discussed in Section 4.2. The regional lithostratigraphy of the geologic sequence that comprises the Southeastern Coastal Plain hydrogeologic province is shown with the corresponding hydrostratigraphic subdivision of the province in Figure 3-1.

The complexly interbedded strata that comprise the three aquifer systems consist primarily of fine- to coarse-grained sand, and locally gravel and limestone, deposited under relatively high energy conditions in fluvial to shallow marine environments (Miller and Renken, 1988). The clay and marl beds are included in the aquifer systems where low-energy water environments occurred locally. On a regional scale, however, each aquifer system behaves as a single hydrogeologic unit.

Less is known about the hydraulic characteristics of the confining systems and units than is known about the aquifer systems of the Coastal Plain (Aucott et al., 1987). In general, the fine-grained sediments that comprise the regional confining systems were deposited in quiet water marine to fluvial environments. Locally, each regional confining system often contains beds of sand or other high-permeability materials, but overall the unit acts to retard vertical flow between the overlying and underlying aquifer systems.

In ascending order, the confining systems and units are the Appleton Confining System, the Allendale Confining Unit, and the Meyers Branch Confining System. The Appleton Confining System is continuous across the SRS while the Meyers Branch Confining System and Allendale Confining Unit thin and become discontinuous in a northerly direction and are recognized, in the A/M Area, as the Crouch Branch and McQueen Branch Confining Units, respectively. Figure 4-1 illustrates the lateral and vertical extent of these confining systems and units.

4.2 A/M Area Hydrogeology and Hydrostratigraphy

4.2.1 A/M Area Hydrogeologic and Hydrostratigraphic Setting

In the A/M Area, the Southeastern Coastal Plain hydrogeologic province consists of the Floridan-Midville Aquifer System, which includes the McQueen Branch Aquifer, the Crouch Branch Aquifer, and the Steed Pond Aquifer (Fig. 4-3).

The majority of the monitoring wells within the A/M Area are constructed in water-bearing sediments overlying the McQueen Branch Confining Unit. Monitoring wells in the A/M Area do not penetrate as deep as the McQueen Branch Confining Unit and the underlying McQueen Branch Aquifer and are therefore not detailed in this report.

The Crouch Branch Aquifer, which overlies the McQueen Branch Confining Unit, is continuous beneath most of the A/M Area. However, the Crouch Branch Confining Unit thins northward and eventually pinches out north of the northern SRS boundary where the Crouch Branch Aquifer and the overlying Steed Pond Aquifer coalesce to form the Hollow Creek Aquifer (Fig. 4-3).

Figure 4-3. Hydrostratigraphic Chart for the A/M Area

The Crouch Branch Confining Unit separates the underlying Crouch Branch Aquifer from the overlying Steed Pond Aquifer. Within the southern portion of the A/M Area (Fig. 4-3), the Crouch Branch Confining Unit, from its base to the top of the unit, can be subdivided as follows:

- "lower clay" confining zone
- "middle sand" aquifer zone
- "upper clay" confining zone

The entire Crouch Branch Confining Unit thins in a northerly direction and when the "upper clay" confining zone is absent, the "middle sand" aquifer zone merges with the overlying Steed Pond Aquifer. Within the southern to central portions of the A/M Area, the Steed Pond Aquifer, from its base to the top of the aquifer, includes the following:

- "Lost Lake" aquifer zone
- "green clay" confining zone
- "M-Area" aquifer zone

In the central and northern portion of the A/M Area, the "green clay" confining zone is absent. The overlying "M-Area" aquifer zone and the underlying "Lost Lake" aquifer zone combine to form the undifferentiated Steed Pond Aquifer.

Within the A/M Area, approximately 30% of precipitation, or 15 in/yr, enters the groundwater system (Cahill, 1982). Recharge for the A/M Area predominantly infiltrates and recharges the Steed Pond Aquifer, and the groundwater discharges as surface water to Tim's Branch, Upper Three Runs Creek, and the Southwest Swamps (Marine and Bledsoe, 1984). The Crouch Branch Aquifer receives recharge from an outcrop area approximately 2.5 miles north of the A/M Area and from the overlying Steed Pond Aquifer through the Crouch Branch Confining Unit. Discharge from the Crouch Branch Aquifer occurs to the southwest along the Savannah River.

Because of an apparent overall strong potential for vertical movement of groundwater throughout the A/M Area, the thickness, horizontal continuity, and extent of the local confining units and zones will control the overall velocity and direction of groundwater within the A/M Area. Hydrostratigraphic interpretations indicate that the "green clay" confining zone thins in a northerly direction and, in fact, is absent in the northern portion of the A/M Area. In addition, the Crouch Branch Confining Unit thins in a similar fashion toward the northern portion of the A/M Area. This hydrostratigraphic condition allows groundwater to penetrate deeper into the underlying units.

Hydraulic gradients within the A/M Area were determined from measurements at the numerous monitoring wells with varying depths located in cluster well sets throughout the area. Porosity can be measured by laboratory testing or assigned values based on physical testing. Estimates of hydraulic conductivity are available from laboratory measurements of samples, aquifer tests, and from groundwater flow modelling. For this report, hydraulic conductivity values for the

modelling are considered representative of the aquifer as a whole and will be generally used in the calculations.

A groundwater flow model was developed by S. S. Papadopoulos & Associates, Inc., and is described in their report entitled "Hydrogeologic Conditions in the Vicinity of the M-Area Settling Basin and Lost Lake" dated July 1986 (Papadopoulos, 1986). The report showed that input parameters were calibrated by matching groundwater levels measured from 1982 to 1984. The model consisted of the following five layers, which roughly correspond to the current hydrostratigraphic aquifers, confining units, and zones:

- Layer 1 – "M-Area" aquifer zone
- Layer 2 – "Lost Lake" aquifer zone (upper)
- Layer 3 – "Lost Lake" aquifer zone (lower)
- Layer 4 – Crouch Branch Confining Unit
- Layer 5 – Crouch Branch Aquifer

Table 4-1 provides a summary of the hydrogeologic variables based on hydraulic head data used in the flow model. These modelled variables correspond well with previous aquifer tests. Figure 4-4 illustrates the conceptual hydrostratigraphic setting underlying the A/M Area with vertical and horizontal groundwater velocities as calculated by the groundwater flow model. This figure shows dominant vertical groundwater velocities through the "M-Area" aquifer zone. As groundwater enters the underlying "Lost Lake" aquifer zone, horizontal groundwater velocities are dominant and persist down to the Crouch Branch Aquifer.

4.2.2 Summary of A/M Area Hydrogeologic Data

A master well list was developed for the A/M Area as shown in Table 4-2. (Tables 4-2 through 4-8 contain the basic hydrogeologic and hydrostratigraphic data used in this chapter and are presented at the conclusion of this chapter for reference.) The master well list provides basic monitoring well information and indicates the availability and source of the hydrostratigraphic data (i.e., geophysical logs, coring, and laboratory core logging). This information was used to select the optimal monitoring well data for the cross sections and to develop the cross sections.

Five cross sections (Plates 3-2 through 3-6) were constructed using available lithologic and hydrostratigraphic data from monitoring wells within the A/M Area. The cross sections depict subsurface conditions from the upper portion of the Crouch Branch Aquifer to the land surface. These sediments represent the upper portion of the Southeastern Coastal Plain hydrogeologic province. Table 4-3 provides a summary of hydrostratigraphic data obtained from monitoring wells within the A/M Area. These data were utilized in the preparation of isopach and structure contour maps and are discussed in the following sections.

The five cross sections (Plates 3-2 through 3-6) were also used in the preparation of potentiometric cross-section maps (Plates 4-1 through 4-5). The data utilized in the preparation of these potentiometric maps are presented in Tables 4-4 through 4-8.

Table 4-1. Summary of Final Hydrogeologic Parameters Used in Flow Model
 (Papadopulos, 1986)

Layer	Transmissivity (ft ² /day)	Hydraulic Conductivity (ft/day)	Leakage Coefficient (day) ⁻¹	Effective Vertical Hydraulic Conductivity (ft/day)
1	175	9		6.1×10^{-3}
1-2			3.52×10^{-4}	
2	2,200	46		2.0×10^{-2}
2-3			4.03×10^{-4}	
3	1,300	35		1.5×10^{-2}
3-4			2.66×10^{-4}	
4	1,600	29		1.1×10^{-2}
4-5			6.43×10^{-5}	
5	12,500	73		6.5×10^{-3}

Figure 4-4. Schematic Diagram of Horizontal and Vertical Groundwater Velocities in the A/M Area

The alpha-numeric classification system for hydrostratigraphic units, used in previous hydrogeologic reports, has been superseded in this report by geographic names based on the work of Aadland et al. (1992). Both the alpha-numeric and the corresponding geographic names are presented on the accompanying plates for reference.

4.3 A/M Area Aquifer Units/Zones and Confining Units/Zones

The basal hydrostratigraphic unit of the A/M Area, overlying the weathered and eroded surface of the crystalline basement rock and Triassic redbeds, is the Appleton Confining System. The McQueen Branch Aquifer and the McQueen Branch Confining Unit overlie the Appleton Confining System as illustrated in Figure 4-3. There currently is sparse data for these deeper hydrostratigraphic units within the A/M Area. The deeper hydrostratigraphic units are described in SRS regional geological reports; however, a brief summary is provided.

The Appleton Confining System in west-central South Carolina rests directly on the weathered and eroded surface of the crystalline basement rocks and the redbeds of the Newark Supergroup which constitutes the Piedmont hydrogeologic province (Fig. 3-1). The system is essentially equivalent to the saprolite overlying the unweathered crystalline basement rocks and the indurated poorly sorted, silty clayey sand, and sand beds of the Cretaceous aged Cape Fear Formation.

The McQueen Branch Aquifer overlies the Appleton Confining System. In the A/M Area, the aquifer is approximately 180 feet thick and consists of tan, purple, and gray, medium- to very coarse-grained, very poorly to moderately sorted, and slightly to moderately indurated sand. The McQueen Branch Aquifer is equivalent to the Middendorf Formation and the lower portion of the Black Creek Formation (Fig. 3-1).

The McQueen Branch Confining Unit separates the underlying McQueen Branch Aquifer from the overlying Crouch Branch Aquifer. The McQueen Branch Confining Unit consists primarily of silty sandy clays of the lower portion of the Black Creek Formation. In the southern portions of the SRS, the McQueen Branch Confining Unit becomes sufficiently thick and continuous to form the regional Allendale Confining Unit (Fig. 4-1).

4.3.1 Crouch Branch Aquifer

4.3.1.1 Horizontal and Vertical Extent

The Crouch Branch Aquifer, which overlies the McQueen Branch Confining Unit, is stratigraphically the lowest unit penetrated by the monitoring wells in the A/M Area (Plates 3-2 through 3-6). All of the deep wells installed in the A/M Area either partially or fully penetrate the Crouch Branch Confining Unit; however, few wells in the A/M Area fully penetrate the Crouch Branch Aquifer. The Crouch Branch Aquifer is the principal water-producing aquifer at the SRS. This aquifer consists primarily of tan to gray, white and yellow, very poorly to well-sorted, medium- to coarse-grained, locally pebbly sand.

Based on lithologic data collected from the fully penetrating well bores, the thickness of the Crouch Branch Aquifer ranges from 152 to 180 feet.

4.3.1.2 Hydraulic Gradients and Groundwater Movement

Hydraulic head measurements from wells completed in the Crouch Branch Aquifer were used to construct a potentiometric surface map of the Crouch Branch Aquifer (Plate 4-6). The potentiometric surface and the corresponding horizontal hydraulic gradients show that groundwater flow in this aquifer is to the southwest. In general, the horizontal hydraulic gradients are uniform and range from 0.0015 feet/foot to 0.008 feet/foot. Parallel equipotential lines and their relatively uniform spacing indicate homogeneous conditions or constant flow velocities and transmissive properties. Hydraulic head data collected from wells near the A/M Area show a small head difference between wells completed in the Crouch Branch Aquifer and the McQueen Branch Aquifer (less than 1.0 foot in eight of nine well clusters) (Bledsoe et al., 1990).

4.3.1.3 Hydraulic Properties

The hydraulic properties of the Crouch Branch Aquifer were determined from laboratory tests on soil samples, single-well tests, aquifer tests, and numerical groundwater flow modelling. Because there are few wells that fully penetrate the Crouch Branch Aquifer, the hydraulic database for this aquifer is limited.

Slug test data collected from monitor well cluster MSB-66 were used to calculate a hydraulic conductivity of 6.5 ft/day (Sirrime, 1991). Aquifer test data collected from well cluster MSB-15 yielded a hydraulic conductivity of 28 ft/day. An aquifer test was conducted using production well 905-20A to determine aquifer properties of the Crouch Branch Aquifer. The test results showed an aquifer transmissivity of 3220 ft²/day, a storage coefficient of 4.2×10^{-4} , and leakance of 1.1×10^{-3} gpd/ft³ (Geraghty & Miller, 1983). Aquifer parameters were also derived from the three-dimensional finite difference flow and transport model developed by Papadopoulos (1986). The results of the calibrated simulation yielded a transmissivity of 12,500 ft²/day, a hydraulic conductivity of 73 ft/day, a leakage coefficient (from the overlying Crouch Branch Confining Unit) of 6.43×10^{-5} , and a vertical hydraulic conductivity of 0.0065 ft/day.

The existing hydraulic database is incomplete; therefore, the model-derived hydraulic properties are considered representative of average hydrologic characteristics of the flow system. The calibrated model solved the flow system by matching the observed hydraulic heads and gradients of the Crouch Branch Aquifer. Given these criteria, model-derived hydraulic data are used for velocity determinations.

The seepage velocity, or interstitial velocity (q), in the Crouch Branch Aquifer is calculated from Darcy's Law as follows:

$$q = \frac{Ki}{n_e}$$

where: q Seepage velocity (ft/day)
 K Hydraulic conductivity (ft/day)
 i Hydraulic gradient (feet/foot)
 η_e Effective porosity (0.29) (Aadland, in preparation 1992)

Based on a range of horizontal hydraulic gradients (0.0015 to 0.008 feet/foot), a horizontal hydraulic conductivity of 73 ft/day, and an effective porosity of 0.29, the horizontal seepage velocity ranges from 0.38 to 2.0 ft/day. The vertical seepage velocity, based on a range of vertical hydraulic gradients (0.13 to 0.48 feet/foot), a vertical hydraulic conductivity of 0.0065 ft/day, and an effective porosity of 0.29, ranges from 0.003 to 0.011 ft/day.

Given the contrast in the calculated horizontal seepage velocity (0.38 to 2.0 ft/day) and the calculated vertical seepage velocity (0.003 to 0.011 ft/day), a particle flow path in the Crouch Branch Aquifer will be in the horizontal direction and consistent with the southwest directional flow of the aquifer. This conclusion is consistent with the observed distribution of solvents within the Crouch Branch Aquifer (refer to Section 5.0 for further information).

4.3.2 Crouch Branch Confining Unit

4.3.2.1 Horizontal and Vertical Extent

The Crouch Branch Confining Unit overlies the Crouch Branch Aquifer. In the A/M Area the Crouch Branch Confining Unit is locally variable in thickness. The Crouch Branch Confining Unit, from the base to the top of the unit, includes the following hydrostratigraphic sequence (Fig. 4-3):

- "lower clay" confining zone
- "middle sand" aquifer zone
- "upper clay" confining zone

The "lower clay" confining zone is, for the most part, the most competent and continuous of the three zones. The "lower clay" confining zone thins to the north and the southwest to a point where the Steed Pond Aquifer and Crouch Branch Aquifer coalesce to form a single aquifer system. Across the A/M Area the "lower clay" confining zone ranges in thickness from 2 to 50 feet. The discontinuous nature of the zones of the Crouch Branch Confining Unit is schematically illustrated in Figure 4-3 and depicted in the five cross sections (Plates 3-2 through 3-6).

The "lower clay" confining zone consists of a massive clay that is variegated and varies in color from gray, to red, to purple, to yellow and orange. The lithology of the "middle sand" aquifer zone is characterized by poorly sorted clayey silty sand. The color of the sand and clay is extremely variable, ranging from tan to light gray to yellow, to brown, to purple and orange. The clay is kaolinitic, and the silt is primarily comprised of muscovite and feldspar. The dominant lithology of the "upper clay" confining zone is silty clay. In the central and southern portion of the A/M Area, the zone consists of gray, tan, yellow, green, orange, brown, and

purple silty clay. In the northern portion of the A/M Area, this confining zone consists of dark gray to black, fissile, and well-indurated silty clay.

The Crouch Branch Confining Unit is continuous (but thins in a northern direction) throughout the A/M Area and ranges in thickness from 18 feet at well cluster MSB-85 to 102 feet at well cluster MSB-21 (Plate 4-7). In this area, the percentage of clay to sand in the Crouch Branch Confining Unit is low, thus reducing the capacity for the unit to retard vertical groundwater movement. The unit is thickest in the west-central and southern portions of the A/M Area.

The "middle sand" aquifer zone, which lies above the "lower clay" confining zone, coalesces with permeable sediments to the north to form the Steed Pond Aquifer. The discontinuous nature of the "middle sand" aquifer zone is due to the absence of the overlying "upper clay" confining zone (Fig. 4-3). Where present as a distinct zone, the thickness of the "middle sand" aquifer zone ranges from 15 feet at well cluster MSB-31 to 70 feet at well cluster ASB-6 (Plates 3-2 through 3-6).

The "upper clay" confining zone of the Crouch Branch Confining Unit is discontinuous in the northern portion of the A/M Area. This zone thins to the north where it pinches out. The thickness of the "upper clay" confining zone varies from 0 to 15 feet (Plates 3-2 through 3-6).

The contour surface of the Crouch Branch Confining Unit is depicted by the elevation contour lines shown in Plate 4-8. The elevation of the confining unit is greatest in the northern portion of the A/M Area due to structural control (faulting). The lowest elevation of this unit occurs in the west-central part of the A/M Area where the unit is thickest. There are two faults shown on Plate 4-8; these are discussed in Section 3.2.2.9. These features may prove to be significant in predicting chemical transport pathways in the overlying "Lost Lake" aquifer zone.

4.3.2.2 Hydraulic Gradients and Groundwater Movement

Hydraulic head measurements made in the "middle sand" aquifer zone were used to construct a potentiometric surface map of this semi-confined aquifer system (Plate 4-9). The potentiometric surface and corresponding horizontal hydraulic gradients show that groundwater flow in this aquifer zone is to the southwest. This directional flow is consistent with the directional flow determined for the underlying Crouch Branch Aquifer. Equipotential lines are fairly uniform in the southern and western parts of the mapped area. There is, however, an area located centrally and to the north where equipotential lines reflect localized changes in the direction and magnitude of hydraulic gradients. These localized deflections in groundwater flow and gradient magnitudes reflect an increase in horizontal hydraulic conductivity or greater downward leakage to underlying units (i.e., water is flowing with less resistance through this area causing the gradients to be lower). The horizontal hydraulic gradients in the "middle sand" aquifer zone range from 0.0005 to 0.0067 feet/foot and average 0.003 feet/foot (third quarter, 1991 data).

Two vertical hydraulic gradients within the "middle sand" aquifer zone were calculated from well clusters. The two downward vertical hydraulic gradients were calculated at 0.02 and 0.17 feet/foot.

Overall, the entire aquifer system shows a downward component of flow. These gradients are consistent with the model-derived horizontal seepage velocity of 73 feet/yr and vertical seepage velocity of 3 feet/yr across the "upper clay" confining zone and 2 feet/yr across the "lower clay" confining zone (Papadopoulos, 1986).

4.3.2.3 Hydraulic Properties

The hydraulic properties of the Crouch Branch Confining Unit were determined from laboratory tests on soil samples, single-well tests, aquifer tests, and numerical groundwater modelling. Numerous wells were constructed within the Crouch Branch Confining Unit. Due to the availability of hydraulic data, the three zones of the Crouch Branch Confining Unit are evaluated separately in the following sections.

Hydraulic conductivity tests on soils collected from the "lower clay" confining zone yielded vertical hydraulic conductivity values averaging 5.4×10^{-4} ft/day (Bledsoe, 1988). Hydraulic head differences across this basal clay ranged from 12 to 28 feet in the A/M Area (Bledsoe, 1988). Hydraulic head data collected from third quarter 1991 showed head differences ranging from 3.0 to 15.7 feet (Plate 4-6). These head differences across the "lower clay" confining zone reflect downward hydraulic vertical gradients of 0.047 to 0.388 feet/foot. Assuming an effective porosity of 0.1 (Dawson and Istok, 1991), the vertical seepage velocity (q_v) of this clay ranges from 0.0021 to 0.00025 ft/day. This seepage velocity suggests that downward vertical leakage from the Crouch Branch Confining Unit may, at least locally, contribute a significant amount of recharge to the underlying Crouch Branch Aquifer.

Measured hydraulic properties of the "middle sand" aquifer zone show that hydraulic conductivity, based on the results of slug tests, varies from 1.33 to 80.51 ft/day and averages 39.97 ft/day (Sirrinc, 1991). Using the average hydraulic conductivities of 39.97 ft/day and assuming an effective porosity of 0.3 and a horizontal hydraulic gradient of 0.0005 to 0.0067, the horizontal seepage velocity (q_h) will range from 0.07 to 0.89 ft/day.

The hydraulic properties of the "upper clay" confining zone are based on soil test data and hydraulic head measurements in adjacent aquifer units. The average vertical hydraulic conductivity determined from tests on soils is 9.64×10^{-3} ft/day. The hydraulic head difference across the "upper clay" confining zone, as calculated from third quarter 1991 water-level data, ranged from 1.4 to 7.6 feet. The vertical hydraulic gradient measured across the zone is 0.082 feet/foot. Using the vertical hydraulic gradient of 0.082 feet/foot, the vertical hydraulic conductivity of 9.64×10^{-3} ft/day, and assuming an effective porosity of 0.12 for silty clay, the vertical seepage velocity (q_v) is 6.6×10^{-3} ft/day, or 2.4 ft/yr.

From a chemical transport perspective it is advantageous to assess the hydraulic properties of the Crouch Branch Confining Unit as a single hydrologic system. The primary reason for this approach is that each zone of the Crouch Branch Confining Unit contributes to its confining properties and existing data for the entire unit are more reliable. As previously mentioned, the Crouch Branch Confining Unit loses its capacity to retard vertical groundwater flow to the north and southeast of the A/M Area. An observed reduction in the hydraulic heads of the water table aquifer (i.e., Steed Pond Aquifer) during an aquifer test of the Crouch Branch

Aquifer indicates downward leakage through the Crouch Branch Confining Unit (Geraghty & Miller, 1985a,b).

In order to properly assess the amount of water that leaks through a confining layer, a volumetric flow (Q) must be determined. The volumetric flow should be based on leakance (K'/b'), the hydraulic head difference (H_1-H_2), and a unit area (A) of the aquitard. The flow rates should include the leakance property and reflect the amount of water that leaks downward through the confining unit thereby recharging the Crouch Branch Aquifer. Based on laboratory tests on soil samples, vertical hydraulic conductivity of the Crouch Branch Confining Unit varied from 0.022 to 0.71 ft/day and averaged 0.21 ft/day; horizontal hydraulic conductivity varied from 3.1 to 0.027 ft/day and averaged 0.75 ft/day. Model-derived (Papadopoulos, 1986) vertical and horizontal hydraulic conductivities for the Crouch Branch Confining Unit were 0.011 ft/day and 29 ft/day, respectively. Porosity values for this unit varied from 0.12 to 0.3 and averaged 0.21. Given these data and considering their origin, it is again suggested that the model-derived hydraulic data be used, when available, to determine seepage velocities. Using a vertical hydraulic gradient of 0.02 to 0.17 feet/foot and a horizontal hydraulic gradient of 0.0005 to 0.0067 feet/foot, which are based on third quarter 1991 water-level data, the vertical seepage velocity (q_v) and the horizontal seepage velocity (q_h) are calculated as follows:

$$q_v = \frac{K_v i_v}{n_e}$$

$$q_v = \frac{(0.011)(0.02)}{0.12} \text{ to } \frac{(0.011)(0.17)}{0.12}$$

$$q_v = 1.8 \times 10^{-3} \text{ ft/day (0.67 ft/yr) to } 1.55 \times 10^{-2} \text{ ft/day (5.69 ft/yr)}$$

and

$$q_h = \frac{K_h i_h}{n_e}$$

$$q_h = \frac{(29)(0.0005)}{0.3} \text{ to } \frac{(29)(0.0067)}{0.3}$$

$$q_h = 0.048 \text{ ft/day (17.64 ft/yr) to } 0.65 \text{ ft/day (236.4 ft/yr)}$$

4.3.3 "Lost Lake" Aquifer Zone

4.3.3.1 Horizontal and Vertical Extent

Overlying the Crouch Branch Confining Unit is the "Lost Lake" aquifer zone of the Steed Pond Aquifer (Fig. 4-3). The "Lost Lake" aquifer zone consists of yellow to tan to orange and brown, loose to slightly indurated, fine- to coarse-grained, moderately to well-sorted, occasionally pebbly sand. The aquifer is discontinuous to the north of the A/M Area and also

within a zone near well clusters MSB-38, MSB-31, and MSB-4, located in the south-central portion of the A/M Area. Where present, the thickness of the "Lost Lake" aquifer zone varies from 46 feet at well cluster MSB-19 to 83 feet at well cluster MSB-71. Where the "green clay" confining zone is absent, the "Lost Lake" aquifer zone coalesces into the Steed Pond Aquifer. The thickness and extent of the "Lost Lake" aquifer zone are shown in Plate 4-10.

In the Lost Lake Aquifer Zone, monitoring wells have been completed in the upper and lower portions of the zone. The prior hydrostratigraphic nomenclature referred to the Congaree Aquifer, and the informal designation of Upper and Lower Congaree aquifer units developed. The distinction is based on the relative locations of wells in clusters and not on hydrologic or lithologic data. The current nomenclature recognizes a single aquifer zone.

4.3.3.2 Hydraulic Gradients and Groundwater Movement

Hydraulic head measurements from or measured in wells completed into the "Lost Lake" aquifer zone were used to construct two potentiometric surface maps of the aquifer zone.

Plate 4-11 reflects the distribution of hydraulic head in the upper part of the "Lost Lake" aquifer zone. The potentiometric surface and corresponding hydraulic gradients across the area show that the direction of groundwater flow is variable. In the south and west, portions of the A/M Area groundwater move in a southwesterly direction. In the northeastern portion of the A/M Area, the groundwater appears to move semi-radially outward toward the southeast and southwest. A localized mound of groundwater flows radially outward in the Lost Lake area (Plate 4-11); however, no obvious hydrologic reason exists for this mounding effect. The mound may be caused by increased recharge to this area either upward or downward. It is also possible that the vertical hydraulic conductivity in this area is lower, resulting in less water being able to move through this area. Horizontal hydraulic gradients in the upper portion of the "Lost Lake" aquifer zone range from 0.0009 to 0.11 feet/foot and average 0.005 feet/foot (third quarter 1991 data).

Plate 4-12 reflects the distribution of hydraulic head in the lower part of the "Lost Lake" aquifer zone. The potentiometric surface and hydraulic gradients are not as variable as those of the upper portion of the aquifer zone. In general, groundwater movement is to the south-southwest. Two areas appear to have localized deviations in groundwater flow. One occurs between well clusters MSB-54 and MSB-25 and Lost Lake. In this area the flow is to the south and the hydraulic gradients are much lower. These conditions imply a higher seepage velocity and/or horizontal hydraulic conductivity. A localized deviation also occurs in the Lost Lake area, similar to that which occurred in the upper portion of the "Lost Lake" aquifer zone. This deviation, however, is a valley or sink and not a groundwater mound, which indicates that greater amounts of water move through this area. Horizontal hydraulic gradients of the lower portion of the "Lost Lake" aquifer zone range from 0.00075 to 0.0076 feet/foot and average 0.004 feet/foot. Vertical hydraulic gradients within the lower portion of the "Lost Lake" aquifer zone range from 0.011 to 0.28 feet/foot and average 0.066 feet/foot (third quarter 1991 data).

4.3.3.3 Hydraulic Properties

The hydraulic properties of the "Lost Lake" aquifer zone were determined by laboratory tests on soil samples, aquifer tests, and numerical groundwater flow modelling. Laboratory tests on soil samples yielded porosity values ranging from 0.32 to 0.41 and averaging 0.35. Laboratory tests on soils for hydraulic conductivity ranged from 8.69 to 426.2 ft/day and averaged 78.9 ft/day. Horizontal hydraulic conductivity values for the "Lost Lake" aquifer zone determined from aquifer tests ranged from 29.4 to 64.22 ft/day (Geraghty & Miller, 1985a,b). Model-derived horizontal hydraulic conductivity values for the "Lost Lake" aquifer zone ranged from 29.0 to 35 ft/day. Corresponding values of vertical hydraulic conductivity for the "Lost Lake" aquifer zone ranged from 0.011 to 0.015 ft/day (Papadopoulos, 1986).

The hydraulic properties of this aquifer zone are best represented by the values derived from the model and aquifer tests. Given these values, the corresponding seepage velocity in the vertical and horizontal directions for the reported hydraulic gradients are as follows:

$$q_v = \frac{K_v i_v}{\eta_e}$$

$$q_v = \frac{(0.011)(0.066)}{0.35}$$

$$q_v = 0.002 \text{ ft/day (0.76 ft/yr)}$$

and

$$q_h = \frac{K_h i_h}{\eta_e}$$

$$q_h = \frac{(29)(0.004)}{0.35}$$

$$q_h = 0.33 \text{ ft/day (121 ft/yr)}$$

4.3.4 "Green Clay" Confining Zone

4.3.4.1 Horizontal and Vertical Extent

Within the Steed Pond Aquifer and overlying the "Lost Lake" aquifer zone is the "green clay" confining zone. Where present, clay of the "green clay" confining zone confines and separates the "Lost Lake" aquifer zone from the overlying "M-Area" aquifer zone. Where the "green clay" confining zone thins and becomes absent, the "Lost Lake" aquifer zone and the "M-Area" aquifer zone coalesce into the Steed Pond Aquifer, a water table aquifer (Fig. 4-3).

The "green clay" confining zone is moderately indurated and is an interbedded sequence of clay and silt varying in color from gray to grayish-green to green. The individual clay beds are

typically 1 to 4 feet thick and may contain glauconitic sand. Plate 4-13 shows the areal distribution and the thickness of the "green clay" confining zone. It should be noted that the thickness of the "green clay" confining zone (Plate 4-13) may include sand layers within the confining zone. This must be considered in an estimate of the hydraulic confining characteristics of this confining zone. Thickness is not a unique determinant of confinement integrity. The hydrogeologic cross sections (Plates 3-2 through 3-6) provide a visual presentation of the "green clay" confining zone.

North of the A/M Area, the "green clay" confining zone becomes discontinuous, and the "Lost Lake" aquifer zone and the "M-Area" aquifer zone coalesce to form one aquifer system (the Steed Pond Aquifer). Also, in an area near well clusters MSB-38 and MSB-1 and the M-Area Basin, the zone is absent. Where present, the thickness of the "green clay" confining zone ranges from 2 feet at well clusters MSB-71, MSB-76, MSB-3, and MSB-2 to 28 feet at well cluster MSB-74.

The structural surface of the "green clay" confining zone is delineated by the elevation contour lines shown in Plate 4-14. Where present, the zone ranges from 190 feet above msl at well cluster MSB-71 to 228 feet above msl at well 905-82. The topography of the clay zone is irregular although there are no apparent high or low trends. Several localized highs do not show any real discernable geometric patterns.

4.3.4.2 Hydraulic Gradients and Groundwater Movement

No wells have been completed in the "green clay" confining zone. As a result, no hydraulic head data have been collected from this zone. Head differences across the "green clay" confining zone were calculated to determine the vertical gradient across the zone, which ranged from 4.5 to 24 feet. Based on these head differences, vertical hydraulic gradients varied from 0.145 to 0.511 feet/foot in a downward direction (third quarter 1991 data).

4.3.4.3 Hydraulic Properties

The hydraulic properties of the "green clay" confining zone were determined from laboratory tests on soil, aquifer tests, and groundwater modelling. Vertical hydraulic conductivity values determined from laboratory tests on soil samples ranged from 2.8×10^{-6} to 1.8×10^{-4} ft/day. Other reported values of hydraulic conductivity for the "green clay" confining zone ranged from 2.3×10^{-6} to 2.35×10^{-3} ft/day (Eddy et al., 1991). Porosity values determined from tests on soil samples ranged from 0.35 to 0.6. The effective porosity of this zone is estimated at 0.1 (Dawson and Istok, 1991). A model-derived leakance value for the "green clay" confining zone is 3.52×10^{-4} (day) $^{-1}$. Using this leakance value and a unit thickness of 28 feet, the vertical hydraulic conductivity is 9.86×10^{-3} ft/day. The vertical hydraulic gradient across the "green clay" confining zone, as determined by modelling, is 0.48 feet/foot. Using a vertical hydraulic gradient of 0.51 to 0.145 feet/foot, the vertical seepage velocity (q_v) in the "green clay" confining zone is calculated as follows:

$$q_v = \frac{K_v i_v}{\eta_e}$$

$$q_v = \frac{(9.86 \times 10^{-3})(0.51)}{0.01} \text{ to } \frac{(9.86 \times 10^{-3})(0.145)}{0.01}$$

$$q_v = 5.03 \times 10^{-1} \text{ ft/day (18.3 ft/yr) to } 1.43 \times 10^{-2} \text{ ft/day (5.21 ft/yr)}$$

4.3.5 Steed Pond Aquifer and the "M-Area" Aquifer Zone

4.3.5.1 Horizontal and Vertical Extent

The Steed Pond Aquifer is formally designated (Aadland et al., 1992) as the permeable sequence of sediments that form a single water table aquifer (i.e., groundwater exists at atmospheric pressure) in the northern part of the A/M Area. The "M-Area" aquifer zone and "Lost Lake" aquifer zone were formally designated as two distinct aquifer zones, within the Steed Pond Aquifer, but are distinctly separate in the central and southern portions of the A/M Area (Fig. 4-3). The discontinuous nature of the hydrostratigraphic zones that comprise the Steed Pond Aquifer impart variable geometry to this aquifer. To reflect this variability, which is solely dependent on the lateral continuity of the "green clay" confining zone and the "upper clay" confining zone, the Steed Pond Aquifer (water table portion) varies in areal extent, thickness, and hydrostratigraphic nomenclature (Fig. 4-3). Because the "M-Area" aquifer zone and the upper part of the Steed Pond Aquifer, in the northern portion of the A/M Area, are water table aquifers, each has similar hydrologic properties. The Steed Pond Aquifer (water table portion) and "M-Area" aquifer zone (water table aquifer) are included in the same hydrogeologic discussion.

The "M-Area" aquifer zone is a water table aquifer that is laterally discontinuous to the north due to the pinching out of the "green clay" confining zone (Plate 4-13). Where the "green clay" confining zone is absent, the "M-Area" aquifer zone coalesces with permeable sediments in the northern portion of the A/M Area forming the water table portion of the Steed Pond Aquifer. The "M-Area" aquifer zone is comprised of brown, tan and yellow, fine to coarse, poorly to well-sorted quartz sand. Clay laminae are also common in this aquifer zone.

The water table portion of the Steed Pond Aquifer includes the permeable, or sandy, parts of all saturated sediments that lie above the "lower clay" confining zone of the Crouch Branch Confining Unit. In general, this sequence lacks a significant vertical hydraulic gradient and competent clay to be further subdivided into aquifer or aquitard zones (Aucott and Speiran, 1985).

The thickness and extent of the "M-Area" aquifer zone are shown in Plate 4-15. The aquifer zone is not present to the north or near wells MSB-38 and MSB-4. In these areas, the zone coalesces to form the water table portion of the Steed Pond Aquifer. Where present, the "M-Area" aquifer zone ranges in thickness from 37 feet at well cluster MSB-51 to 180 feet at well cluster MSB-27. In general, the "M-Area" aquifer zone is thinnest to the southeast and gradually thickens in a northwesterly direction.

The thickness and extent of the water table portion of the Steed Pond Aquifer are shown in Plate 4-16. This aquifer is present in the northern part of the A/M Area. Where mapped, the

aquifer ranges in thickness from 172 feet at well cluster MSB-52 to 251 feet at well cluster MSB-17. The aquifer is also present in an isolated area (M-Area Basin) where it reaches a thickness of 218 feet.

4.3.5.2 Hydraulic Gradients and Groundwater Movement

Hydraulic head measurements made in the water table aquifer (Steed Pond Aquifer and "M-Area" aquifer zone) were used to construct the water table surface shown in Plate 4-17. The water table and corresponding horizontal hydraulic gradients show variation in the direction of groundwater movement in the two aquifers. Most of the variation occurs in the south-central portion of the A/M Area. The water table is elevated between well clusters MSB-19 and ASB-9 and between MSB-19 and MSB-27, creating a partial groundwater divide where flow is from the higher portions of this ridge-like feature to the southeast and southwest. In the northern portion of the A/M Area, the water table is depressed creating a potentiometric low where groundwater flows in a northerly direction and diverges toward well cluster MSB-66. The elevated water table near well cluster MSB-19 is attributable to discharge of effluent water at a National Pollutant Discharge Elimination System (NPDES)-permitted discharge point, the A-014 Outfall, which recharges the water table aquifer. The potentiometric low near well cluster MSB-66 may be attributed to the absence of the "green clay" confining zone. This results in an increase in the downward volumetric flow rate into the unconfined portion of the Steed Pond Aquifer. The absence of the "green clay" confining zone in the south-central portion of the A/M Area has not affected the current distribution of hydraulic heads in this area.

Based on third quarter 1991 water-level data, calculated horizontal hydraulic gradients of the "M-Area" aquifer zone ranged from 0.01 to 0.0011 feet/foot and averaged 0.005 feet/foot. Other reported horizontal hydraulic gradients ranged from 0.0035 feet/foot (Sirrinc, 1991) to 0.0015 feet/foot (Papadopoulos, 1986). Vertical hydraulic gradients calculated from third quarter 1991 water-level data ranged from 0.225 to 0.353 feet/foot and averaged 0.28 feet/foot. Other reported vertical hydraulic gradients for the "M-Area" aquifer zone ranged from 0.01 to 0.17 feet/foot.

4.3.5.3 Hydraulic Properties

Hydraulic properties of the "M-Area" aquifer zone and Steed Pond Aquifer (water table portion) were determined from laboratory tests on soil samples, single well tests, and groundwater modelling. Laboratory tests on soil samples yielded an effective porosity of 0.20 for slightly silty or clayey sand units. The horizontal hydraulic conductivity of the "M-Area" aquifer zone, as determined from slug tests, is 5.18 ft/day (Sirrinc, 1991). A model-derived horizontal hydraulic conductivity of 9.0 ft/day was determined for the "M-Area" aquifer zone. The only available vertical hydraulic conductivity value for the "M-Area" aquifer zone was determined from groundwater modelling. This value was 0.0061 ft/day (Papadopoulos, 1986). Given these data, the vertical and horizontal seepage velocity for the "M-Area" aquifer zone is as follows:

$$q(v) = \frac{K_{vi} i_v}{\eta_e}$$

$$q(v) = \frac{(0.0061)(0.28)}{0.20}$$

$$q(v) = 0.009 \text{ ft/day (3.3 ft/yr)}$$

and

$$q(h) = \frac{K_{hi} i_h}{\eta_e}$$

$$q(h) = \frac{(9.0)(0.005)}{0.20}$$

$$q(h) = 0.225 \text{ ft/day (82.13 ft/yr)}$$

4.4 Summary of Hydrogeologic Conditions of the A/M Area

The groundwater system underlying the A/M Area, as characterized in this report, includes all the hydrostratigraphic units that overlie the McQueen Branch Confining Unit (Fig. 4-3). Based on available hydraulic and geologic data, this system is variable due to lateral and vertical nonhomogeneity of the section as a whole, as well as the heterogeneous nature of the textures (grain size and cementation) that comprise the different hydrostratigraphic units. Even though hydrologic data is locally abundant, flow patterns for the whole area cannot be completely characterized with existing hydrologic data.

Overlying the McQueen Branch Confining Unit within the southern portion of the A/M Area are four distinct aquifers or aquifer zones. The aquifers consist of sand with variable amounts of silt and clay and may contain clay lenses of less continuity and hydraulic competency than the formally designated aquitards. As a result, the percentage of clay within the stratigraphic sequence, although it is not separable as a hydrostratigraphic unit, plays an important role in controlling the flow path of a particle moving through this groundwater system.

An important component of fate and transport analyses is the ability to predict the hydraulic variables that control the rate and direction of contaminant migration. The following is a summary of the important hydraulic properties:

- Hydraulic heads in the horizontal plane
- Vertical and horizontal hydraulic gradients
- Vertical and horizontal hydraulic conductivity
- Rate of groundwater movement (seepage velocity)

In addition to the aforementioned factors, five flow nets show the vertical distribution of hydraulic head. This is an important factor because vertical distribution of hydraulic heads in

the groundwater system above the McQueen Branch Confining Unit shows a downward hydraulic gradient indicating that the A/M Area is a recharge zone (Plates 4-1 through 4-5). Another condition is apparent from the flow nets. The equipotential lines generally parallel the lithologic contacts of the formally designated confining units and zones; thus, the flow lines perpendicular to the equipotential lines show a significant downward component of flow. In a homogeneous, isotropic groundwater flow system, equipotential lines are always perpendicular to groundwater flow boundaries, and flow lines are always parallel to groundwater flow boundaries (Freeze and Cherry, 1986). Using the flow nets (Plates 4-1 through 4-5), the tangent law of groundwater refraction indicates the flow path of a particle. Applying the tangent law to this system shows that the refraction angle in the aquitard units is approximately 90° , or vertical. This configuration results within a sequence of aquifer and aquitard units when the difference in hydraulic conductivity between the aquifer(s) and aquitard(s) is at least on the order of 10^2 (Freeze and Cherry, 1986). In addition, due to the anisotropic and heterogeneous nature of the system, the refraction angle was indeterminate relative to adjacent aquifer units, and flow net analysis is inconclusive. The flow nets and the vertical gradients do not indicate whether a particle, at any given point in the system, will move either horizontally or vertically. The vertical gradients indicate that a potential exists for downward movement.

The direction and rate of vertical movement are dependent on whether a permeable pathway exists within the confining beds and on the transmissive properties of the flow path (i.e., will the confining beds transmit or retard groundwater movement). Given the existing hydraulic data of the confining units and the heterogeneous nature of the granular materials that comprise the confining units of this system, predicting the rate and direction of groundwater movement in and through these units is highly subjective and, in this analysis, point specific. Aquifer test methods are available, which are designed to specifically test leakage across confining beds and to determine vertical hydraulic conductivity of both aquifer and aquitard systems. Collecting data of these types may help to better understand the vertical flow properties of this system.

Given the existing hydraulic data of this groundwater flow system, assessing the rate and direction of groundwater flow will be based on a comparative analysis of the seepage velocity vector (q). The seepage velocity vector is an interstitial flow rate which has magnitude and direction and is a function of the hydraulic conductivity, hydraulic gradient, and effective porosity. Because the seepage velocity incorporates three integral flow parameters into one variable, it can best represent the hydraulic conditions. For each hydrostratigraphic unit, with available hydraulic data, the horizontal and vertical seepage velocities were calculated. Figure 4-5 shows the values for the vertical and horizontal hydraulic conductivity and the corresponding seepage velocities for each hydrostratigraphic unit. The vectorial representation is a generalized approach to characterizing the probable flow path in each of the hydrostratigraphic units. It is intended to graphically show the contrast between the magnitudes of the horizontal and vertical seepage velocities. The longest vector within each hydrostratigraphic unit implies the dominant flow direction. Since existing hydraulic data are insufficient to accurately and thoroughly characterize the vertical flow properties of the system, the vertical vectors are derived from available data and observed phenomena. Additional data, including aquifer testing in conjunction with three-dimensional flow and chemical transport modelling, are necessary to fully characterize this complex groundwater system.

(1) Units are ft/day.
(2) Reflects hydraulic conditions across entire Crouch Branch Confining Unit.

Fig. 4-5. Vectorial Representation of Seepage Velocities

Table 4-2. A/M Area Master Well List (Page 1 of 7)

UPDATED: DECEMBER 10, 1993

A/M AREA MASTER WELL LIST

(EXPLANATION OF ABBREVIATIONS ATTACHED AT END OF LIST)

WELLS	CROSS SECTION					Date Completed	COORDINATES		Elevations (ft MSL)			UNIT	UNIT II	Report	CORE LOG	SOIL CORE	GEOPHY LOGS
	A	B	C	D	E		North	East	Screen Zones	Ground	Casing						
ABP 1A						08-15-84	97501.6	44425.6	202.9 - 172.9	357.9	359.9	W.T.	GCL	N/A	N/A	N/A	N/A
ABP 10D						06-30-89	97511.4	44433.6	227.2 - 207.2	357.9	360.1	W.T.	MGC	N/A	N/A	N/A	N/A
ABP 2A						08-10-84	97764.3	44118.8	211.1 - 181.1	370.1	371.9	W.T.	GCL	N/A	N/A	N/A	N/A
ABP 2DD						06-23-89	97753.7	44126.7	222.3 - 202.2	368.3	370.6	W.T.	MGC	N/A	N/A	N/A	N/A
ABP 3						08-04-83	97744.1	44509.3	236.9 - 206.9	351.9	353.7	W.T.	MGC	N/A	N/A	N/A	N/A
ABP 3C						07-10-89	97778.2	44506.3	165.3 - 160.3	352.3	354.5	UP. CONG.	UL	-	YES	YES	YES
ABP 4						06-21-84	97489.7	44096.0	212.5 - 182.6	362.5	364.3	W.T.	MGCL	N/A	N/A	N/A	N/A
ABP 4DD						06-23-89	97495.5	44101.3	223.2 - 203.2	362.7	365.0	W.T.	MGC	N/A	N/A	N/A	N/A
ABP 6D						07-05-89	97889.7	44101.4	222.4 - 202.4	363.0	365.3	W.T.	MGC	N/A	N/A	N/A	N/A
ABP 7D						06-30-89	97449.7	43930.1	225.2 - 205.2	361.9	364.2	W.T.	MGC	N/A	N/A	N/A	N/A
ABP 8C						07-20-89	97855.6	43968.7	190.6 - 185.6	369.8	372.1	UP. CONG.	UL	704	-	-	YES
ABP 8D						07-20-89	97854.9	43984.1	228.2 - 208.1	368.8	370.9	W.T.	M	N/A	N/A	N/A	N/A
ABW 1						06-02-83	105939.9	55016.4	215.1 - 185.1	323.1	324.8	UP. CONG.	UL	N/A	N/A	N/A	N/A
AC 1A						08-03-81	105865.0	42238.8	145.7 - 140.7	260.7	262.1	UP. CONG.	UL	N/A	N/A	N/A	N/A
AC 1B						07-28-81	105862.8	42250.5	202.1 - 197.1	261.1	262.0	W.T.	GCL	N/A	N/A	N/A	N/A
AC 2A						09-09-81	105636.4	46428.6	146.0 - 141.0	342.7	344.7	UP. CONG.	UL	704	N/A	N/A	YES
AC 2B						08-12-81	105648.7	46444.5	236.4 - 216.4	342.8	344.8	W.T.	MGC	N/A	N/A	N/A	N/A
AC 3A						09-15-81	100989.1	42119.8	153.6 - 148.6	300.4	302.3	UP. CONG.	UL	704	N/A	N/A	YES
AC 3B						08-21-81	100996.5	42113.6	213.4 - 193.4	300.1	302.5	W.T.	M	N/A	N/A	N/A	N/A
ACB 1A						01-11-84	102622.9	51369.9	247.6 - 217.6	357.6	359.6	W.T.	M	N/A	N/A	N/A	N/A
ACB 2A						01-30-84	102367.4	51661.3	237.8 - 207.8	347.8	349.8	W.T.	M	N/A	N/A	N/A	N/A
ACB 3A						01-25-84	102154.3	51313.3	236.3 - 206.3	346.3	348.3	W.T.	M	N/A	N/A	N/A	N/A
ACB 4A						02-02-84	102343.9	51116.2	241.7 - 211.7	356.7	359.1	W.T.	MGC	N/A	N/A	N/A	N/A
AMB 4A						08-30-91	104131.6	51469.8	126.3 - 121.3	378.3	380.5	ELLEN. SAND	MCBC				
AMB 4B						09-09-91	104145.6	51482.7	157.3 - 152.3	378.3	380.4	L.C.	LL				
AMB 4D						09-09-91	104154.7	51489.0	233.4 - 213.4	378.4	380.3	W.T.	M				
AMB 5						09-14-88	104083.4	51467.2	242.1 - 222.1	377.6	379.6	W.T.	MGCL	704	N/A	N/A	YES
AMB 6						09-15-88	104034.1	51466.0	242.6 - 222.6	375.1	377.2	W.T.	GCL	704	N/A	N/A	YES
AMB 7						09-06-88	103920.0	51624.9	242.1 - 222.1	368.1	369.9	W.T.	M	704	YES	YES	YES
AMB 7A						07-26-91	103987.1	51591.0	125.6 - 115.6	371.6	373.6	ELLEN. SAND	MCBC				
AMB 7B						07-26-91	103972.0	51590.3	162.9 - 152.9	370.9	373.0	LOW CONG.	LL				
AMB 8D						10-31-89	103874.7	51400.5	240.8 - 220.8	367.8	369.6	W.T.	M	N/A	N/A	N/A	N/A
AMB 9D						10-25-89	103585.2	51263.0	239.7 - 219.7	365.7	367.9	W.T.	M	704	N/A	N/A	YES
AMB 10A						08-26-91	103326.4	51410.0	111.4 - 108.4	364.4	366.5	ELLEN. SAND	MCBC				
AMB 10B						09-03-91	103337.3	51418.3	154.3 - 149.3	364.3	366.4	LOW CONG.	LL				
AMB 10D						11-03-89	103293.4	51456.0	239.4 - 219.4	363.4	365.5	W.T.	M	N/A	N/A	N/A	N/A
AMB 10DD						06-07-89	103278.7	51456.0	358.6 - 338.6	363.6	365.4	W.T.	M	N/A	N/A	N/A	N/A
AMB 11B						08-13-91	103154.2	51919.5	184.5 - 174.5	362.5	364.6	UP CONG.	UL				
AMB 11D						06-13-89	103132.3	51932.6	240.5 - 220.5	362.0	364.0	W.T.	M	704	N/A	N/A	YES
AMB 12D						06-16-89	103602.4	51901.6	239.4 - 219.4	367.8	369.8	W.T.	M	704	N/A	N/A	YES
AMB 13AR						08-08-91	103082.0	51396.0	110.9 - 100.9	362.9	365.1	ELLEN. SAND	MCBC				
AOB 1						05-27-83	101910.7	50485.9	248.5 - 218.5	338.5	341.1	W.T.	M	N/A	N/A	N/A	N/A
AOB 2						05-27-83	102009.8	50724.7	250.2 - 220.2	343.2	345.4	W.T.	M	N/A	N/A	N/A	N/A
AOB 3						04-21-89	102164.4	50959.4	243.9 - 223.9	350.6	352.6	W.T.	M	N/A	N/A	N/A	N/A
ARP 1A						02-03-84	99102.9	44317.4	223.0 - 193.0	353.0	355.1	W.T.	GCL	N/A	N/A	N/A	N/A
ARP 2						12-22-83	99119.8	44876.1	220.3 - 190.3	335.3	337.3	W.T.	GC	N/A	N/A	N/A	N/A
ARP 3						12-14-83	98638.2	44903.7	218.2 - 188.2	338.2	339.8	W.T.	GCL	N/A	N/A	N/A	N/A
ARP 4						06-25-84	98567.7	44374.8	227.8 - 197.8	346.8	348.4	W.T.	GCL	N/A	N/A	N/A	N/A
ASB 1A						01-05-84	105535.0	52614.0	247.2 - 217.2	347.2	349.1	W.T.	M	N/A	N/A	N/A	N/A
ASB 2A						12-30-83	105608.8	52856.9	246.9 - 216.9	346.9	349.0	W.T.	M	N/A	N/A	N/A	N/A
ASB 2AR						02-12-93	105550.5	52881.7	240.1 - 220.2	353.1	355.6	W.T.	MGCL				
ASB 2CR						01-04-93	105540.2	52862.7	183.1 - 173.1	353.1	355.6	LOW CONG.	LL				
ASB 2C						11-30-90	105605.4	52843.6	177.4 - 172.4	347.4	349.4	LOW CONG.	UL	704	N/A	N/A	YES
ASB 3A						10-13-81	105657.4	53152.7	247.9 - 217.9	342.9	345.0	W.T.	M	N/A	N/A	N/A	N/A
ASB 3AR						01-22-93	105605.1	53115.0	243.1 - 223.1	339.1	341.6	W.T.	MGCL				
ASB 3C						11-29-90	105668.8	53160.3	173.8 - 168.8	343.8	346.0	LOW CONG.	UL	704	N/A	N/A	YES
ASB 3CR						01-22-93	105614.5	53130.4	184.0 - 174.0	339.0	341.5	LOW CONG.	LL				
ASB 4						08-20-81	105935.7	53177.2	256.1 - 226.1	333.1	335.6	W.T.	M	N/A	N/A	N/A	N/A
ASB 5A						02-13-84	105885.5	52865.7	247.9 - 217.9	342.9	345.0	W.T.	M	N/A	N/A	N/A	N/A
ASB 5AR						02-01-93	105900.5	52854.4	243.8 - 223.8	344.5	347.0	W.T.	MGCL				
ASB 5C						01-19-93	105884.8	52837.8	175.1 - 165.1	344.8	347.3	LOW CONG.	LL				
ASB 6A						02-20-84	105716.0	52675.9	248.2 - 218.2	348.2	350.2	W.T.	MGCL	N/A	N/A	N/A	N/A
ASB 6AA				X		12-09-88	105727.0	52643.9	82.8 - 78.1	351.8	354.2	ELLEN. SAND	MCBC	3	YES	YES	YES
ASB 6C					X	12-21-90	105736.8	52655.9	178.5 - 174	351.5	353.6		UL	4	-	-	-
ASB 6TA					X	01-30-91	105749.5	52671.3	40.0 - 34.5	351.0	352.9	BLK. CRK.	CBA	4	YES	YES	YES
ASB 7							105770.6	52626.4	231.3 - 211.3	351.3	353.4	W.T.	MGCL	N/A	N/A	N/A	N/A

Table 4-2. A/M Area Master Well List (Page 2 of 7)

UPDATED: DECEMBER 10, 1993

A/M AREA MASTER WELL LIST

(EXPLANATION OF ABBREVIATIONS ATTACHED AT END OF LIST)

WELLS	CROSS SECTION					Date Completed	COORDINATES		Elevations (ft MSL)			UNIT	UNIT II	Report	CORE LOG	SOIL CORE	GEOPHY LOGS
	A	B	C	D	E		Northing	Eastng	Screen Zones	Ground	Casing						
ASB 8					X		106381.6	53136.6	226.8 - 206.6	346.6	349.0	W.T.	GCL	N/A	-	-	-
ASB 8A					X	03-26-85	106369.3	53117.5	83.5 - 77.9	347.2	349.3	ELLEN. SAND	MCBC	1	-	-	-
ASB 8B					X	12-14-84	106362.3	53109.6	128.4 - 122.8	347.6	349.8	LOW CONG.	(LL)/MCBC	1	-	-	-
ASB 8C					X	12-18-84	106354.4	53101.0	188.3 - 182.7	347.6	349.7	UP. CONG.	UL	1	-	-	-
ASB 8TA					X	10-17-84	106375.8	53124.7	24.6 - 19.4	347.3	349.6	BLK. CRK.	CBA	1	YES	YES	YES
ASB 9							104589.2	54226.2	236.4 - 216.4	308.4	309.0	W.T.	MGC	704	YES	YES	YES
ASB 9B						07-16-87	104564.7	54215.3	164.4 - 158.8	306.6	309.0	LOW CONG.	L (UD)	2B	YES	YES	YES
ASB 9C						02-16-89	104568.1	54201.1	182.9 - 178.2	307.9	309.9	UP. CONG.	UL	3	YES	YES	YES
ASB 10C						11-26-90	105673.1	52965.5	176.8 - 171.9	346.8	348.9	LOW CONG.	UL	704	YES	YES	YES
ASB 10CR						02-01-93	105655.4	52969.7	181.7 - 171.7	348.7	349.2	LOW CONG.	LL				
MCB 2						04-13-87	97012.6	45129.0	225.9 - 205.9	326.1	328.4	W.T.	M	N/A	YES	YES	N/A
MCB 4						04-02-87	97532.5	44705.1	229.8 - 208.6	348.2	350.4	W.T.	MGCL	N/A	YES	YES	N/A
MCB 5						04-14-87	97335.6	44863.9	226.3 - 206.3	337.7	339.6	W.T.	MGC	N/A	YES	YES	N/A
MCB 5C						07-10-89	97315.1	44862.8	161.2 - 155.2	337.2	339.1	UP. CONG.	UL	704	-	-	YES
MCB 6						08-10-87	97425.7	45214.0	219.7 - 199.7	329.9	332.1	W.T.	MGC	N/A	N/A	N/A	N/A
MCB 6C						06-21-89	97413.1	45207.7	170.0 - 165.0	330.0	332.1	UP. CONG.	UL	704	YES	YES	YES
MCB 7C						07-17-89	97139.9	44870.6	160.7 - 155.7	335.7	337.7	UP. CONG.	UL	704	-	-	YES
MCB 8D						07-07-89	97180.6	44769.9	225.7 - 205.7	337.4	340.7	W.T.	MGC	N/A	N/A	N/A	N/A
MCB 9D						07-07-89	97605.8	44858.8	226.2 - 206.2	339.1	342.9	W.T.	MGCL	N/A	N/A	N/A	N/A
MSB 1A					X	01-01-83	101833.7	48467.3	253.2 - 223.2	352.2	353.2	W.T.	M	N/A	N/A	N/A	N/A
MSB 1B					X	10-18-90	101833.0	48483.2	142.6 - 137.9	352.6	354.8	LOW CONG.	LL	4	-	-	YES
MSB 1C					X	08-07-90	101832.5	48512.7	166.0 - 161.3	353.0	355.1	UP. CONG.	UL	4	YES	YES	YES
MSB 1CC					X	10-26-90	101832.5	48498.0	192.5 - 187.8	352.9	354.9	UP. CONG.	UL	4	-	-	-
MSB 1D					X	10-10-90	101833.4	48452.2	229.8 - 210.4	352.8	354.8	W.T.	MGCL	4	-	-	-
MSB 2A					X	01-01-83	102028.3	48746.4	252.6 - 222.6	351.2	352.6	W.T.	MGC	N/A	N/A	N/A	N/A
MSB 2B					X	08-30-90	101997.9	48748.2	150.3 - 145.6	352.3	354.6	LOW CONG.	LL	4	YES	YES	YES
MSB 2C					X	08-30-90	101982.5	48749.3	194.7 - 190.0	352.7	354.7	UP. CONG.	UL	4	-	-	-
MSB 2D					X	11-16-90	102014.0	48755.7	230.1 - 210.7	351.7	353.8	W.T.	MGCL	4	-	-	-
MSB 3A					X X	01-01-83	102189.9	48553.7	259.5 - 229.5	358.1	359.5	W.T.	M	N/A	N/A	N/A	N/A
MSB 3B					X X	09-17-90	102191.7	48568.0	145.8 - 141.1	358.8	361.0	LOW CONG.	LL	4	YES	YES	YES
MSB 3C					X X	09-20-90	102189.6	48538.5	193.7 - 189.0	358.7	360.8	UP. CONG.	UL	4	-	-	-
MSB 3D					X X	09-20-90	102188.6	48524.6	230.7 - 211.2	358.7	360.2	W.T.	MGC	4	-	-	-
MSB 4A					X X	10-08-82	101933.4	48313.0	254.8 - 224.8	352.9	354.8	W.T.	M	N/A	N/A	N/A	N/A
MSB 4B					X X	10-03-90	101978.3	48312.8	143.1 - 138.4	353.1	355.3	LOW CONG.	LL	4	-	-	YES
MSB 4C					X X	08-23-90	101963.2	48313.6	168.1 - 163.3	353.1	355.2	UP. CONG.	UL	4	YES	YES	YES
MSB 4D					X X	09-28-90	102007.5	48311.7	228.4 - 209.0	353.4	355.5	W.T.	M	4	-	-	-
MSB 5A						10-25-82	101971.5	46998.7	247.2 - 217.2	342.2	344.6	W.T.	M	N/A	N/A	N/A	N/A
MSB 5B						05-25-90	101971.1	46983.6	136.1 - 131.4	343.1	345.0	LOW CONG.	LL	4	BL	YES	YES
MSB 5C						05-25-90	101970.4	46968.6	188.1 - 183.4	343.1	345.2	UP. CONG.	UL	4	-	-	-
MSB 6A						10-01-82	101133.8	46319.9	241.9 - 211.9	341.9	343.8	W.T.	M	N/A	N/A	N/A	N/A
MSB 6B						05-09-90	101148.5	46321.6	129.8 - 125.1	341.8	343.9	LOW CONG.	LL	4	BL	YES	YES
MSB 6C						05-10-90	101169.1	46324.1	194.0 - 189.3	342.0	343.8	UP. CONG.	UL	4	-	-	-
MSB 7A						10-01-82	100585.7	46726.1	242.0 - 212.0	342.0	344.3	W.T.	MGC	N/A	N/A	N/A	N/A
MSB 7B						04-18-90	100597.6	46718.1	147.5 - 142.7	342.1	344.1	LOW CONG.	LL	4	BL	YES	YES
MSB 7C						04-18-90	100609.2	46709.1	200.1 - 195.4	342.1	344.5	UP. CONG.	GCL	4	-	-	-
MSB 8A					X	10-01-82	100815.1	47293.2	242.4 - 212.4	342.4	344.2	W.T.	M	N/A	N/A	N/A	N/A
MSB 8B					X	04-05-90	100805.8	47281.9	150.8 - 146.1	341.8	343.9	LOW CONG.	LL	4	YES	YES	YES
MSB 8C					X	04-18-90	100793.2	47264.6	195.9 - 191.2	341.9	344.0	UP. CONG.	UL	4	-	-	-
MSB 9A						07-28-81	102236.7	48242.5	144.2 - 139.2	357.2	359.1	LOW CONG.	LL/CBC	N/A	N/A	N/A	N/A
MSB 9B							102239.4	48251.7	209.3 - 204.3	357.3	359.3	W.T.	GCL	N/A	N/A	N/A	N/A
MSB 9C						12-18-81	102245.6	48273.0	241.8 - 221.6	357.6	359.6	W.T.	M	704	YES	YES	YES
MSB 10A						09-03-81	102451.8	47954.4	125.2 - 120.2	355.2	357.2	ELLEN. SAND	MCBC	704	YES	N/A	YES
MSB 10B						09-11-81	102488.2	47943.1	157.4 - 152.4	355.6	357.6	LOW CONG.	LL	N/A	N/A	N/A	N/A
MSB 10C						09-01-81	102465.6	47951.1	211.0 - 206.2	355.1	357.1	W.T.	GCL	N/A	N/A	N/A	N/A
MSB 10D						09-09-81	102476.9	47947.4	251.1 - 231.1	354.9	356.6	W.T.	M	N/A	N/A	N/A	N/A
MSB 11A					X	10-14-81	102638.9	48577.8	135.8 - 130.8	363.4	365.4	ELLEN. SAND	LL	704	N/A	N/A	YES
MSB 11B					X	10-09-81	102648.9	48578.5	165.7 - 160.7	363.4	365.4	UP. CONG.	UL	N/A	N/A	N/A	N/A
MSB 11C					X	10-13-81	102658.6	48579.4	182.9 - 177.9	363.5	365.5	UP. CONG.	UL	N/A	N/A	N/A	N/A
MSB 11D					X	10-15-81	102669.5	48579.7	208.0 - 203.9	363.9	365.8	W.T.	GC	N/A	N/A	N/A	N/A
MSB 11E					X	10-16-81	102678.5	48579.6	251.0 - 231.0	363.5	365.2	W.T.	M	N/A	N/A	N/A	N/A
MSB 11F					X	12-01-81	102629.3	48577.0	243.1 - 223.1	363.6	365.6	W.T.	M	N/A	N/A	N/A	N/A
MSB 12A					X	10-29-81	102283.2	47138.2	121.5 - 116.5	346.5	348.9	LOW CONG.	LL	704	N/A	N/A	YES
MSB 12B					X	10-14-81	102251.8	47139.6	162.2 - 157.2	347.5	349.5	UP. CONG.	UL	N/A	N/A	N/A	N/A
MSB 12C					X	10-19-81	102274.4	47138.4	183.9 - 178.9	347.0	349.0	UP. CONG.	UL	N/A	N/A	N/A	N/A
MSB 12D					X	10-05-81	102262.2	47139.7	245.3 - 225.3	347.3	349.4	W.T.	MGC	N/A	N/A	N/A	N/A
MSB 12TA					X	12-01-81	102266.7	47127.3	(102.8) - 88.8	347.2	348.9	BLK. CRK.	MCBC	704	N/A	N/A	YES

Table 4-2. A/M Area Master Well List (Page 3 of 7)

UPDATED: DECEMBER 10, 1993

A/M AREA MASTER WELL LIST

(EXPLANATION OF ABBREVIATIONS ATTACHED AT END OF LIST)

WELL'S	CROSS SECTION				Date Completed	COORDINATES		Elevations (ft MSL)			UNIT	UNIT II	Report	CORE LOG	SOIL CORE	GEOPHY. LOGS
	A	B	C	D		Northing	Easting	Screen Zones	Ground	Casing						
MSB 12TB				X	12-01-81	102260.1	47133.0	14.5 - (5.5)	347.5	349.3	BLK. CRK.	CBA	N/A	N/A	N/A	N/A
MSB 13A					10-22-81	101725.7	47525.4	136.5 - 131.4	344.8	346.7	LOW CONG.	LL	704	YES	YES	YES
MSB 13B					10-28-81	101735.7	47523.5	177.5 - 172.5	345.0	347.1	UP. CONG.	UL	N/A	N/A	N/A	N/A
MSB 13C					10-07-81	101745.7	47521.9	244.1 - 224.1	345.1	347.3	W.T.	M	N/A	N/A	N/A	N/A
MSB 13CC					11-13-80	101728.8	47525.7	196.8 - 192.0	344.8	346.9	UP. CONG.	GCL	4	BL	YES	YES
MSB 13D					08-23-90	101778.1	47517.5	231.5 - 211.5	345.5	347.6	W.T.	MGC	4	-	-	-
MSB 14A					10-10-81	101629.5	48521.9	164.6 - 144.8	346.6	348.7	LOW CONG.	L (UD)	704	YES	YES	YES
MSB 14B					10-20-81	101639.0	48519.1	193.9 - 188.9	346.9	348.9	UP. CONG.	GCL	N/A	N/A	N/A	N/A
MSB 14C					10-09-81	101648.6	48517.3	243.9 - 223.9	347.2	349.2	W.T.	M	N/A	N/A	N/A	N/A
MSB 15A				X	11-09-81	102983.5	48827.0	167.8 - 162.8	365.8	367.7	UP. CONG.	UL	704	YES	YES	YES
MSB 15AA				X	02-20-89	102953.2	48818.5	147.1 - 142.4	367.1	369.2	ELLEN. SAND	LL	3	-	-	YES
MSB 15C				X	11-10-81	103002.1	48834.0	260.6 - 240.6	364.8	366.7	W.T.	M	N/A	N/A	N/A	N/A
MSB 15D				X	09-06-88	102971.2	48827.5	241.4 - 221.9	366.4	368.5	W.T.	MGC	3	-	-	-
MSB 16A				X	11-16-81	103593.9	48965.1	166.8 - 161.8	365.5	367.5	UP. CONG.	UL	704	N/A	N/A	YES
MSB 16C				X	12-09-81	103714.1	48970.5	244.8 - 224.8	365.8	367.6	W.T.	M	N/A	N/A	N/A	N/A
MSB 17A				X	11-02-81	101976.6	46245.7	160.6 - 155.6	357.3	359.3	UP. CONG.	UL	N/A	N/A	N/A	YES
MSB 17B				X	12-16-81	101994.6	46237.7	190.8 - 185.8	357.2	359.2	W.T.	GCL	N/A	N/A	N/A	N/A
MSB 17BB				X	01-09-88	102009.5	46220.8	137.3 - 132.6	357.3	359.0	LOW CONG.	LL	3	-	-	YES
MSB 17C				X	11-03-81	102004.6	46234.3	253.9 - 233.9	356.9	358.2	W.T.	M	N/A	N/A	N/A	N/A
MSB 17D				X	09-16-88	102056.9	46226.2	232.8 - 213.3	357.8	359.9	W.T.	M	3	-	-	-
MSB 18A				X	12-09-81	100416.1	46110.4	163.9 - 158.9	339.9	341.9	UP. CONG.	UL	704	N/A	N/A	YES
MSB 18B				X	12-01-81	100424.1	46115.7	198.5 - 193.5	340.0	342.1	W.T.	GCL	N/A	N/A	N/A	N/A
MSB 18C				X	12-01-81	100430.9	46121.4	229.2 - 209.2	340.4	342.5	W.T.	MGC	N/A	N/A	N/A	N/A
MSB 19A				X	12-08-81	100983.0	50934.4	119.7 - 114.7	298.2	300.3	ELLEN. SAND	MCBC	704	YES	YES	YES
MSB 19B				X	12-11-81	100990.3	50934.8	147.7 - 142.7	298.5	300.4	UP. CONG.	UL	N/A	N/A	N/A	N/A
MSB 19C				X	12-09-81	100992.1	50942.4	218.7 - 198.7	298.7	300.8	W.T.	M	N/A	N/A	N/A	N/A
MSB 20A		X			11-20-81	103545.1	46060.5	162.6 - 157.6	353.3	355.3	UP. CONG.	L (UD)	704	YES	YES	YES
MSB 20C		X			11-23-81	103556.3	46088.8	232.7 - 212.7	352.7	354.7	W.T.	M	N/A	N/A	N/A	N/A
MSB 21A		X			11-19-81	103967.0	47217.2	159.5 - 154.5	352.9	354.8	UP. CONG.	LL	704	YES	YES	YES
MSB 21B		X			02-20-89	104000.1	47271.8	147.2 - 142.5	353.2	355.0	LOW CONG.	LL	3	-	-	-
MSB 21C		X			11-23-81	103973.0	47234.6	233.2 - 213.2	353.0	354.8	W.T.	M	N/A	N/A	N/A	N/A
MSB 21TA		X			12-01-81	103980.9	47218.2	22.6 - 17.3	352.6	354.6	BLK. CRK.	CBA	1	YES	YES	YES
MSB 22					06-01-82	102186.5	48508.8	243.2 - 223.2	358.2	360.1	W.T.	M	N/A	N/A	N/A	N/A
MSB 23				X	08-01-82	104312.0	49294.0	250.4 - 230.4	370.4	371.8	W.T.	M (VZ)	N/A	N/A	N/A	N/A
MSB 23TA				X		104298.8	49225.8	65.4 - 60.4	370.4	372.9	BLK. CRK.	CBA	704	YES	YES	YES
MSB 23B				X	02-16-83	104336.6	49286.4	176.1 - 171.1	370.1	371.6	UP. CONG.	UL	N/A	N/A	N/A	N/A
MSB 24					09-22-82	104614.4	49842.9	243.9 - 223.9	378.9	380.2	W.T.	M	N/A	N/A	N/A	N/A
MSB 24A					02-07-83	104625.3	49845.3	178.8 - 168.8	379.9	381.6	UP. CONG.	UL	N/A	N/A	N/A	N/A
MSB 25					08-01-82	103498.8	49668.9	244.7 - 224.7	364.7	366.9	W.T.	M	N/A	N/A	N/A	N/A
MSB 25A					02-02-83	103504.8	49657.9	169.7 - 159.7	364.7	366.4	LOW CONG.	LL	N/A	N/A	N/A	N/A
MSB 26		X			08-01-82	104612.8	48941.7	240.7 - 220.7	359.7	361.7	W.T.	M	N/A	N/A	N/A	N/A
MSB 26A		X			01-12-83	104602.3	48440.7	179.8 - 169.8	359.8	361.8	UP. CONG.	UL	N/A	N/A	N/A	N/A
MSB 26B		X			2-13-89	104646.7	48944.6	136.9 - 132.1	360.7	362.8	LOW CONG.	LL	3	YES	YES	YES
MSB 27		X			08-01-82	104972.8	49487.7	244.0 - 234.0	374.0	375.5	W.T.	M	N/A	N/A	N/A	N/A
MSB 27A		X			01-11-83	104962.8	49487.8	203.8 - 193.8	373.8	375.2	UP. CONG.	MGC	N/A	N/A	N/A	N/A
MSB 27B		X			12-12-84	104940.3	49496.4	169.9 - 164.4	374.7	376.8	UP. CONG.	UL	1	-	-	-
MSB 27TA		X			10-10-84	104951.4	49496.5	55.9 - 50.6	374.5	376.6	BLK. CRK.	CBA	1	-	-	YES
MSB 28					08-01-82	104941.8	48517.3	230.6 - 210.6	352.6	354.8	W.T.	M	N/A	N/A	N/A	N/A
MSB 28A					01-14-83	104947.7	48521.9	157.8 - 152.8	352.8	355.0	UP. CONG.	UL	N/A	N/A	N/A	N/A
MSB 29A			X		03-22-85	107326.8	51236.4	122.9 - 117.3	362.9	365.2	ELLEN. SAND	MCBC	1	-	-	-
MSB 29B			X		12-07-84	107319.3	51217.5	151.7 - 145.1	362.7	365.0	LOW CONG.	LL	1	-	-	-
MSB 29C			X		12-12-84	107315.0	51206.6	179.7 - 174.1	362.7	365.0	UP. CONG.	UL	1	-	-	-
MSB 29D			X		12-18-84	107323.3	51226.9	227.6 - 207.0	362.6	364.9	W.T.	MGC	1	-	-	-
MSB 29DD			X		08-23-88	107311.4	51191.3	250.4 - 230.4	362.4	364.4	W.T.	M	3	-	-	-
MSB 29TA			X		09-27-84	107330.4	51245.7	63.9 - 58.6	362.9	365.0	BLK. CRK.	CBA	1	YES	YES	YES
MSB 30A					03-29-83	105727.4	48004.1	36.9 - 26.9	352.9	355.0	BLK. CRK.	CBA	704	YES	YES	YES
MSB 30AA					01-25-85	105715.7	47970.5	96.4 - 90.8	351.4	353.0	ELLEN. SAND	MCBC	1	-	-	-
MSB 30B					04-04-85	105719.9	47981.8	128.7 - 123.1	351.7	353.5	LOW CONG.	LL	1	-	-	-
MSB 30C					03-31-83	105731.1	48013.7	237.6 - 217.6	352.6	354.6	W.T.	M	N/A	N/A	N/A	N/A
MSB 30CC					01-16-84	105724.2	47993.3	164.0 - 158.4	352.0	354.0	UP. CONG.	UL	1	-	-	YES
MSB 31A				X		101979.3	50100.2	22.0 - 12.0	346.0	348.1	BLK. CRK.	CBA	704	YES	YES	N/A
MSB 31B				X	05-03-83	101981.3	50078.7	157.3 - 152.3	346.3	348.3	LOW CONG.	LL	N/A	N/A	N/A	N/A
MSB 31C				X	05-05-83	101979.6	50089.9	236.1 - 216.1	346.1	348.1	W.T.	MGC	N/A	N/A	N/A	N/A
MSB 31CC				X	02-27-89	101983.1	50067.9	181.4 - 176.7	346.4	348.6	UP. CONG.	UL	3	-	-	YES
MSB 32					04-14-83	99655.6	52733.9	218.1 - 198.1	253.1	255.1	W.T.	MGC	704	YES	YES	YES
MSB 33				X	04-28-83	98031.0	51736.3	228.7 - 208.7	253.7	255.9	W.T.	MGC	N/A	N/A	N/A	N/A

Table 4-2. A/M Area Master Well List (Page 4 of 7)

UPDATED: DECEMBER 10, 1993

A/M AREA MASTER WELL LIST

(EXPLANATION OF ABBREVIATIONS ATTACHED AT END OF LIST)

WELLS	CROSS SECTION					Date Completed	COORDINATES		Elevations (ft. MSL)			UNIT	UNIT II	Report	CORE LOG	SOIL CORE	GEOPHY. LOGS
	A	B	C	D	E		Northing	Easting	Screen Zones	Ground	Casing						
MSB 33A				X		02-07-85	98006.7	51738.0	88.4 - 82.8	253.4	255.4	ELLEN. SAND	MCBC	1	-	-	-
MSB 33B				X		01-29-85	97995.9	51741.9	126.3 - 120.7	253.3	255.0	LOW CONG.	LL/CBC	1	-	-	-
MSB 33C				X		02-08-85	97984.8	51746.7	171.0 - 165.4	253.0	255.3	UP. CONG.	UL	1	-	-	-
MSB 33TA				X		01-17-85	98018.2	51734.0	23.4 - 18.1	253.4	255.5	BLK. CRK.	CBA	1	-	-	YES
MSB 34A	X				X		104954.9	50534.9	118.6 - 113.6	382.1	384.0	LOW CONG.	CBC	N/A	N/A	N/A	N/A
MSB 34B	X				X		104944.7	50534.9	187.0 - 182.0	382.0	384.0	UP. CONG.	UL	N/A	N/A	N/A	N/A
MSB 34C	X				X		104934.1	50535.5	240.9 - 220.9	381.9	383.9	W.T.	MGCL	N/A	N/A	N/A	N/A
MSB 34TA	X				X		104905.8	50536.6	(-91.9) - (-101.9)	381.8	383.4	BLK. CRK.	MCBC	704	N/A	YES	YES
MSB 34TB	X				X		104891.6	50537.9	75.8 - 65.8	381.8	383.6	BLK. CRK.	CBA	N/A	N/A	N/A	N/A
MSB 35A	X					03-05-85	102098.0	50845.2	128.8 - 123.2	348.8	350.9	ELLEN. SAND	CBC	1	-	-	-
MSB 35B	X					02-04-85	102110.8	50947.9	169.3 - 163.7	349.3	351.6	UP. CONG.	UL	1	-	-	-
MSB 35D	X					02-07-85	102122.4	50849.7	254.5 - 233.8	349.5	351.9	W.T.	M (VZ)	1	-	-	-
MSB 35TA	X					11-02-84	102101.6	50919.6	38.2 - 32.9	348.2	350.3	BLK. CRK.	CBA	1	-	-	YES
MSB 36A	X					02-20-85	100511.3	49514.9	100.5 - 94.9	338.5	340.6	ELLEN. SAND	MCBC	1	-	-	-
MSB 36B	X					01-25-85	100514.9	49526.3	163.7 - 158.1	338.7	340.8	LOW CONG.	LL	1	-	-	-
MSB 36C	X					01-29-85	100518.3	49537.2	194.2 - 188.6	339.2	340.9	UP. CONG.	UL	1	-	-	-
MSB 36D	X					01-31-85	100521.7	49548.3	249.5 - 228.8	339.5	341.6	W.T.	M	1	-	-	-
MSB 36TA	X					11-21-84	100507.7	49503.0	53.4 - 48.4	338.4	340.6	BLK. CRK.	CBA	1	YES	YES	YES
MSB 37A	X				X	03-12-85	105295.0	51439.8	73.7 - 68.1	380.7	383.0	BLK. CRK.	CBA	1	YES	YES	-
MSB 37B	X				X	01-03-85	105289.5	51450.0	142.3 - 136.7	380.3	382.7	LOW CONG.	MCBC	1	-	-	-
MSB 37C	X				X	02-07-85	105283.2	51439.8	180.8 - 175.2	380.8	383.0	UP. CONG.	UL	1	-	-	-
MSB 37D	X				X	02-01-85	105271.0	51440.3	245.7 - 225.1	380.7	382.7	W.T.	MGC	1	-	-	-
MSB 37TA	X				X	11-7-84	105301.3	51449.8	35.1 - 29.8	380.1	382.3	BLK. CRK.	CBA	1	-	-	YES
MSB 38B						10-19-88	102360.8	49748.1	146.5 - 141.8	357.0	359.0	LOW CONG.	LL/CBC	3	YES	YES	-
MSB 38C						10-20-88	102373.1	49762.0	169.0 - 164.3	356.8	358.8	UP. CONG.	LL	3	-	-	-
MSB 38D						09-16-88	102385.6	49777.8	240.4 - 220.9	356.4	358.5	W.T.	M	3	-	-	-
MSB 38TA						10-25-84	102434.9	49810.4	32.0 - 26.7	357.0	359.1	BLK. CRK.	CBA	1	-	-	YES
MSB 39A						03-05-85	100837.6	48367.3	111.7 - 106.1	339.7	341.6	ELLEN. SAND	MCBC	1	-	-	-
MSB 39B						1-7-85	100844.6	48376.9	149.6 - 144.0	339.6	341.8	LOW CONG.	LL	1	-	-	-
MSB 39C						01-01-85	100852.1	48386.7	199.6 - 194.0	339.7	341.5	UP. CONG.	UL	1	-	-	-
MSB 39D						01-14-85	100858.7	48396.0	239.7 - 219.0	339.7	341.8	W.T.	MGC	1	-	-	-
MSB 39TA						10-04-84	100830.6	48357.7	49.7 - 44.4	339.7	341.8	BLK. CRK.	CBA	1	-	-	YES
MSB 40A	X					03-01-85	97672.8	48279.4	116.2 - 110.6	319.2	321.2	ELLEN. SAND	MCBC	1	-	-	-
MSB 40B	X					01-31-85	97685.0	48281.6	154.7 - 149.1	319.7	321.7	LOW CONG.	LL	1	-	-	-
MSB 40C	X					02-04-85	97697.8	48283.5	192.4 - 186.8	320.4	322.0	UP. CONG.	UL	1	-	-	-
MSB 40D	X					02-07-85	97709.3	48285.1	236.8 - 216.2	320.8	322.9	W.T.	MGC	1	-	-	-
MSB 40TA	X					11-30-84	97660.4	48277.2	29.0 - 23.7	319.0	320.9	BLK. CRK.	CBA	1	YES	YES	YES
MSB 41A		X				12-13-84	102184.4	53424.1	87.9 - 82.3	321.9	323.8	ELLEN. SAND	MCBC	1	-	-	-
MSB 41B		X				02-25-85	102194.5	53417.8	114.2 - 108.6	322.2	324.0	ELLEN. SAND	MCBC	1	-	-	-
MSB 41C		X				02-11-85	102203.9	53410.6	152.5 - 146.9	322.5	324.6	LOW CONG.	LL	1	-	-	-
MSB 41D		X				02-13-85	102213.4	53403.7	247.8 - 227.1	322.8	325.0	W.T.	M	1	-	-	-
MSB 41TA		X				01-11-85	102176.5	53429.7	26.7 - 21.4	321.7	323.7	BLK. CRK.	CBA	1	YES	YES	YES
MSB 42A	X	X				03-19-85	104557.9	51582.3	129.4 - 123.8	374.4	376.5	LOW CONG.	MCBC	1	-	-	-
MSB 42B	X	X				01-16-85	104569.8	51582.8	166.3 - 160.7	374.3	376.4	UP. CONG.	LL	1	-	-	-
MSB 42C	X	X				01-24-85	104581.9	51582.8	204.3 - 198.7	374.3	376.4	UP. CONG.	UL	1	-	-	-
MSB 42D	X	X				01-30-85	104595.2	51582.5	247.2 - 226.6	374.2	376.4	W.T.	MGC	1	-	-	-
MSB 42TA	X	X				10-31-84	104545.6	51581.7	45.8 - 40.5	374.5	376.6	BLK. CRK.	CBA	1	YES	YES	YES
MSB 43A			X			04-01-85	107275.3	49293.7	140.5 - 134.9	355.5	357.7	LOW CONG.	LL	1	-	-	-
MSB 43B			X			12-12-84	107274.6	49311.8	175.5 - 169.9	355.5	357.8	UP. CONG.	UL	1	-	-	-
MSB 43D			X			01-03-85	107274.2	49322.0	220.8 - 200.2	355.8	358.0	W.T.	MGCL	1	-	-	-
MSB 43DD			X			08-23-88	107273.0	49341.2	243.2 - 223.1	356.2	357.9	W.T.	M	3	-	-	-
MSB 43TA			X			08-25-84	107275.8	49281.8	40.3 - 35.0	355.3	357.5	BLK. CRK.	CBA	1	-	-	YES
MSB 44A	X						103296.5	51106.9	134.6 - 124.6	374.4	376.9	ELLEN. SAND	MCBC	N/A	N/A	N/A	YES
MSB 44B	X						103296.2	51096.4	184.6 - 174.6	374.6	377.0	UP. CONG.	L(UD)	N/A	N/A	N/A	N/A
MSB 44C	X						103296.3	51106.6	239.4 - 229.4	374.4	376.8	W.T.	MGCL	N/A	N/A	N/A	N/A
MSB 45A							103998.1	50554.7	139.2 - 129.2	378.4	380.8	ELLEN. SAND	LL	704	N/A	N/A	YES
MSB 45B							103987.9	50555.3	190.0 - 180.0	378.3	380.9	UP. CONG.	UL	N/A	N/A	N/A	N/A
MSB 45C							103997.7	50554.7	243.7 - 233.4	378.4	380.8	W.T.	MGC	N/A	N/A	N/A	N/A
MSB 46A							103098.6	50548.3	130.0 - 120.0	370.0	372.6	ELLEN. SAND	MCBC	N/A	N/A	N/A	N/A
MSB 46B							103102.4	50557.5	189.8 - 179.8	370.8	373.6	UP. CONG.	UL	N/A	N/A	N/A	N/A
MSB 46C							103098.5	50548.7	247.0 - 237.0	370.0	372.6	W.T.	MGC	N/A	N/A	N/A	N/A
MSB 47B	X					07-10-87	106978.5	52207.2	171.5 - 165.9	366.7	368.7	UP. CONG.	LL	2B	-	-	-
MSB 47BB	X					10-16-89	106999.7	52234.4	120.3 - 115.6	366.3	368.8	LOW CONG.	MCBC	4	-	-	YES
MSB 47C	X					07-14-87	106999.2	52195.5	202.6 - 197.0	366.8	369.0	UP. CONG.	UL	2B	-	-	-
MSB 47D	X					08-07-87	106960.1	52184.0	246.1 - 226.5	366.6	368.8	W.T.	MGC	2B	-	-	-
MSB 47TA	X					06-22-87	106987.7	52219.0	55.1 - 50.1	366.2	368.7	BLK. CRK.	CBA	2B	YES	YES	YES

Table 4-2. A/M Area Master Well List (Page 5 of 7)

UPDATED: DECEMBER 10, 1993

A/M AREA MASTER WELL LIST

(EXPLANATION OF ABBREVIATIONS ATTACHED AT END OF LIST)

WELLS	CROSS SECTION					Date Completed	COORDINATES		Elevations (ft MSL)			UNIT	UNIT II	Report	CORE LOG	SOIL CORE	GEOPHY. LOGS
	A	B	C	D	E		Northing	Eastng	Screen Zones	Ground	Casing						
MSB 48A			X		X	01-12-90	107936.6	54099.8	129.4 - 124.7	359.4	361.6	ELLEN. SAND	CBC	4	-	-	-
MSB 48B			X		X	01-16-90	107945.0	54112.2	158.3 - 153.6	359.3	361.4	LOW CONG.	CBC	4	-	-	-
MSB 48C			X		X	05-25-89	107917.5	54077.0	180.2 - 175.4	360.2	362.3	UP. CONG.	LL	3A	YES	YES	YES
MSB 48D			X		X		107914.4	54056.3	243.5 - 222.0	360.5	362.6	W.T.	UL	N/A	N/A	N/A	N/A
MSB 48TA			X		X	01-15-90	107925.8	54089.2	107.8 - 102.5	359.8	361.9	BLK. CRK.	CBA	4	YES	YES	YES
MSB 49A					X	01-20-89	99759.0	45864.6	76.7 - 72.0	332.7	334.7	ELLEN. SAND	MCBC	3	YES	YES	YES
MSB 49B					X	07-31-87	99737.8	45868.2	116.3 - 110.7	331.8	334.1	LOW CONG.	LL	2B	YES	YES	YES
MSB 49D					X	08-10-87	99724.9	45856.4	236.4 - 216.7	331.8	334.3	W.T.	M	2B	-	-	-
MSB 50B						05-20-87	96433.0	51053.5	155.2 - 149.6	221.3	223.7	LOW CONG.	UL	2B	YES	YES	YES
MSB 50D						08-04-87	96416.7	51044.1	210.9 - 190.8	220.7	223.2	W.T.	M	2B	-	-	-
MSB 51B				X		05-26-87	96992.7	52818.0	160.0 - 154.4	281.1	263.2	LOW CONG.	L(UD)	2B	YES	YES	YES
MSB 51D				X		06-31-87	97015.7	52816.2	218.5 - 198.8	260.0	262.2	W.T.	GC	2B	-	-	-
MSB 51DD				X		08-04-87	97006.2	52830.3	235.4 - 215.8	261.0	263.2	W.T.	MGC	2B	-	-	-
MSB 52B		X				07-21-87	103077.7	53418.4	171.4 - 165.8	319.5	321.7	LOW CONG.	LL	2B	YES	YES	YES
MSB 52D		X				08-06-87	103062.7	53416.8	250.8 - 231.1	319.4	321.6	W.T.	M	2B	-	-	-
MSB 53B						02-07-89	106443.6	54574.3	152.3 - 147.6	342.3	344.3	LOW CONG.	LL	3	YES	YES	YES
MSB 53C						03-12-87	106456.2	54540.5	192.6 - 187.8	343.2	345.2	UP. CONG.	UL	2B	YES	YES	YES
MSB 53D							106448.2	54553.1	244.9 - 223.6	342.9	344.8	W.T.	MGC	N/A	N/A	N/A	N/A
MSB 54B	X					07-24-87	108446.8	52970.5	136.4 - 130.8	371.1	373.4	LOW CONG.	MCBC	2B	-	-	-
MSB 54C	X					07-28-87	108447.4	52955.7	175.6 - 170.0	371.2	373.4	UP. CONG.	LL	2B	-	-	-
MSB 54D	X						108461.5	52984.5	244.8 - 223.8	371.4	373.6	W.T.	GCL	704	N/A	N/A	YES
MSB 54TA	X					07-22-87	108446.3	52985.8	80.9 - 75.3	371.1	373.5	BLK. CRK.	CBA	2B	YES	YES	YES
MSB 55B						01-03-90	108342.4	52006.2	152.7 - 148.0	366.7	368.7	LOW CONG.	CBC	4	-	-	-
MSB 55C						04-28-89	108324.6	52029.7	189.3 - 184.6	367.3	369.4	UP. CONG.	LL	3A	YES	YES	YES
MSB 55D							108391.4	52032.5	245.9 - 224.7	365.9	367.7	W.T.	GCL	704	N/A	N/A	YES
MSB 55HC						10-06-90	108338.7	52020.1	218.8 - 214.1	366.8	368.7	UP. CONG.	UL	4	-	-	-
MSB 55TA						12-06-89	108322.8	52014.7	91.6 - 86.2	366.6	368.7	BLK. CRK.	CBA	4	YES	YES	YES
MSB 56D							108463.5	44207.9	232.4 - 211.1	277.4	279.5	W.T.	M	704	N/A	N/A	YES
MSB 57D						10-26-90	101829.5	48701.5	229.6 - 210.1	354.1	356.2	W.T.	M	4	-	-	-
MSB 58D						10-26-90	102200.6	48693.5	230.5 - 211.1	355.8	357.9	W.T.	M	4	-	-	-
MSB 59D						09-25-90	102182.2	48314.8	229.3 - 209.9	357.3	359.3	W.T.	M	4	N/A	YES	-
MSB 60D						10-05-90	101835.5	48326.8	228.3 - 208.9	352.3	354.5	W.T.	M	4	N/A	YES	-
MSB 61C						04-14-87	106091.1	55406.6	179.7 - 174.1	315.1	317.3	UP. CONG.	UL	2B	YES	YES	YES
MSB 61D						08-06-87	106094.6	55390.6	234.2 - 214.3	315.7	317.8	W.T.	GCL	2B	-	-	-
MSB 62B				X		11-15-90	101865.3	47908.8	141.0 - 136.3	347.0	349.1	LOW CONG.	LL	4	BL	YES	YES
MSB 62C				X		11-26-90	101857.2	47895.0	190.0 - 185.2	347.0	349.1	UP. CONG.	UL	4	-	-	-
MSB 62D				X		11-26-90	101849.0	47882.9	231.9 - 212.4	347.4	349.5	W.T.	M	4	-	-	-
MSB 63B				X		03-21-90	101184.4	47861.0	140.9 - 136.2	344.9	346.9	LOW CONG.	LL	4	YES	YES	YES
MSB 63C				X		03-23-90	101174.6	47849.2	195.8 - 191.1	344.8	347.0	UP. CONG.	UL	4	-	-	-
MSB 63D				X		07-23-90	101165.2	47837.4	232.8 - 212.8	344.8	346.8	W.T.	MGC	4	-	-	-
MSB 64B						02-28-90	101831.0	46579.7	124.3 - 119.6	346.3	348.3	LOW CONG.	MCBC	4	YES	YES	YES
MSB 64C						03-12-90	101842.9	46589.2	181.2 - 176.5	346.2	348.4	UP. CONG.	UL	4	-	-	-
MSB 64D						07-23-90	101854.8	46598.5	230.1 - 210.1	346.6	348.6	W.T.	MGC	4	-	-	-
MSB 65D						10-12-88	101815.5	49413.7	243.9 - 224.4	347.1	349.2	W.T.	M	3	-	-	-
MSB 66B						11-17-88	105842.0	51064.6	143.9 - 139.2	381.4	383.4	LOW CONG.	MCBC	3	-	-	-
MSB 66C						11-28-88	105842.1	51053.5	170.9 - 166.2	381.4	383.4	UP. CONG.	LL	3	-	-	-
MSB 66D						12-21-88	105841.8	51044.0	239.5 - 220.0	381.5	383.2	W.T.	MGC	3	-	-	-
MSB 66TA						12-21-88	105842.6	51096.7	35.5 - 30.8	380.5	382.7	BLK. CRK.	CBA	3	YES	YES	YES
MSB 67B						11-09-88	106842.0	51989.6	134.9 - 130.1	362.7	365.1	LOW CONG.	MCBC	3	YES	YES	YES
MSB 67C						11-11-88	106819.8	51988.6	174.9 - 170.1	362.7	364.8	UP. CONG.	LL	3	-	-	-
MSB 67D						11-11-88	106830.7	51971.5	241.0 - 221.5	363.1	365.0	W.T.	MGC	3	-	-	-
MSB 68B						12-01-88	106744.9	52308.5	133.0 - 128.3	355.0	356.9	LOW CONG.	MCBC	3	-	-	YES
MSB 68C						12-14-88	106730.5	52304.9	171.7 - 167.0	354.7	356.7	UP. CONG.	LL	3	-	-	-
MSB 68D						12-06-88	106741.4	52293.6	239.9 - 220.4	354.9	357.0	W.T.	MGC	3	-	-	-
MSB 69B	X		X			01-26-89	107776.1	52432.9	144.5 - 139.8	379.5	381.5	LOW CONG.	MCBC	3	-	-	-
MSB 69C	X		X			01-31-89	107780.1	52447.5	175.7 - 171.0	379.7	381.6	UP. CONG.	LL	3	-	-	-
MSB 69D	X		X			02-01-89	107784.3	52462.0	239.8 - 220.3	379.8	382.0	W.T.	MGC	3	-	-	-
MSB 69TA	X		X			01-26-89	107772.5	52418.4	80.3 - 74.6	379.3	381.4	BLK. CRK.	CBA	3	YES	YES	YES
MSB 70C						08-29-88	101785.2	45012.0	178.8 - 174.1	359.8	361.8	UP. CONG.	UL	3	YES	YES	YES
MSB 70D						07-23-90	101781.8	44997.3	228.3 - 208.2	360.3	362.2	W.T.	M	4	-	-	-
MSB 71B		X		X		10-28-88	103801.6	44054.7	135.9 - 131.1	342.0	344.7	LOW CONG.	L(UD)	3	YES	YES	YES
MSB 72B						01-31-89	96387.6	48350.3	156.7 - 152.0	326.7	328.2	LOW CONG.	LL	3	YES	YES	YES
MSB 73B					X	02-03-89	99270.3	45694.0	135.5 - 130.8	337.5	339.6	LOW CONG.	LL	3	-	-	YES
MSB 74B				X		11-01-89	99197.4	50443.2	147.5 - 142.8	312.5	314.5	LOW CONG.	LUCBC	4	YES	YES	YES
MSB 74C				X		11-09-89	99191.1	50457.1	177.8 - 173.1	312.8	315.0	UP. CONG.	UL	4	-	-	-
MSB 74D				X		11-09-89	99185.3	50469.7	237.1 - 217.1	313.1	315.1	W.T.	MGC	4	-	-	-

Table 4-2. A/M Area Master Well List (Page 6 of 7)

UPDATED: DECEMBER 10, 1993

A/M AREA MASTER WELL LIST

(EXPLANATION OF ABBREVIATIONS ATTACHED AT END OF LIST)

WELLS	CROSS SECTION					Date Completed	COORDINATES		Elevations (ft MSL)			UNIT I	UNIT II	Report	CORE LOG	SOIL CORE	GEOPHY LOGS
	A	B	C	D	E		Northing	Easting	Screen Zones	Ground	Casing						
MSB 75B	X					11-17-89	98937.4	48875.5	161.7 - 156.9	324.7	326.7	LOW CONG.	LL	4	YES	YES	YES
MSB 75C	X					11-21-89	98942.3	48859.7	193.5 - 188.8	325.5	327.5	UP. CONG.	UL	4	-	-	-
MSB 76C			X			02-06-90	103061.6	45344.0	186.0 - 181.3	350.0	352.4	UP. CONG.	UL	4	YES	YES	YES
MSB 77B				X		07-10-90	107065.8	54217.4	145.1 - 140.4	355.1	357.2	LOW CONG.	MCBC	4	-	-	-
MSB 77C				X		07-10-90	107078.3	54225.9	173.2 - 168.5	355.2	357.2	UP. CONG.	LL	4	-	-	-
MSB 77D				X		07-12-90	107090.7	54233.4	236.2 - 216.2	355.2	357.4	W.T.	MGCL	4	-	-	-
MSB 77TA				X		07-05-90	107053.8	54208.9	82.9 - 77.6	354.9	356.9	BLK. CRK.	CBA	4	YES	YES	YES
MSB 78D		X				10-23-90	103643.8	45482.2	225.5 - 206.1	361.1	363.6	W.T.	MGC	4	-	-	YES
MSB 79B						12-04-90	99296.9	47300.2	140.8 - 136.1	345.8	347.9	LOW CONG.	LL	4	YES	YES	YES
MSB 79C						01-03-90	99290.2	47286.8	199.6 - 194.9	345.6	347.8	UP. CONG.	UL	4	-	-	-
MSB 81B						06-04-90	103762.7	55230.4	146.1 - 141.4	265.1	267.0	LOW CONG.	LL	4	BL	YES	YES
MSB 82A		X				08-14-90	107529.5	51978.4	126.1 - 121.4	372.1	374.3	ELLEN. SAND	MCBC	4	-	-	-
MSB 82B		X				08-14-90	107533.4	51993.3	148.2 - 143.5	372.2	374.2	LOW CONG.	UL/CBC	4	-	-	-
MSB 82C		X				05-15-89	107521.9	51949.4	177.7 - 173.0	371.7	373.9	UP. CONG.	LL	3A	YES	YES	YES
MSB 82D		X				08-06-90	107518.1	51934.6	236.9 - 216.8	371.4	373.6	W.T.	MGCL	4	-	-	-
MSB 82TA		X				08-06-90	107525.7	51964.2	93.8 - 88.4	371.8	373.7	BLK. CRK.	CBA	4	YES	YES	YES
MSB 83B						12-17-90	108426.7	52421.4	146.3 - 141.6	369.8	371.8	LOW CONG.	MCBC	4	-	-	-
MSB 83C						05-10-89	108405.3	52384.7	182.8 - 178.0	369.8	372.0	UP. CONG.	LL	3A	YES	YES	YES
MSB 83D						11-16-90	108418.4	52391.2	236.1 - 216.7	369.3	371.6	W.T.	MGCL	4	-	-	-
MSB 83TA						12-14-90	108416.3	52410.9	75.7 - 70.2	369.7	371.7	BLK. CRK.	CBA	4	BL	YES	YES
MSB 84C						05-04-89	108967.9	51973.7	194.9 - 190.2	359.9	361.9	UP. CONG.	LL	3A	YES	YES	YES
MSB 85B		X				01-24-90	107827.0	53122.7	137.3 - 132.6	378.3	380.3	LOW CONG.	CBA	4	-	-	-
MSB 85C		X				05-19-89	107835.2	53151.4	173.6 - 168.8	378.6	380.9	UP. CONG.	LL	3A	YES	YES	YES
MSB 85D		X				08-23-90	107822.8	53108.8	236.3 - 216.2	378.8	380.8	W.T.	MGCL	4	-	-	-
MSB 85TA		X				01-02-90	107831.2	53137.2	88.2 - 82.8	378.4	380.4	BLK. CRK.	CBA	4	YES	YES	YES
MSB 86C			X			10-13-89	108500.4	53560.5	164.8 - 160.1	354.8	357.0	UP. CONG.	LL	4	YES	YES	YES
RWM 1						05-07-85	102599.1	48575.1	232.3 - 172.3	362.8	364.7	MZ	MGCL	N/A	N/A	N/A	N/A
RWM 2						05-03-85	104434.1	49205.5	208.3 - 138.3	368.3	371.3	MZ	L	N/A	N/A	N/A	N/A
RWM 3						06-06-85	104730.2	49680.0	214.0 - 144.0	374.0	377.0	MZ	GCL	N/A	N/A	N/A	N/A
RWM 4						02-22-85	103719.3	48948.2	211.9 - 129.5	363.5	366.5	MZ	MGC	704	N/A	N/A	YES
RWM 5						02-27-85	103502.2	49628.0	216.8 - 133.9	363.9	366.9	MZ	GCL	704	N/A	N/A	YES
RWM 6						05-03-85	102001.5	50107.4	218.7 - 141.1	346.1	349.1	MZ	GCL	704	N/A	N/A	YES
RWM 7						02-25-85	101904.6	49449.5	216.3 - 144.0	346.0	349.0	MZ	GCL	704	N/A	N/A	YES
RWM 8						02-21-85	101948.2	47353.3	197.2 - 109.3	345.3	348.3	MZ	LCBC	704	N/A	N/A	YES
RWM 9						02-26-85	104099.8	50400.0	220.6 - 132.6	377.6	380.6	MZ	GCL	N/A	N/A	N/A	N/A
RWM 10						02-21-85	102000.9	48244.1	215.5 - 127.5	352.5	355.5	MZ	GCL	N/A	N/A	N/A	N/A
RWM 11						02-26-85	104875.0	50400.2	214.6 - 141.9	380.3	383.3	MZ	L	N/A	N/A	N/A	N/A
RWM 12						01-16-90	106879.2	52500.1	210.4 - 159.2	359.0	359.4	UP. CONG.	L	4	YES	YES	YES
RWM 16						05-01-90	97647.2	48244.8	188.4 - 147.2	318.4	319.4	UP. CONG.	L	4	BL	YES	YES
RWM 16PA						07-26-90	97783.9	48364.9	188.9 - 148.8	327.9	328.7	UP. CONG.	L	4	-	-	-
RWM 16PB						07-26-90	97672.1	48212.5	189.3 - 149.2	317.8	319.5	UP. CONG.	L	4	-	-	-
SRW 1						10-21-81	103776.7	41407.0	230.2 - 200.2	313.2	315.2	W.T.	M	N/A	N/A	N/A	N/A
SRW 2						10-22-81	103721.8	41627.2	228.6 - 198.6	318.6	320.6	W.T.	M	N/A	N/A	N/A	N/A
SRW 2A						08-08-83	103720.8	41634.6	98.4 - 88.6	319.1	320.6	LOW CONG.	MCBC	N/A	N/A	N/A	N/A
SRW 2B						12-20-83	103729.7	41631.7	162.6 - 152.8	319.2	320.6	UP. CONG.	UL	N/A	N/A	N/A	N/A
SRW 3A						08-20-84	103516.4	41851.2	193.1 - 163.1	330.1	332.1	W.T.	GCL	N/A	N/A	N/A	N/A
SRW 4						09-28-81	103359.9	41612.4	230.1 - 200.1	318.1	320.1	W.T.	M	N/A	N/A	N/A	N/A
SRW 5						10-29-81	103418.2	41240.0	224.6 - 194.6	307.6	309.4	W.T.	M	N/A	N/A	N/A	N/A
SRW 6						11-03-81	103602.7	41243.9	222.6 - 192.6	305.6	307.7	W.T.	M	N/A	N/A	N/A	N/A
SRW 7						05-03-82	103541.5	40925.2	217.5 - 197.5	296.7	299.1	W.T.	M	N/A	N/A	N/A	N/A
SRW 8						05-10-82	103470.0	40455.9	215.7 - 195.7	286.7	288.1	W.T.	M	N/A	N/A	N/A	N/A
SRW 9						07-20-82	103259.8	39688.4	196.3 - 166.3	251.3	253.4	W.T.	M	N/A	N/A	N/A	N/A
SRW 9A						08-21-83	103251.1	39692.9	124.3 - 114.4	251.4	253.3	LC	MGC	N/A	N/A	N/A	N/A
SRW 9B						12-19-83	103241.6	39697.6	162.4 - 152.6	251.7	253.4	UP. CONG.	M	N/A	N/A	N/A	N/A
SRW 10						09-16-82	103387.9	40944.3	223.0 - 193.0	301.0	303.4	W.T.	M	N/A	N/A	N/A	N/A
SRW 11						09-20-82	103693.2	40874.2	220.6 - 190.6	293.6	295.8	W.T.	M	N/A	N/A	N/A	N/A
SRW 12A						09-20-83	103710.3	39013.3	113.7 - 103.9	234.1	236.3	LOW CONG.	M	N/A	N/A	N/A	N/A
SRW 12B						12-17-83	103702.7	39020.3	156.1 - 146.3	234.1	236.3	UP. CONG.	M	N/A	N/A	N/A	N/A
SRW 12C						09-30-83	103712.5	39023.1	198.9 - 179.1	234.3	236.3	W.T.	M	N/A	N/A	N/A	N/A
SRW 13A						12-05-83	103001.0	40668.2	103.6 - 93.8	295.7	297.7	LOW CONG.	LL	N/A	N/A	N/A	N/A
SRW 13B						12-16-83	102993.6	40675.8	163.2 - 153.3	295.7	297.7	UP. CONG.	MCBC	N/A	N/A	N/A	N/A
SRW 13C						12-13-83	102986.5	40682.7	225.4 - 195.8	295.9	297.7	W.T.	M	N/A	N/A	N/A	N/A
SRW 14A						09-03-83	102831.3	41538.6	123.7 - 107.9	324.9	327.0	LOW CONG.	MCBC	N/A	N/A	N/A	N/A
SRW 14B						12-16-83	102836.1	41548.1	162.9 - 153.1	324.9	326.9	UP. CONG.	UL	N/A	N/A	N/A	N/A
SRW 14C						11-15-83	102824.2	41546.4	228.3 - 198.6	325.3	326.9	W.T.	M	N/A	N/A	N/A	N/A
SRW 15A						10-02-83	104778.0	41234.7	107.6 - 97.8	317.4	319.1	LOW CONG.	MCBC	N/A	N/A	N/A	N/A

Table 4-2. A/M Area Master Well List (Page 7 of 7)

UPDATED: DECEMBER 10, 1993

A/M AREA MASTER WELL LIST

(EXPLANATION OF ABBREVIATIONS ATTACHED AT END OF LIST)

WELLS	CROSS SECTION					Date		COORDINATES		Elevations (ft MSL)				UNIT	UNIT II	Report	CORE LOG	SOIL CORE	GEOPHY LOGS
	A	B	C	D	E	Completed	North	East	Screen Zone	Ground	Casing								
SRW 15B						11-12-83	104772.9	41252.5	161.6 - 151.8	317.1	319.1			UP. CONG.	UL	N/A	N/A	N/A	N/A
SRW 15C						10-18-83	104774.9	41245.1	217.3 - 187.7	317.3	319.1			W.T.	M	N/A	N/A	N/A	N/A
SRW 16A						10-28-83	103763.4	42830.9	144.1 - 119.4	344.5	346.8			LOW CONG.	LCBC	N/A	N/A	N/A	N/A
SRW 16B						11-13-83	103772.0	42825.8	169.9 - 160.1	344.4	346.8			UP. CONG.	L	N/A	N/A	N/A	N/A
SRW 16C						07-04-84	103772.4	42841.8	235.7 - 205.7	345.3	346.6			W.T.	MGC	N/A	N/A	N/A	N/A

** Wells abandoned after issue of well inventory 9-93

INDEX OF ACRONYMS USED

N/A	-	NO DATA FOUND FOR THIS ITEM
704	-	INFORMATION AVAILABLE AT SRS BUILDING 704-B, CORE LOGGING LAB
YES	-	DATA AVAILABLE
1	-	INFORMATION AVAILABLE IN 'INSTALLATION OF MONITORING WELLS IN THE A/M AREAS OF THE SAVANNAH RIVER PLANT', 1986, PHASE I, FINAL REPORT
2B	-	INFORMATION AVAILABLE IN 'A/M AREA PHASE IIB MONITORING WELL INSTALLATION REPORT', E.I. DU PONT DE NEMOURS & COMPANY, INC., 1987
3	-	INFORMATION AVAILABLE IN 'A/M AREA PHASE III MONITORING WELL INSTALLATION REPORT', E.I. DU PONT DE NEMOURS & COMPANY, INC., 1989
4	-	INFORMATION AVAILABLE IN 'A/M AREA PHASE IV MONITORING AND RECOVERY WELL INSTALLATION REPORT', WESTINGHOUSE SAVANNAH RIVER COMPANY, 1991, WSRC-RP-91-180
BL	-	CORE AVAILABLE BUT LOGGING INCOMPLETE OR ON BACKLOG AS OF FEBRUARY, 1992

UNIT - NAMES FORMERLY USED

W.T.	-	WATER TABLE AQUIFER
UP. CONG.	-	UPPER CONGAREE AQUIFER
LOW CONG.	-	LOWER CONGAREE AQUIFER
ELLEN. SAND	-	ELLENTON SANDS
BLK. CRK.	-	BLACK CREEK AQUIFER

UNIT II - NAMES PROPOSED THIS STUDY

MGC	-	M-AREA AZ - GREEN CLAY CZ
MGCL	-	M-AREA AZ - GREEN CLAY CZ - LOST LAKE AZ
L	-	"LOST LAKE" (UNDIFFERENTIATED) AZ
UL	-	UPPER "LOST LAKE" AZ
LL	-	LOWER "LOST LAKE" AZ
M	-	M-AREA AZ
GC	-	"GREEN CLAY" CZ
CBC	-	CROUCH BRANCH CU
MCBC	-	MIDDLE SAND AZ OF THE CBCU
CBA	-	CROUCH BRANCH AQUIFER
(UD)	-	UNDIFFERENTIATED
GCL	-	GREEN CLAY - LOST LAKE
(VZ)	-	VADOSE ZONE
LCBC	-	LOST LAKE AZ - CROUCH BRANCH CU

Table 4-3. Summary of Hydrostratigraphic Data from Monitoring Wells in the A/M Area

* - UNITS IN FEET

A - ASSENT

NP - NOT PENETRATED

WELL #	SFB Easting	SFB Northing	THICKNESS OF "M-AREA" AQUIFER ZONE	TOP OF "GREEN CLAY" CONFINING ZONE	THICKNESS OF "GREEN CLAY" CONFINING ZONE	THICKNESS OF "LOST LAKE" AQUIFER ZONE	THICKNESS OF STEED POND AQUIFER	TOP OF CROUCH BRANCH CONFINING UNIT	THICKNESS OF CROUCH BRANCH CONFINING UNIT
ASB-006TA	52671.3	105749.5	A	A	A	A	210	141	83
ASB-008TA	53124.7	106375.8	A	A	A	A	212	135	83
ASB-009C	54201.1	104568.1	A	A	A	A	175	133	NP
MSB-001B	48483.2	101833.0	A	A	A	A	218	135	NP
MSB-002B	48748.2	101997.9	145	207	2	65	A	140	65
MSB-003B	48568.0	102191.7	156	203	2	68	A	133	NP
MSB-004B	48312.8	101978.3	A	A	A	A	218	135	NP
MSB-007B	48718.1	100597.6	122	220	20	56	A	148	NP
MSB-079B	47300.2	99296.9	138	208	20	56	A	152	NP
MSB-006B	47281.9	100805.8	132	210	3	68	A	139	NP
MSB-011A	48577.6	102638.9	163	200	4	69	A	127	NP
MSB-012TA	47127.3	102266.7	154	192	3	77	A	112	NP
MSB-015AA	48818.5	102953.2	145	222	20	71	A	131	NP
MSB-016A	48965.1	103693.9	146	219	18	66	A	135	NP
MSB-017A	46245.7	101976.6	A	A	A	A	251	105	NP
MSB-018A	48110.4	100416.1	128	210	9	70	A	131	NP
MSB-019A	50934.4	100963.0	99	199	12	46	A	141	74
MSB-020A	48060.5	103545.1	A	A	A	A	217	135	NP
MSB-021TA	47218.2	103980.9	A	A	A	A	218	135	102
MSB-023TA	49220.0	104298.8	170	200	5	67	A	128	58
MSB-026	48941.7	104612.8	160	200	3	68	A	129	83
MSB-027TA	49486.5	104951.4	180	195	4	62	A	129	67
MSB-029A	51236.4	107326.8	A	A	A	A	226	137	36
MSB-031A	50100.2	101979.3	A	A	A	A	205	141	75
MSB-033TA	51734.0	98018.2	42	212	26	66	A	120	68
MSB-034TA	50536.6	104905.8	161	220	4	75	A	141	64
MSB-035TA	50919.6	102101.6	148	202	5	60	A	137	73
MSB-036TA	49503.0	100507.7	116	222	19	59	A	144	66
MSB-037TA	51449.8	105301.3	A	A	A	A	220	160	78
MSB-038TA	49810.4	102434.9	A	A	A	A	214	141	76
MSB-039TA	48357.7	100830.6	132	208	4	65	A	139	56
MSB-040TA	48277.2	97660.4	96	223	3	79	A	141	95
MSB-041TA	53429.7	102178.5	112	210	3	80	A	127	65
MSB-042TA	51581.7	104545.6	A	A	A	A	224	151	60
MSB-043TA	49281.8	107275.8	A	A	A	A	229	126	54
MSB-047TA	52219.0	106987.7	A	A	A	A	218	148	69
MSB-048TA	54089.2	107925.8	153	207	3	57	A	161	48
MSB-049A	45864.6	99759.0	122	211	10	72	A	129	NP
MSB-051B	52818.0	96992.7	37	224	26	70	A	128	NP
MSB-052B	53418.4	103077.7	A	A	A	A	172	147	NP
MSB-054TA	52985.8	108446.3	A	A	A	A	210	161	55
MSB-055TA	52014.7	108322.8	A	A	A	A	198	169	59
MSB-062B	47906.8	101865.3	149	198	3	71	A	124	NP
MSB-063B	47861.0	101184.4	134	211	6	77	A	128	NP
MSB-069TA	52418.4	107772.5	A	A	A	A	220	159	59
MSB-070C	45012.0	101785.2	A	A	A	A	238	122	NP
MSB-071B	44054.7	103801.6	153	190	2	83	A	105	NP
MSB-073B	45694.0	99270.3	124	214	12	78	A	126	NP
MSB-074B	50443.2	99197.4	90	223	28	54	A	141	62
MSB-075B	48875.5	98937.4	107	218	22	51	A	145	85
MSB-076C	45344.0	103061.6	154	197	2	82	A	113	NP
MSB-077TA	54206.9	107053.8	A	A	A	A	223	160	46
MSB-078D	45482.2	103643.8	A	A	A	A	NP	NP	NP
MSB-081B	55230.4	103762.7	51	214	10	64	A	140	NP
MSB-082TA	51984.2	107525.7	A	A	A	A	211	161	51
MSB-083TA	52410.9	108416.3	A	A	A	A	201	171	NP
MSB-084C	51973.7	108967.9	A	A	A	A	175	185	NP
MSB-085TA	53137.2	107831.2	A	A	A	A	215	164	18
MSB-086C	54560.5	108500.4	139	216	14	59	A	143	NP
905-82A	51106.9	103296.5	146	228	6	71	A	151	72

Table 4-4. Cross Section A-A' Monitoring Wells Showing Potentiometric Elevations

Page 1 of 2

Monitoring Wells	Hydrostratigraphic Interval	Potentiometric Elevation (above msl) 3Q91
MSB-40A	"middle sand" aquifer zone	202.6
MSB-40B	"Lost Lake" aquifer zone	204.2
MSB-40C	"Lost Lake" aquifer zone	WLBS
MSB-40D	"M-Area" aquifer zone	WLBS
MSB-40TA	Crouch Branch Aquifer	189.2
MSB-75B	"Lost Lake" aquifer zone	209.5
MSB-75C	"Lost Lake" aquifer zone	210.5
MSB-36A	"middle sand" aquifer zone	208.3
MSB-36B	"Lost Lake" aquifer zone	213.0
MSB-36C	"Lost Lake" aquifer zone	213.6
MSB-36D	"M-Area" aquifer zone	N/A
MSB-36TA	Crouch Branch Aquifer	194.6
MSB-35A	"middle sand" aquifer zone	216.1
MSB-35B	"Lost Lake" aquifer zone	219.1
MSB-35D	"M-Area" aquifer zone	DRY
MSB-35TA	Crouch Branch Aquifer	199.0
MSB-44A	"middle sand" aquifer zone	217.1
MSB-44B	"Lost Lake" aquifer zone	223.5
MSB-44C	"M-Area" aquifer zone	236.4
MSB-42A	"middle sand" aquifer zone	217.9
MSB-42B	Steed Pond Aquifer	225.1
MSB-42C	Steed Pond Aquifer	230.1
MSB-42D	Steed Pond Aquifer	DRY
MSB-42TA	Crouch Branch Aquifer	205.6
MSB-37A	Crouch Branch Aquifer	207.2
MSB-37B	"middle sand" aquifer zone	219.0
MSB-37C	Steed Pond Aquifer	217.6
MSB-37D	Steed Pond Aquifer	230.9
MSB-37TA	Crouch Branch Aquifer	206.6
MSB-47B	Steed Pond Aquifer	227.1
MSB-47BB	"middle sand" aquifer zone	219.5
MSB-47C	Steed Pond Aquifer	232.5
MSB-47D	Steed Pond Aquifer	232.9
MSB-47TA	Crouch Branch Aquifer	216.5
MSB-69B	"middle sand" aquifer zone	221.0
MSB-69C	Steed Pond Aquifer	227.9
MSB-69D	Steed Pond Aquifer	232.8
MSB-69TA	Crouch Branch Aquifer	215.7

Table 4-4. Cross Section A-A' Monitoring Wells Showing Potentiometric Elevations
Page 2 of 2

Monitoring Wells	Hydrostratigraphic Interval	Potentiometric Elevation (above msl) 3Q91
MSB-54B	"middle sand" aquifer zone	221.9
MSB-54C	Steed Pond Aquifer	226.6
MSB-54D	Steed Pond Aquifer	233.0
MSB-54TA	Crouch Branch Aquifer	218.9

NOTE: WLBS Water Level Below Standpipe

Table 4-5. Cross Section B-B' Monitoring Wells Showing Potentiometric Elevations

Monitoring Wells	Hydrostratigraphic Interval	Potentiometric Elevation (above msl) 3Q91
MSB-71B	"Lost Lake" aquifer zone	216.9
MSB-78D	Steed Pond Aquifer	222.6
MSB-20A	Steed Pond Aquifer	218.0
MSB-20C	Steed Pond Aquifer	WLBS
MSB-21A	Steed Pond Aquifer	220.0
MSB-21B	Steed Pond Aquifer	219.8
MSB-21C	Steed Pond Aquifer	228.6
MSB-21TA	Crouch Branch Aquifer	194.2
MSB-26	"M-Area" aquifer zone	N/A
MSB-26A	"Lost Lake" aquifer zone	223.4
MSB-26B	"Lost Lake" aquifer zone	218.7
MSB-27	"M-Area" aquifer zone	238.0
MSB-27A	"M-Area" aquifer zone	229.0
MSB-27B	"Lost Lake" aquifer zone	224.5
MSB-27TA	Crouch Branch Aquifer	200.5
MSB-34A	"middle sand" aquifer zone	218.9
MSB-34B	"Lost Lake" aquifer zone	226.3
MSB-34C	"M-Area" aquifer zone	WLBS
MSB-34TA	Crouch Branch Aquifer	202.2
MSB-34TB	Crouch Branch Aquifer	203.2
MSB-42A	"middle sand" aquifer zone	217.9
MSB-42B	Steed Pond Aquifer	225.1
MSB-42C	Steed Pond Aquifer	230.1
MSB-42D	Steed Pond Aquifer	DRY
MSB-42TA	Crouch Branch Aquifer	205.6
MSB-52B	Steed Pond Aquifer	218.7
MSB-52D	Steed Pond Aquifer	236.4
MSB-41A	"middle sand" aquifer zone	216.4
MSB-41B	"middle sand" aquifer zone	216.5
MSB-41C	"Lost Lake" aquifer zone	217.1
MSB-41D	"M-Area" aquifer zone	DRY
MSB-41TA	Crouch Branch Aquifer	205.6

NOTE: WLBS Water Level Below Standpipe

Table 4-6. Cross Section C-C' Monitoring Wells Showing Potentiometric Elevations

Monitoring Wells	Hydrostratigraphic Interval	Potentiometric Elevation (above msl) 3Q91
MSB-43A	Steed Pond Aquifer	229.3
MSB-43B	Steed Pond Aquifer	229.5
MSB-43D	Steed Pond Aquifer	230.7
MSB-43DD	Steed Pond Aquifer	231.3
MSB-43TA	Crouch Branch Aquifer	202.9
MSB-29A	"middle sand" aquifer zone	219.8
MSB-29B	Steed Pond Aquifer	223.2
MSB-29C	Steed Pond Aquifer	230.0
MSB-29D	Steed Pond Aquifer	231.5
MSB-29DD	Steed Pond Aquifer	232.0
MSB-29TA	Crouch Branch Aquifer	212.1
MSB-82A	"middle sand" aquifer zone	226.6
MSB-82B	"middle sand" aquifer zone	220.1
MSB-82C	Steed Pond Aquifer	223.6
MSB-82D	Steed Pond Aquifer	232.4
MSB-82TA	Crouch Branch Aquifer	214.2
MSB-69B	"middle sand" aquifer zone	221.0
MSB-69C	Steed Pond Aquifer	227.9
MSB-69D	Steed Pond Aquifer	232.8
MSB-69TA	Crouch Branch Aquifer	215.7
MSB-85B	Crouch Branch Aquifer	221.8
MSB-85C	Steed Pond Aquifer	224.8
MSB-85D	Steed Pond Aquifer	232.9
MSB-85TA	Crouch Branch Aquifer	221.3
MSB-48A	"middle sand" aquifer zone	222.4
MSB-48B	"Lost Lake" aquifer zone	223.7
MSB-48C	"Lost Lake" aquifer zone	224.8
MSB-48D	"M-Area" aquifer zone	232.9
MSB-48TA	Crouch Branch Aquifer	222.4

Table 4-7. Cross Section D-D' Monitoring Wells Showing Potentiometric Elevations

Page 1 of 2

Monitoring Wells	Hydrostratigraphic Interval	Potentiometric Elevation (above msl) 3Q91
MSB-71B	"Lost Lake" aquifer zone	216.9
MSB-76C	"Lost Lake" aquifer zone	219.9
MSB-17A	Steed Pond Aquifer	215.8
MSB-17B	Steed Pond Aquifer	224.2
MSB-17BB	Steed Pond Aquifer	212.1
MSB-17C	Steed Pond Aquifer	N/A
MSB-17D	Steed Pond Aquifer	226.0
MSB-12A	"Lost Lake" aquifer zone	209.3
MSB-12B	"Lost Lake" aquifer zone	217.0
MSB-12C	"Lost Lake" aquifer zone	222.2
MSB-12D	"M-Area" aquifer zone	DRY
MSB-12TA	Crouch Branch Aquifer	193.0
MSB-12TB	Crouch Branch Aquifer	192.9
MSB-62B	"Lost Lake" aquifer zone	209.9
MSB-62C	"Lost Lake" aquifer zone	221.7
MSB-62D	"M-Area" aquifer zone	227.3
MSB-4A	Steed Pond Aquifer	STANDBY STATUS
MSB-4B	Steed Pond Aquifer	209.2
MSB-4C	Steed Pond Aquifer	215.5
MSB-4D	Steed Pond Aquifer	228.1
MSB-3A	"M-Area" aquifer zone	STANDBY STATUS
MSB-3B	"Lost Lake" aquifer zone	212.1
MSB-3C	"Lost Lake" aquifer zone	218.8
MSB-3D	"M-Area" aquifer zone	230.0
MSB-2A	"M-Area" aquifer zone	STANDBY STATUS
MSB-2B	"middle sand" aquifer zone	212.8
MSB-2C	"Lost Lake" aquifer zone	217.7
MSB-2D	"M-Area" aquifer zone/"Lost Lake" aquifer zone	230.3
MSB-31A	Crouch Branch Aquifer	197.7
MSB-31B	Steed Pond Aquifer	213.7
MSB-31C	Steed Pond Aquifer	234.4
MSB-31CC	Steed Pond Aquifer	213.8
MSB-19A	"middle sand" aquifer zone	214.0
MSB-19B	"Lost Lake" aquifer zone	216.5
MSB-19C	"M-Area" aquifer zone	239.5
MSB-74B	"Lost Lake" aquifer zone	210.1
MSB-74C	"Lost Lake" aquifer zone	210.5
MSB-74D	"M-Area" aquifer zone	234.5

Table 4-7. Cross Section D-D' Monitoring Wells Showing Potentiometric Elevations

Page 2 of 2

Monitoring Wells	Hydrostratigraphic Interval	Potentiometric Elevation (above msl) 3Q91
MSB-33	"M-Area" aquifer zone	219.2
MSB-33A	"middle sand" aquifer zone	204.5
MSB-33B	"Lost Lake" aquifer zone	207.8
MSB-33C	"Lost Lake" aquifer zone	210.6
MSB-33TA	Crouch Branch Aquifer	194.4
MSB-51B	"Lost Lake" aquifer zone	205.0
MSB-51D	"M-Area" aquifer zone	211.1
MSB-51DD	"M-Area" aquifer zone	N/A

Table 4-8. Cross Section E-E' Monitoring Wells Showing Potentiometric Elevations

Page 1 of 2

Monitoring Wells	Hydrostratigraphic Interval	Potentiometric Elevation (above msl) 3Q91
MSB-73B	"Lost Lake" aquifer zone	201.8
MSB-49A	"middle sand" aquifer zone	197.8
MSB-49B	"middle sand" aquifer zone	202.7
MSB-49D	"M-Area" aquifer zone	228.2
MSB-18A	"Lost Lake" aquifer zone	221.5
MSB-18B	"Lost Lake" aquifer zone	220.4
MSB-18C	"M-Area" aquifer zone	224.8
MSB-8A	"M-Area" aquifer zone	DRY
MSB-8B	"Lost Lake" aquifer zone	208.8
MSB-8C	"Lost Lake" aquifer zone	219.0
MSB-63B	"Lost Lake" aquifer zone	209.8
MSB-63C	"Lost Lake" aquifer zone	220.0
MSB-63D	"M-Area" aquifer zone	227.9
MSB-1A	Steed Pond Aquifer	DRY
MSB-1B	Steed Pond Aquifer	210.5
MSB-1C	Steed Pond Aquifer	217.0
MSB-1CC	Steed Pond Aquifer	218.1
MSB-1D	Steed Pond Aquifer	229.1
MSB-4A	Steed Pond Aquifer	STANDBY STATUS
MSB-4B	Steed Pond Aquifer	209.2
MSB-4C	Steed Pond Aquifer	215.5
MSB-4D	Steed Pond Aquifer	228.1
MSB-3A	"M-Area" aquifer zone	STANDBY STATUS
MSB-3B	"Lost Lake" aquifer zone	212.1
MSB-3C	"Lost Lake" aquifer zone	218.8
MSB-3D	"M-Area" aquifer zone	230.0
MSB-11A	"Lost Lake" aquifer zone	214.0
MSB-11B	"Lost Lake" aquifer zone	217.5
MSB-11C	"Lost Lake" aquifer zone	219.1
MSB-11D	"M-Area" aquifer zone	228.8
MSB-11E	"M-Area" aquifer zone	DRY
MSB-11F	"M-Area" aquifer zone	229.9
MSB-15A	"Lost Lake" aquifer zone	220.6
MSB-15AA	"Lost Lake" aquifer zone	215.4
MSB-15C	"M-Area" aquifer zone	244.5
MSB-15D	"M-Area" aquifer zone	231.0
MSB-16A	"Lost Lake" aquifer zone	219.0
MSB-16C	"M-Area" aquifer zone	230.1

Table 4-8. Cross Section E-E' Monitoring Wells Showing Potentiometric Elevations

Page 2 of 2

Monitoring Wells	Hydrostratigraphic Interval	Potentiometric Elevation (above msl) 3Q91
MSB-23	"M-Area" aquifer zone	DRY
MSB-23B	"Lost Lake" aquifer zone	222.4
MSB-23TA	Crouch Branch Aquifer	200.2
MSB-34A	"middle sand" aquifer zone	218.9
MSB-34B	"Lost Lake" aquifer zone	226.3
MSB-34C	"M-Area" aquifer zone	WLBS
MSB-34TA	Crouch Branch Aquifer	202.2
MSB-34TB	Crouch Branch Aquifer	203.2
MSB-37A	"middle sand" aquifer zone	207.2
MSB-37B	"middle sand" aquifer zone	219.0
MSB-37C	Steed Pond Aquifer	217.6
MSB-37D	Steed Pond Aquifer	230.9
MSB-37TA	Crouch Branch Aquifer	206.6
ASB 6A	Steed Pond Aquifer	236.0
ASB 6AA	"middle sand" aquifer zone	218.0
ASB 6C	Steed Pond Aquifer	220.9
ASB 6TA	Crouch Branch Aquifer	211.5
ASB 8	Steed Pond Aquifer	233.7
ASB 8A	"middle sand" aquifer zone	218.6
ASB 8B	"middle sand" aquifer zone	219.5
ASB 8C	Steed Pond Aquifer	223.1
ASB 8TA	Crouch Branch Aquifer	215.0
MSB-77B	Steed Pond Aquifer	221.3
MSB-77C	Steed Pond Aquifer	223.4
MSB-77D	Steed Pond Aquifer	234.0
MSB-77TA	Crouch Branch Aquifer	221.1
MSB-48A	"middle sand" aquifer zone	222.4
MSB-48B	"Lost Lake" aquifer zone	223.7
MSB-48C	"Lost Lake" aquifer zone	224.8
MSB-48D	"M-Area" aquifer zone	232.9
MSB-48TA	Crouch Branch Aquifer	222.4
MSB-86C	"Lost Lake" aquifer zone	224.6

NOTE: WLBS Water Level Below Standpipe

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5.0 CONTAMINANT PLUME DESCRIPTIONS FOR TRICHLOROETHYLENE AND TETRACHLOROETHYLENE

The primary contaminants detected in groundwater in the A/M Area are chlorinated aliphatic compounds (trichloroethylene and tetrachloroethylene). Both of these compounds were commonly used as degreasing solvents. Available reports were reviewed to obtain background information related to the past usage of degreasing solvents within the A/M Area. The majority of the information presented in Sections 5.1 and 5.2 was obtained from the *1992 Resource Conservation and Recovery Act (RCRA) Part B Permit Renewal Application* (WSRC, 1991).

5.1 General Information

The M-Area Hazardous Waste Management Facility (HWMF) located near the Fuel and Target Fabrication Facility was operated from 1958 to 1985 and was managed by the Reactor Materials (RM) Department. The M-Area manufacturing operations included aluminum forming and metal finishing processes. Degreasing solvents were used in the metal finishing processes. When production started in 1954, the process effluent was routed to a tributary of Tim's Branch. The discharge point is identified as A-014 Outfall (Plate 5-1). However, as a result of process operations at Building 321-M, the effluent contained slightly enriched uranium. In an effort to restrict the transport of enriched uranium, the M-Area Settling Basin was constructed in 1958 and process wastewater from these operations was discharged to the M-Area HWMF, which consisted of a surface impoundment basin (known locally as the M-Area Settling Basin), an overflow area, and Lost Lake (Plate 5-1). The Process Sewer Line, which is outside the HWMF, is located between the basin and the fuel and process buildings.

The basin was an unlined, man-made depression constructed with small berms around the sides and a depth of 17 feet. The designed liquid capacity was 8 million gallons. An underground Process Sewer Line, which entered the basin, was used to discharge wastewater from the process facilities to the M-Area Settling Basin. Overflow from the basin flowed to a natural seepage area and to a shallow depression (known locally as Lost Lake) via a drainage ditch.

Operation of the M-Area Settling Basin was discontinued in 1985 and the surface impoundment was closed. Prior to closing the facility, contaminated sludge and soils were excavated from the M-Area Settling Basin Process Sewer Line, overflow ditch, seepage area, and Lost Lake. The contaminated sludge and soils were stabilized with Portland cement and placed in the basin. A RCRA style cap was constructed over the basin, isolating the contamination from rainwater infiltration. The surrounding areas are being restored to natural conditions.

In 1981, groundwater contamination at the M-Area HWMF was reported to the South Carolina Department of Health and Environmental Control (SCDHEC); the contaminants included trichloroethylene and tetrachloroethylene. In 1983, a pilot system was developed and went on line to pump and treat contaminated groundwater through a 20-gpm air stripper. The pilot study demonstrated that air stripping was an appropriate remedial technology, and in 1985, a full-scale air stripper went on line supported by a network of 11 recovery wells. Flow was

increased to this air stripper from 400 to 500 gpm in 1990 to optimize the efficiency of air stripping. Since full-scale startup in September 1985 through January 1992, the air stripper has removed over 200,000 pounds of solvent from over 1.3 billion gallons of groundwater.

Since the initial discovery of solvent contamination in groundwater, quarterly sampling events have confirmed trichloroethylene and tetrachloroethylene compounds as the primary contaminants in the A/M Area. Solvent contamination and information on the areal extent of the plume is provided in the Groundwater Corrective Action Reports submitted quarterly to the U.S. Environmental Protection Agency (EPA) and SCDHEC. As discussed in Section 1.2, the SRS has been developing a comprehensive monitoring and remediation program for the A/M Area to encompass several sources of contamination.

The network of plume assessment monitoring wells has been expanded from the HWMF, since 1981, to better define the extent of the solvent plume. Subsequent investigations and monitoring have revealed other sources of contamination, including the solvent storage tanks behind Building 321-M (M-Area Solvent Handling/Storage Area) and the A-014 Outfall Area (where wastewater was previously discharged) (Plate 5-1).

In February 1991, a separate phase of a liquid solvent, also referred to as a dense nonaqueous phase liquid (DNAPL), was discovered in a monitoring well located adjacent to the M-Area Settling Basin. The DNAPL consists of tetrachloroethylene, and, to a lesser extent, trichloroethylene. Trichloroethylene and tetrachloroethylene are minimally soluble in water and have densities of 1.46 and 1.62, respectively.

The SRS is currently performing a DNAPL assessment, and a corrective action program will be determined once these data have been evaluated.

To augment the remediation of the groundwater in the A/M Area, full-scale Soil-Vapor Extraction (SVE) programs are being developed. SVE does not remediate dissolved groundwater contaminants directly; however, it removes volatile organic compounds from unsaturated sediments (vadose zone) before they can migrate downward and contribute to further groundwater contamination.

5.2 Sources of Groundwater Contamination in the A/M Area

Sources of groundwater contamination have been subdivided into the following categories:

- Known sources
- Potential sources
- Distant sources
- Savannah River Laboratory Seepage Basins
- Metallurgical Laboratory Basin

The "known sources" category includes areas where groundwater is known to be contaminated by solvents and sufficient documentation exists to estimate where and how much contamination has entered the groundwater system. The "potential sources" category includes areas where

contamination has been detected but detailed historical documentation is lacking. The "distant sources" are defined as areas where contamination was detected far enough away from the general A/M Area solvent plume to be characterized as a distinct separate plume. The "Savannah River Laboratory Seepage Basins" and the "Metallurgical Laboratory Basin" are discussed separately. Separate extensive characterization studies were conducted within these areas.

5.2.1 Known Sources of Contamination

The facilities for fabricating fuel and target elements to be irradiated in the SRS reactors are located in the Reactor Materials Engineering and Technology (RMET) Area. During fabrication, these elements were cleaned with degreasing solvents at several stages in the process and with hot caustic and hot nitric acid at other stages in the process. From 1952 to 1982, the M-Area used an estimated 13 million pounds of solvents (Table 5-1). Although an estimated 50 to 95 percent of the solvents evaporated during degreasing operations, the remainder was discharged to the Process Sewer Line and was directed to the M-Area Settling Basin. It is estimated that as much as 2 million pounds of solvents may have been released to the sewer that leads to the M-Area Settling Basin and about 1-1/2 million pounds may have been released to the A-014 Outfall Area. (See Plate 5-1 for locations.)

M-Area production facilities are located in Buildings 313-M, 320-M, and 321-M (M-Area Solvent Handling/Storage Area). In the past at these facilities, the degreasers consisted of large vats partitioned in half. On one side, the solvent was boiled, and the items to be degreased were exposed to the vapors. These vapors were then allowed to flow to the other half of the vat where they were collected and condensed. After condensation, the degreasing fluid was then allowed to overflow from the cool side of the vat to the hot side where it was again vaporized. Over time, soil and grease accumulated in the solvent solution, raising its boiling point, whereby the cleaning efficiency decreased. Periodically in the past, the contents of the cleaning vats in Buildings 320-M and 321-M were passed through a still to recover solvent. The smaller vats in Building 313-M were periodically emptied, and clean solvent was substituted. Plate 5-1 depicts the locations of Buildings 313-M, 320-M, and 321-M.

Spent degreaser solvent was then either drained into the process sewers or pumped into drums and then distilled for reuse. Occasionally, during the 1970s, still bottoms, degreaser sludges, and some solvents were collected in drums and stored on concrete pads awaiting distillation recovery. Beginning in 1979, all waste solvents and sludges were drummed and stored in Building 710-U, a permitted hazardous waste storage facility.

Figure 5-1 summarizes the usage period of the three degreaser solvents in the M-Area, and Table 5-1 shows the estimated amounts of the three main solvents used. The usage of tetrachloroethylene and 1,1,1-trichloroethane has been estimated from historical purchase records. Trichloroethylene records are not available and use estimates were developed based on discussions with M-Area personnel. Figure 5-1 shows that trichloroethylene was used from the early 1950s up to 1970. Tetrachloroethylene was used from the early 1960s up to 1979.

Table 5-1. Estimated Amount of Solvent Use at M-Area

Solvent	Total Used	Estimated Release to Settling Basin	Estimated Release to Tim's Branch
Trichloroethylene	3,700	317	383
Tetrachloroethylene	8,700	1,800	1,000
1,1,1-Trichloroethane	<u>670</u>	<u>19</u>	<u>12</u>
Total	13,070	2,136	1,395

NOTE: Units are 10³ pounds

REFERENCE: Marine and Bledsoe, 1985

Reference: Marine and Bledsoe, 1985

Figure 5-1. Time Period of Solvent Use

Figure 5-2 shows the estimated annual quantity of degreaser solvents that was discharged to the process sewers leading to the M-Area Settling Basin and the A-014 Outfall Area. It must be emphasized that these discharge figures represent estimated data; there are no records of solvent discharges. However, these estimates represent the best data available and provide an indication of the relative magnitude of the discharges during the period. Both the M-Area Settling Basin and the A-014 Outfall Area are major sources of solvent contamination and are shown on Plate 5-1.

Apart from the release to the Process Sewer Line leading to the M-Area Settling Basin and to the A-014 Outfall Area, it is difficult to estimate the quantities of degreaser solvent, such as spills around the Building 321-M solvent storage tank, that actually penetrated the ground.

Unlike the M-Area, the A-Area has very little documentation on the use and disposal of solvents. However, groundwater monitoring shows the Savannah River Laboratory (SRL) (now the Savannah River Technology Center [SRTC]) Complex Area to be a source of groundwater contamination and is discussed in the following section.

5.2.2 *Potential Sources of Contamination*

Based on groundwater monitoring data and the waste disposal practices described above, the M-Area Settling Basin, the Process Sewer Line to the basin, the A-014 Outfall Area, and the Building 321-M solvent storage tanks were the primary sources of degreaser solvent groundwater contamination beneath the A/M Area. As stated earlier, these areas are the principal focus of current monitoring and remediation efforts.

Although other sources of contamination are suspected, they are extremely difficult to pinpoint and/or quantify. For this reason, the history of degreaser solvent use was researched to identify potential sources. Much of the information produced by this investigation is not available in verifiable records and was obtained by interviewing employees who work or have worked in the A/M Area. Many of these locations are identified as potential sources only because solvents were used in these areas. Listing these sites, however, does not imply known sources of groundwater contamination.

Buildings 313-M and 320-M in the M-Area were operational by the end of 1952 and initially used trichloroethylene as the degreasing agent. The trichloroethylene was shipped to the SRS in railroad tank cars. Although there is not a consensus among employees, railroad tank cars located on the railroad siding were possibly used as a storage facility for solvents. Solvent was pumped from the tank cars into pipelines leading to Buildings 313-M and 320-M. Spills are likely to have occurred during tank unloading operations, but none are documented. A ditch drained stormwater from the vicinity of Building 313-M to the back of Building 320-M and then to a low swampy spot where Building 321-M was eventually built.

Reference: Marston and Bledsoe, 1985

Figure 5-2. Degreaser Solvent Discharges to Process Sewers

Degreasing solvents were also used in the reactors and other areas of the SRS. However, the M-Area production facilities were the primary user, and shipments of solvents came to the M-Area before being sent to other areas. To accommodate the shipment of degreasing solvents to other areas of the SRS, a drum-loading facility was established at the south end of Building 313-M.

Building 321-M was constructed in 1957 and utilized three degreasers. A 17,000-gallon solvent storage tank was also built behind Building 321-M. Solvent was pumped from the incoming tank cars directly into the storage tank. The drum-loading station, however, remained at the south end of Building 313-M. Spills and leaks may have occurred in the vicinity of the solvent storage tank due to transfers from the railroad tank cars and at the drum-loading facility that continued to supply other SRS areas with solvent.

Because the area around Building 321-M was swampy when the facility was completed in 1957, a stormwater drainfield was installed that discharged to the south and west of the facility, but most drainage was still to the natural draw over which Building 320-M was built.

In 1962, Building 313-M redesigned its degreasing process and tetrachloroethylene was substituted for trichloroethylene. Trichloroethylene continued to be stored in the solvent tank and was pumped to the drum-loading facility. Process wastewater containing tetrachloroethylene was discharged through the Process Sewer Line leading to the A-014 Outfall. During 1971, Buildings 320-M and 321-M substituted tetrachloroethylene for trichloroethylene, and the solvent storage tank was changed over to tetrachloroethylene use. In 1979, the use of tetrachloroethylene was discontinued, and 1,1,1-trichloroethane was substituted. Following conversion, the excess tetrachloroethylene was apparently disposed of in the M-Area Settling Basin sewer, although no documentation exists.

The SRL also used or operated a process facility which included degreasing vats. Between 1954 and 1955, two 450-gallon-capacity degreaser vats were installed in the two chemical cleaning rooms in the basement of Building 773-A (Plate 5-1). These degreasers could be used as vapor degreasers or dip vats depending on the object to be cleaned. When the vapors were used, the object dried immediately. When dipping was used, the object went into a rinse tank. Contents of the rinse tank were added to the laboratory waste stream, which discharged at the A-001 Outfall Area.

In 1962, a 30-gallon-capacity degreaser vat was added to the nickel-plating facility located in Building 773-A. In 1964, because of declining usage, one of the 450-gallon degreaser vats was removed, and in 1973, the small degreaser vat was removed. Around 1973, the solvent used in the one remaining degreaser was changed from trichloroethylene to tetrachloroethylene. In 1979, the solvent was to be changed to 1,1,1-trichloroethane, but usage had so declined that the old solvent was removed and the degreaser vat was never loaded with new solvent. The degreaser process has not been in use since 1979.

Numerous investigations have been conducted in the northeastern sector of the A/M Area to define the source area for solvent contamination (in the vicinity of the SRL Complex). High values of solvent contamination occur near the vicinity of the MSB-47 well cluster. The use of

solvents has been documented in the SRL Complex Area and the MSB-47 vicinity does coincide with unlined ditches leading to the A-001 Outfall.

Groundwater monitoring and surface soil gas measurements indicates that the general SRL Complex Area is a solvent source area.

5.2.3 Distant Sources of Contamination

Several waste disposal areas are located within the southwestern portion of the A/M Area. These areas will be assessed through the ongoing RCRA Facility Investigation/Remedial Investigation (RFI/RI) programs and include the A-Area Rubble Pit, A-Area Metal Burning Pit, Silverton Road Waste Site (M-Area West Unit), and Miscellaneous Chemical Basin (Plate 5-1). Adjacent monitoring wells within these areas exhibit elevated trichloroethylene and tetrachloroethylene values (third quarter 1991 data). The source of the solvent contamination is presently under investigation; however, it is not believed that the detection of solvents near the A-Area Rubble Pit, A-Area Metal Burning Pit, and Miscellaneous Chemical Basin are related to upgradient source areas (i.e., M-Area Settling Basin, Process Sewer Line, A-014 Outfall Area, Building 321-M solvent storage tanks, etc.).

5.2.4 Savannah River Laboratory Seepage Basins

The SRL Seepage Basins (Plate 5-1) are also underlain by solvent groundwater contamination (i.e., Volatile Organic Compounds [VOCs]). The source of the VOCs is documented in the Westinghouse Savannah River Company (WSRC) report entitled "Waste Assessment Report, Savannah River Laboratory Seepage Basins" (WSRC, 1989). The report concluded that the occurrence of VOCs in the groundwater originates from a source area in the SRL Complex Area, upgradient of the SRL Seepage Basins.

5.2.5 Metallurgical Laboratory Basin

The Metallurgical Laboratory (Met Lab) Basin (Plate 5-1) is described in detail in the "Application For A Hazardous Waste Part B Post Closure Permit", Revision 1, December 1991. Similar to the SRL Seepage Basins, the Met Lab Basin is underlain by solvent contamination, which is migrating through the groundwater system from upgradient sources. Some localized and shallow solvent groundwater contamination has occurred as a result of seepage through the Met Lab Basin. Although minor solvent contamination has occurred, the Met Lab Basin is not considered to be a source area in the context of this report.

5.3 Trichloroethylene

5.3.1 Horizontal Distribution

The horizontal distribution of trichloroethylene throughout the A/M Area is illustrated on five isoconcentration contour maps (Plates 5-2 through 5-6). These maps were modified, by reduction and utilizing new nomenclature, from the report entitled "M-Area Hazardous Waste Management Facility Post Closure Care Permit Groundwater Monitoring and Corrective Action

Program" 1991 Fourth Quarter Report (WSRC, 1991c). As previously discussed, the Steed Pond Aquifer is subdivided into the "M-Area" aquifer zone and the "Lost Lake" aquifer zone based on the presence of greater than 50 percent clay in the "green clay" confining zone. Because the "green clay" confining zone exhibits localized lateral variation in percent of clay-size particles, only a single aquifer unit, instead of two aquifer zones, is distinguished where less than 50 percent clay occurs in this aquitard. However, for the purpose of graphically displaying the horizontal distribution of trichloroethylene, the "M-Area" and "Lost Lake" aquifer zones are shown as continuous zones (Plates 5-2 through 5-6).

Maximum and minimum contour intervals were selected based on the highest current concentration of dissolved solvents reported and also on U.S. Environmental Protection Agency (EPA) regulatory drinking water standards (5 ppb).

5.3.1.1 "M-Area" Aquifer Zone

Plate 5-2 is an isoconcentration contour map for trichloroethylene in the "M-Area" aquifer zone. The map depicts several distinct plumes throughout the A/M Area. The largest plume in volume and concentrations underlies the M-Area Solvent Handling/Storage Area, the Process Sewer Line Area, the M-Area Settling Basin, and a portion of the "Lost Lake" (refer to Plate 5-1 for location of facilities). Past solvent handling and disposal practices concentrated within this central portion of the A/M Area have resulted in the release of solvents to the unsaturated (vadose) zone (typically >100 feet thick within the A/M Area), which have served as a continuing source of contaminants to the "M-Area" aquifer zone.

Another distinct plume occurs at the A-014 Outfall Area and along the drainage features of the outfall. Release of contaminated effluent has been discontinued at the A-014 Outfall Area; however, residual contamination persists within this area.

Within the northern portion of the A/M Area, another trichloroethylene plume is defined. Spatially this area underlies the SRL Complex Area and the A-001 Outfall Area.

Within the southwestern portion of the A/M Area and underlying the A-Area Rubble Pit, A-Area Metal Burning Pit, and Miscellaneous Chemical Basin are two small plumes. Trichloroethylene concentrations are less than 200 ppb and the contamination is limited to the "M-Area" and "Lost Lake" aquifer zones (see following sections).

5.3.1.2 Upper "Lost Lake" Aquifer Zone

Plate 5-3 is an isoconcentration contour map for trichloroethylene in the upper "Lost Lake" aquifer zone. The map illustrates a substantially larger area of contamination as compared to the "M-Area" aquifer zone plume due to the horizontal (lateral) spreading and coalescing of the three major plumes.

The horizontal component of groundwater flow is dominant within the "Lost Lake" aquifer zone and results in lateral spreading of trichloroethylene. The direction of lateral movement is governed by the horizontal hydraulic gradient, which is southeast, south, and southwest from

the northern, central, and southern portions of the A/M Area, respectively. The plume, in the area of the A-014 Outfall, shows greater lateral spreading in the downgradient direction relative to the overlying M-Area aquifer zone. This increased lateral migration is in response to the more permeable characteristics of upper "Lost Lake" aquifer zone.

5.3.1.3 Lower "Lost Lake" Aquifer Zone

Plate 5-4 presents a concentration contour map for trichloroethylene in the lower "Lost Lake" aquifer zone. This plate is similar to Plate 5-3; however, lateral spreading of trichloroethylene appears to shift in response to different horizontal hydraulic gradients (anisotropic conditions). In addition, the distribution of trichloroethylene appears to be more widespread in response to hydraulic properties.

5.3.1.4 "Middle Sand" Aquifer Zone

Plate 5-5 is an isoconcentration contour map for trichloroethylene in the "middle sand" aquifer zone. The trichloroethylene (greater than 100 ppb) is present in three plumes that underlie the three major source areas, including the M-Area Settling Basin/Process Sewer Line, the M-Area Solvent Handling/Storage Area, and the SRL Complex Area. Due to the observation of contaminants within the "middle sand" aquifer zone, the "upper clay" confining zone of the Crouch Branch Confining Unit appears to be ineffective in restricting vertical migration.

5.3.1.5 Crouch Branch Aquifer

Plate 5-6 is an isoconcentration contour map for trichloroethylene in the Crouch Branch Aquifer. The detection of trichloroethylene in the northern portion of the A/M Area within the Crouch Branch Aquifer corresponds with the thinning and lateral discontinuity of the Crouch Branch Confining Unit, as described in this report. In general, the "lower clay" confining zone is restricting vertical migration of contamination except for the northern portion of the A/M Area within the vicinity of the SRL Complex Area. The lateral distribution of trichloroethylene, within the Crouch Branch Aquifer, is more restrictive than the overlying aquifers due to the confining characteristic of the Crouch Branch Confining Unit.

5.3.2 Vertical Distribution

Analytical data used to construct the isoconcentration contour maps are taken primarily from the report "M-Area Hazardous Waste Management Facility Post Closure Care Permit, Groundwater Monitoring and Corrective Action Program, 1991 Third Quarter Report" (WSRC, 1991b). However, while compiling data for use in this report, it was found that key well cluster locations did not have analytical results for third quarter 1991 (3Q91). These wells were known to have constituent concentrations which exceeded the Toxicity Characteristic Leaching Procedure (>TCLP) values. To provide a more complete data representation, fourth quarter 1991 (4Q91) data (WSRC, 1991c) was used.

The combined data sets (3Q91 and 4Q91) for each of the cross sections A-A' through E-E' are presented in Tables 5-2 through 5-6, respectively. Because of the combination of the two

quarters, the position of the concentration contours shown on the cross sections are similar to but do not match exactly the contours shown on the concentration contour maps for the individual aquifer zones (Plates 5-2 through 5-6) which were constructed using only fourth quarter 1991 data.

In preparing the trichloroethylene concentration contour cross sections, the analytical data were posted at the corresponding monitoring well screened interval. The contours were then drawn to include data within the indicated range of concentration and, to the extent practical, the contours were drawn to illustrate both the horizontal component of contaminant transport in the aquifers and the spatial association of known or probable source areas. The resulting figures are interpretations of the available data and do not represent the results of a detailed flow and transport model calculation.

5.3.2.1 Cross Section A-A'

Plate 5-7 is an isoconcentration contour map of Cross Section A-A' for trichloroethylene. The south-north cross section is positioned generally parallel to groundwater flow and therefore illustrates the direction of contaminant migration. The direction of groundwater flow is in a southerly direction for all water-bearing sediments, except within the Steed Pond Aquifer in the vicinity of well cluster MSB-47. Within this area, there is a component of radial groundwater flow, as shown by the detection of trichloroethylene (Plate 5-7) within the Steed Pond Aquifer at the MSB-69 cluster. The underlying "middle sand" aquifer zone and Crouch Branch Aquifer show a southerly flow throughout the length of Cross Section A-A'.

The cross section shows two distinct plumes of trichloroethylene. The plume at the south end of Cross Section A-A' originated from the A-014 Outfall Area as previously shown in the horizontal distribution of trichloroethylene in the "M-Area" aquifer zone (Plate 5-2). The topographic low between well clusters MSB-36 and MSB-35 represents the drainage area from the A-014 Outfall Area. As discussed in previous sections, the A-014 Outfall Area is a known source of solvent contamination due to past effluent releases.

From the source area (A-014 Outfall), trichloroethylene appears to have migrated vertically through the "M-Area" aquifer zone and "green clay" confining zone. From well cluster MSB-36 and continuing south past well cluster MSB-40, the trichloroethylene plume has moved horizontally through the "Lost Lake" aquifer zone. The Crouch Branch Confining Unit is relatively thick in the southern portion of the A/M Area and has limited the vertical migration of contaminants. Low levels of trichloroethylene have been detected in the "middle sand" aquifer zone and in the Crouch Branch Aquifer at 24 ppb and 2 ppb, respectively (Plate 5-7).

The second plume on A-A' appears to originate near well cluster MSB-47. Investigations concerning the activity and exact location of solvent contamination near cluster MSB-47 have been inconclusive, and in this report, this source area is defined as the "SRL Complex Area". The "green clay" confining zone and the Crouch Branch Confining Unit are thin and are characterized by decreasing confining characteristics within the northern portion of the A/M Area. Cross Section A-A' illustrates that all aquifers and aquifer zones contain contaminants from the water table surface down to the Crouch Branch Aquifer and that preferred horizontal contaminant pathways flow in a southerly direction through zones of higher permeability. In

Table 5-2. Cross Section A-A' Monitoring Wells Showing Trichloroethylene Concentrations

Page 1 of 2

Monitoring Wells	Hydrostratigraphic Interval	Trichloroethylene (ppb) 3Q91	Trichloroethylene (ppb) 4Q91
MSB-40A	"middle sand" aquifer zone	<1.0	
MSB-40B	"Lost Lake" aquifer zone	>TCLP	888.0
MSB-40C	"Lost Lake" aquifer zone	13.0	
MSB-40D	"M-Area" aquifer zone	<1.0	
MSB-40TA	Crouch Branch Aquifer	<1.0	
MSB-75B	"Lost Lake" aquifer zone	427.0	
MSB-75C	"Lost Lake" aquifer zone	<1.0	
MSB-36A	"middle sand" aquifer zone	23.5	
MSB-36B	"Lost Lake" aquifer zone	>TCLP	1800.0
MSB-36C	"Lost Lake" aquifer zone	137.0	
MSB-36D	"M-Area" aquifer zone	<1.0	
MSB-36TA	Crouch Branch Aquifer	1.8	
MSB-35A	"middle sand" aquifer zone	1.3	
MSB-35B	"Lost Lake" aquifer zone	<1.0	
MSB-35D	"M-Area" aquifer zone	DRY	
MSB-35TA	Crouch Branch Aquifer	<1.0	
MSB-44A	"middle sand" aquifer zone	4.0	
MSB-44B	"Lost Lake" aquifer zone	<1.0	
MSB-44C	"M-Area" aquifer zone	<1.0	
MSB-42A	"middle sand" aquifer zone	>TCLP	823.0
MSB-42B	Steed Pond Aquifer	75.8	
MSB-42C	Steed Pond Aquifer	8.1	
MSB-42D	Steed Pond Aquifer	DRY	
MSB-42TA	Crouch Branch Aquifer	7.9	
MSB-37A	Crouch Branch Aquifer	50.1	
MSB-37B	"middle sand" aquifer zone	186.0	
MSB-37C	Steed Pond Aquifer	385.0	
MSB-37D	Steed Pond Aquifer	NOT SAMPLED	
MSB-37TA	Crouch Branch Aquifer	>TCLP	1420.0
MSB-47B	Steed Pond Aquifer	>TCLP	2290.0
MSB-47BB	"middle sand" aquifer zone	13.5	
MSB-47C	Steed Pond Aquifer	>TCLP	8150.0
MSB-47D	Steed Pond Aquifer	1.3	
MSB-47TA	Crouch Branch Aquifer	>TCLP	758.0
MSB-69B	"middle sand" aquifer zone	<5.0	
MSB-69C	Steed Pond Aquifer	121.0	
MSB-69D	Steed Pond Aquifer	<5.0	

Table 5-2. Cross Section A-A' Monitoring Wells Showing Trichloroethylene Concentrations

Page 2 of 2

Monitoring Wells	Hydrostratigraphic Interval	Trichloroethylene (ppb) 3Q91	Trichloroethylene (ppb) 4Q91
MSB-69TA	Crouch Branch Aquifer	<5.0	
MSB-54B	"middle sand" aquifer zone	<1.0	
MSB-54C	Steed Pond Aquifer	<1.0	
MSB-54D	Steed Pond Aquifer	<1.0	
MSB-54TA	Crouch Branch Aquifer	<1.0	

NOTE: >TCLP Greater than Toxicity Characteristic Leaching Procedure quantitative limits

Table 5-3. Cross Section B-B' Monitoring Wells Showing Trichloroethylene Concentrations

Monitoring Wells	Hydrostratigraphic Interval	Trichloroethylene (ppb) 3Q91	Trichloroethylene (ppb) 4Q91
MSB-71B	"Lost Lake" aquifer zone	<5.0	
MSB-78D	Steed Pond Aquifer	DRY	
MSB-20A	Steed Pond Aquifer	>TCLP	891.0
MSB-20C	Steed Pond Aquifer	2.3	
MSB-21A	Steed Pond Aquifer	4.1	
MSB-21B	Steed Pond Aquifer	205.0	
MSB-21C	Steed Pond Aquifer	<1.0	
MSB-21TA	Crouch Branch Aquifer	<1.0	
MSB-26	"M-Area" aquifer zone	>TCLP	117.0
MSB-26A	"Lost Lake" aquifer zone	>TCLP	1700.0
MSB-26B	"Lost Lake" aquifer zone	143.0	
MSB-27	"M-Area" aquifer zone	6.3	
MSB-27A	"M-Area" aquifer zone	>TCLP	65200.0
MSB-27B	"Lost Lake" aquifer zone	1130.0	
MSB-27TA	Crouch Branch Aquifer	<5.0	
MSB-34A	"middle sand" aquifer zone	>TCLP	3240.0
MSB-34B	"Lost Lake" aquifer zone	>TCLP	40.3
MSB-34C	"M-Area" aquifer zone	92.0	
MSB-34TA	Crouch Branch Aquifer	<1.0	
MSB-34TB	Crouch Branch Aquifer	<1.0	
MSB-42A	"middle sand" aquifer zone	>TCLP	823.0
MSB-42B	Steed Pond Aquifer	75.8	
MSB-42C	Steed Pond Aquifer	8.1	
MSB-42D	Steed Pond Aquifer	DRY	
MSB-42TA	Crouch Branch Aquifer	7.9	
MSB-52B	Steed Pond Aquifer	2.3	
MSB-52D	Steed Pond Aquifer	<1.0	
MSB-41A	"middle sand" aquifer zone	<1.0	
MSB-41B	"middle sand" aquifer zone	1.8	
MSB-41C	"Lost Lake" aquifer zone	<1.0	
MSB-41D	"M-Area" aquifer zone	DRY	
MSB-41TA	Crouch Branch Aquifer	<1.0	

NOTE: >TCLP Greater than Toxicity Characteristic Leaching Procedure quantitative limits.

Table 5-4. Cross Section C-C' Monitoring Wells Showing Trichloroethylene Concentrations

Monitoring Wells	Hydrostratigraphic Interval	Trichloroethylene (ppb) 3Q91	Trichloroethylene (ppb) 4Q91
MSB-43A	Steed Pond Aquifer	<1.0	
MSB-43B	Steed Pond Aquifer	<1.0	
MSB-43D	Steed Pond Aquifer	<1.0	
MSB-43DD	Steed Pond Aquifer	PIEZ	
MSB-43TA	Crouch Branch Aquifer	<1.0	
MSB-29A	"middle sand" aquifer zone	<1.0	
MSB-29B	Steed Pond Aquifer	<1.0	
MSB-29C	Steed Pond Aquifer	<1.0	
MSB-29D	Steed Pond Aquifer	<1.0	
MSB-29DD	Steed Pond Aquifer	PIEZ	
MSB-29TA	Crouch Branch Aquifer	3.0	
MSB-82A	"middle sand" aquifer zone	14.0	
MSB-82B	"middle sand" aquifer zone	<1.0	
MSB-82C	Steed Pond Aquifer	<5.0	
MSB-82D	Steed Pond Aquifer	<1.0	
MSB-82TA	Crouch Branch Aquifer	34.0	
MSB-69B	"middle sand" aquifer zone	<5.0	
MSB-69C	Steed Pond Aquifer	121.0	
MSB-69D	Steed Pond Aquifer	<5.0	
MSB-69TA	Crouch Branch Aquifer	<5.0	
MSB-85B	Crouch Branch Aquifer	<1.0	
MSB-85C	Steed Pond Aquifer	22.4	
MSB-85D	Steed Pond Aquifer	1.1	
MSB-85TA	Crouch Branch Aquifer	10.1	
MSB-48A	"middle sand" aquifer zone	<1.0	
MSB-48B	"Lost Lake" aquifer zone	>TCLP	330.0
MSB-48C	"Lost Lake" aquifer zone	65.8	
MSB-48D	"M-Area" aquifer zone	DRY	
MSB-48TA	Crouch Branch Aquifer	1.6	

NOTES: >TCLP Greater than Toxicity Characteristic Leaching Procedure quantitative limits
PIEZ Piezometer

Table 5-5. Cross Section D-D' Monitoring Wells Showing Trichloroethylene Concentrations

Page 1 of 2

Monitoring Wells	Hydrostratigraphic Interval	Trichloroethylene (ppb) 3Q91	Trichloroethylene (ppb) 4Q91
MSB-71B	"Lost Lake" aquifer zone	<5.0	
MSB-76C	"Lost Lake" aquifer zone	>TCLP	1580.0
MSB-17A	Steed Pond Aquifer	57.4	
MSB-17B	Steed Pond Aquifer	>TCLP	4800.0
MSB-17BB	Steed Pond Aquifer	>TCLP	1250.0
MSB-17C	Steed Pond Aquifer	NOT SAMPLED	
MSB-17D	Steed Pond Aquifer	<5.0	
MSB-12A	"Lost Lake" aquifer zone	>TCLP	<1.0
MSB-12B	"Lost Lake" aquifer zone	>TCLP	10900.0
MSB-12C	"Lost Lake" aquifer zone	>TCLP	3800.0
MSB-12D	"M-Area" aquifer zone	DRY	
MSB-12TA	Crouch Branch Aquifer	<1.0	
MSB-12TB	Crouch Branch Aquifer	4.3	
MSB-62B	"Lost Lake" aquifer zone	5.0	
MSB-62C	"Lost Lake" aquifer zone	25.0	
MSB-62D	"M-Area" aquifer zone	58.0	
MSB-4A	Steed Pond Aquifer	STANDBY STATUS	
MSB-4B	Steed Pond Aquifer	1540.0	
MSB-4C	Steed Pond Aquifer	1250.0	
MSB-4D	Steed Pond Aquifer	166.0	
MSB-3A	"M-Area" aquifer zone	STANDBY STATUS	
MSB-3B	"Lost Lake" aquifer zone	1180.0	
MSB-3C	"Lost Lake" aquifer zone	<250.0	
MSB-3D	"M-Area" aquifer zone	<250000.0	
MSB-2A	"M-Area" aquifer zone	STANDBY STATUS	
MSB-2B	"middle sand" aquifer zone	2250.0	
MSB-2C	"Lost Lake" aquifer zone	64000.0	
MSB-2D	"M-Area" aquifer zone/ "Lost Lake" aquifer zone	900.0	
MSB-31A	Crouch Branch Aquifer	<1.0	
MSB-31B	Steed Pond Aquifer	851.0	
MSB-31C	Steed Pond Aquifer	>TCLP	212000.0
MSB-31CC	Steed Pond Aquifer	281.0	
MSB-19A	"middle sand" aquifer zone	45.7	
MSB-19B	"Lost Lake" aquifer zone	2.4	
MSB-19C	"M-Area" aquifer zone	51.5	
MSB-74B	"Lost Lake" aquifer zone	>TCLP	892.0
MSB-74C	"Lost Lake" aquifer zone	27.2	

Table 5-5. Cross Section D-D' Monitoring Wells Showing Trichloroethylene Concentrations

Page 2 of 2

Monitoring Wells	Hydrostratigraphic Interval	Trichloroethylene (ppb) 3Q91	Trichloroethylene (ppb) 4Q91
MSB-74D	"M-Area" aquifer zone	4.1	
MSB-33	"M-Area" aquifer zone	NOT SAMPLED	
MSB-33A	"middle sand" aquifer zone	12.3	
MSB-33B	"Lost Lake" aquifer zone	17.8	
MSB-33C	"Lost Lake" aquifer zone	NOT SAMPLED	
MSB-33TA	Crouch Branch Aquifer	<1.0	
MSB-51B	"Lost Lake" aquifer zone	<1.0	
MSB-51D	"M-Area" aquifer zone	<1.0	
MSB-51DD	"M-Area" aquifer zone	PIEZ	

NOTES: >TCLP Greater than Toxicity Characteristic Leaching Procedure quantitative limits
 PIEZ Piezometer
 STANDBY STATUS To be used later with Soil Vacuum Extraction Systems

Table 5-6. Cross Section E-E' Monitoring Wells Showing Trichloroethylene Concentrations

Page 1 of 2

Monitoring Wells	Hydrostratigraphic Interval	Trichloroethylene (ppb) 3Q91	Trichloroethylene (ppb) 4Q91
MSB-73B	"Lost Lake" aquifer zone	24.0	
MSB-49A	"middle sand" aquifer zone	<1.0	
MSB-49B	"middle sand" aquifer zone	72.7	
MSB-49D	"M-Area" aquifer zone	<1.0	
MSB-18A	"Lost Lake" aquifer zone	15.3	
MSB-18B	"Lost Lake" aquifer zone	8.2	
MSB-18C	"M-Area" aquifer zone	<1.0	
MSB-8A	"M-Area" aquifer zone	DRY	
MSB-8B	"Lost Lake" aquifer zone	18.5	
MSB-8C	"Lost Lake" aquifer zone	78.5	
MSB-63B	"Lost Lake" aquifer zone	3.0	
MSB-63C	"Lost Lake" aquifer zone	4.0	
MSB-63D	"M-Area" aquifer zone	62.8	
MSB-1A	Steed Pond Aquifer	STANDBY STATUS	
MSB-1B	Steed Pond Aquifer	425.0	
MSB-1C	Steed Pond Aquifer	41.0	
MSB-1CC	Steed Pond Aquifer	34.0	
MSB-1D	Steed Pond Aquifer	21.0	
MSB-4A	Steed Pond Aquifer	STANDBY STATUS	
MSB-4B	Steed Pond Aquifer	1540.0	
MSB-4C	Steed Pond Aquifer	1250.0	
MSB-4D	Steed Pond Aquifer	166.0	
MSB-3A	"M-Area" aquifer zone	STANDBY STATUS	
MSB-3B	"Lost Lake" aquifer zone	1180.0	
MSB-3C	"Lost Lake" aquifer zone	<250.0	
MSB-3D	"M-Area" aquifer zone	<250000.0	
MSB-11A	"Lost Lake" aquifer zone	7.6	
MSB-11B	"Lost Lake" aquifer zone	483.0	
MSB-11C	"Lost Lake" aquifer zone	>TCLP	94400.0
MSB-11D	"M-Area" aquifer zone	>TCLP	330.0
MSB-11E	"M-Area" aquifer zone	DRY	
MSB-11F	"M-Area" aquifer zone	>TCLP	789.0
MSB-15A	"Lost Lake" aquifer zone	>TCLP	2350.0
MSB-15AA	"Lost Lake" aquifer zone	52.0	
MSB-15C	"M-Area" aquifer zone	>TCLP	11300.0
MSB-15D	"M-Area" aquifer zone	>TCLP	15200.0
MSB-16A	"Lost Lake" aquifer zone	>TCLP	7120.0
MSB-16C	"M-Area" aquifer zone	>TCLP	464.0

Table 5-6. Cross Section E-E' Monitoring Wells Showing Trichloroethylene Concentrations

Page 2 of 2

Monitoring Wells	Hydrostratigraphic Interval	Trichloroethylene (ppb) 3Q91	Trichloroethylene (ppb) 4Q91
MSB-23	"M-Area" aquifer zone	DRY	
MSB-23B	"Lost Lake" aquifer zone	513.0	
MSB-23TA	Crouch Branch Aquifer	36.8	
MSB-34A	"middle sand" aquifer zone	>TCLP	3240.0
MSB-34B	"Lost Lake" aquifer zone	>TCLP	40.0
MSB-34C	"M-Area" aquifer zone	92.0	
MSB-34TA	Crouch Branch Aquifer	<1.0	
MSB-34TB	Crouch Branch Aquifer	<1.0	
MSB-37A	"middle sand" aquifer zone	50.1	
MSB-37B	"middle sand" aquifer zone	186.0	
MSB-37C	Steed Pond Aquifer	385.0	
MSB-37D	Steed Pond Aquifer	NOT SAMPLED	
MSB-37TA	Crouch Branch Aquifer	>TCLP	1420.0
ASB 6A	Steed Pond Aquifer	2.5	
ASB 6AA	"middle sand" aquifer zone	>TCLP	2490.0
ASB 6C	Steed Pond Aquifer	10.0	
ASB 6TA	Crouch Branch Aquifer	1120.0	
ASB 8	Steed Pond Aquifer	56.0	
ASB 8A	"middle sand" aquifer zone	<1.0	
ASB 8B	"middle sand" aquifer zone	>TCLP	1520.0
ASB 8C	Steed Pond Aquifer	>TCLP	2430.0
ASB 8TA	Crouch Branch Aquifer	<1.0	
MSB-77B	Steed Pond Aquifer	1.8	
MSB-77C	Steed Pond Aquifer	154.0	
MSB-77D	Steed Pond Aquifer	<1.0	
MSB-77TA	Crouch Branch Aquifer	<1.0	
MSB-48A	"middle sand" aquifer zone	<1.0	
MSB-48B	"Lost Lake" aquifer zone	>TCLP	330.0
MSB-48C	"Lost Lake" aquifer zone	65.8	
MSB-48D	"M-Area" aquifer zone	DRY	
MSB-48TA	Crouch Branch Aquifer	1.6	
MSB-86C	"Lost Lake" aquifer zone	<1.0	

NOTE: >TCLP Greater than Toxicity Characteristic Leaching Procedure quantitative limits

STANDBY STATUS To be used later with Soil Vacuum Extraction Systems

addition, trichloroethylene appears to be migrating north, in the vicinity of well clusters MSB-47, MSB-69, and MSB-54 through the Steed Pond Aquifer.

5.3.2.2 Cross Section B-B'

Plate 5-8 is an isoconcentration contour map for trichloroethylene on Cross Section B-B'. The west-east cross section, which traverses through the M-Area Solvent Handling/Storage Area (well clusters MSB-27 and MSB-34), is perpendicular to groundwater flow and therefore does not depict the direction of contaminant migration. Observed trichloroethylene between well clusters MSB-34 and MSB-42 may represent the leading edge of the plume from the SRL Complex Area while the remaining observed trichloroethylene originates from the M-Area Solvent Handling/Storage Area.

The "green clay" confining zone is represented in the center portion of the cross section in proximity to well clusters MSB-26, MSB-27, and MSB-34. The relatively high trichloroethylene value of 65,200 ppb at well MSB-27A and the structural relationship of the "green clay" confining zone suggest the possibility of DNAPL occurrence in this vicinity. Well MSB-27A is constructed (the screened portion) immediately above the "green clay" confining zone. Both the hydrostratigraphic cross section and the altitude contours on top of the "green clay" confining zone of the Steed Pond Aquifer and the Crouch Branch Confining Unit suggest a very slight dip toward well cluster MSB-27. From well cluster MSB-26 on the southwest, the dip would be slightly less than 1° and from well cluster MSB-34 to the northeast, the dip would be approximately 2°. Even such a slight dip might allow accumulation of DNAPL on top of confining layers. During 1991, for this reason, well MSB-27A was investigated for DNAPL; however, none was detected.

Underlying both the "green clay" confining zone and "Lost Lake" aquifer zone, a separate contaminant plume of trichloroethylene appears to be migrating through the "middle sand" aquifer zone (well clusters MSB-34 and MSB-42) within the Crouch Branch Confining Unit. Contamination may have entered the "middle sand" aquifer zone in an upgradient area where the "upper clay" confining zone is thin and discontinuous. The thin and discontinuous characteristics of the "lower clay" confining zone of the Crouch Branch Confining Unit appear to account for the observed level of 8 ppb within the Crouch Branch Aquifer at well MSB-42TA.

In general, the majority of trichloroethylene detected within this portion of the A/M Area appears to be confined to the Steed Pond Aquifer due to the apparent thickness and continuity of the Crouch Branch Confining Unit, which is restricting vertical movement of contaminants.

5.3.2.3 Cross Section C-C'

Plate 5-9 is an isoconcentration contour map for trichloroethylene on Cross Section C-C'. The west-east cross section is oriented perpendicular to groundwater flow and therefore does not accurately depict the direction of contaminant migration. The highest concentration of contaminants for this cross section is observed in the lower portion of the Steed Pond Aquifer (22-330 ppb) at well clusters MSB-82, 69, and 85. Lower levels of trichloroethylene are also

observed within the "middle sand" aquifer zone and the Crouch Branch Aquifer. Downward movement of contamination within this portion of the A/M Area is consistent with the thin and laterally discontinuous nature of the "green clay" confining zone and the Crouch Branch Confining Unit.

Although Cross Section C-C' is perpendicular to the general north to south flow of groundwater in this area, the source of the contamination most likely is the SRL Complex Area (near well cluster MSB-47) and the contamination has spread to the north from the complex (Section 5.3.2.2). An alternate interpretation is that the source area lies north of the cross section.

5.3.2.4 Cross Section D-D'

Plate 5-10 is an isoconcentration contour map for trichloroethylene on Cross Section D-D'. The northwest-southeast cross section is oriented perpendicular to groundwater flow and therefore does not accurately depict the direction of contaminant migration.

Although a single plume is depicted, observed trichloroethylene, as shown on Plate 5-10, appears to originate from four different source areas. The discussion of these areas begins with the northwest end of the cross section and moves to the southeast end.

Trichloroethylene between well clusters MSB-76 and MSB-17 occurs primarily within the "Lost Lake" aquifer zone. The plume in this portion of the A/M Area appears to be migrating laterally through the "Lost Lake" aquifer zone. The upgradient source area is probably the M-Area Solvent Handling/Storage Area (Plate 5-1).

Increased levels of trichloroethylene (10,900 ppb) are observed at well MSB-12B. The source area may be the Process Sewer Line. High levels of trichloroethylene have been observed adjacent to the Process Sewer Line, representing known leakage from pipe cracks, pipe joints, and unlined manhole/cleanouts. (See well cluster MSB-15 on Plate 5-11.)

The center portion of the plume (between well clusters MSB-62 and MSB-19) has two different source areas. Well clusters MSB-2, MSB-3, and MSB-4 are immediately adjacent to the M-Area Settling Basin, and elevated levels within this area suggest it is the source area. Well cluster MSB-3 is the site of confirmed DNAPL occurrence. The highest concentrations are difficult to determine because they exceed the quantitative limits of the laboratory analysis.

Well cluster MSB-31 is adjacent to and directly downgradient from the A-014 Outfall Area. The highest levels of trichloroethylene within the A/M Area are associated with MSB-31. Although the A-014 Outfall Area no longer receives contaminated effluent, in the past, solvent contamination was discharged along the outfall drainage area. The highest levels are associated with the A-014 Outfall Area and decrease with distance along the topographic gradient. The remaining portions of the plume (well clusters MSB-19 to MSB-33) are also associated with the A-014 Outfall Area. The distribution of trichloroethylene suggests vertical movement through the "M-Area" aquifer zone and "green clay" confining zone, along the A-014 Outfall

drainage area, then south-southwest within the "Lost Lake" aquifer zone and, to a lesser degree, within the "middle sand" aquifer zone.

In general, the distribution of trichloroethylene, coupled with hydrostratigraphic data, along Cross Section D-D' indicates that the "lower clay" confining zone of the Crouch Branch Confining Unit has substantially restricted downward migration of trichloroethylene.

5.3.2.5 Cross Section E-E'

Plate 5-11 is a trichloroethylene isoconcentration contour map of Cross Section E-E'. The northeast-southwest cross section is oriented generally parallel to groundwater flow and therefore approximately depicts the direction of contaminant migration. Cross Section E-E', which is also the longest cross section, traverses through Lost Lake, M-Area Settling Basin, Process Sewer Line, M-Area Solvent Storage/Handling Area, SRL Seepage Basins, and the A-001 Outfall Area. These known and suspected source areas contribute to the trichloroethylene plume as shown on Plate 5-11.

At the southern portion of the cross section, in the vicinity of well cluster MSB-8, a relatively dilute plume of trichloroethylene (8-79 ppb) appears to be migrating in a southerly direction from the Lost Lake area. The distribution of trichloroethylene is generally restricted to the Steed Pond Aquifer (undifferentiated).

Three monitoring well clusters (MSB-1, MSB-3, and MSB-4) are located immediately adjacent to the M-Area Settling Basin and show a similar trichloroethylene distribution as Cross Section D-D' (Plate 5-10). On Cross Section E-E', trichloroethylene appears to have moved farther within the basal section of the Steed Pond Aquifer (undifferentiated), indicating a more transmissive zone.

In the vicinity of well cluster MSB-15 (immediately adjacent to the Process Sewer Line), trichloroethylene distributions indicate a near-source area. The higher levels of trichloroethylene (15,200 ppb) correspond with the area around the Process Sewer Line where cracks and misalignments were discovered in 1983.

Cross Section E-E' traverses through the M-Area Solvent Handling/Storage Area. Trichloroethylene values do not exceed 1000 ppb in this area. Within this area, contamination has migrated down to the Crouch Branch Aquifer (37 ppb).

Within the northern portion of Cross Section E-E', trichloroethylene distributions indicate a source area which corresponds to the A-001 Outfall Area (Plate 5-1). The northern portions of both Cross Sections E-E' and A-A' have similar plume geometry and contaminant levels and appear to represent the same plume. The source areas for this plume are the A-001 Outfall Area and the SRL Complex Area, respectively. These two source areas may represent a common source of trichloroethylene. Additional investigations will be required to make this determination.

The plume originating from the A-001 Outfall Area on Cross Section E-E' extends from the water table surface down to the Crouch Branch Aquifer. The thin and discontinuous nature of confining units within the northern portion of the A/M Area is evident by observation of trichloroethylene within the deeper aquifers and aquifer zones. Once contamination has reached the deeper aquifers, preferential horizontal groundwater flow occurs in the "middle sand" aquifer zone and the Crouch Branch Aquifer in a southerly direction.

As described in Section 5.3.2.1, radial groundwater flow occurs in the northern portion of the A/M Area. This interpretation is supported by the northerly migration of trichloroethylene at well clusters MSB-77 and MSB-48 within the Steed Pond Aquifer (undifferentiated).

5.4 Tetrachloroethylene

5.4.1 Horizontal Distribution

The horizontal distribution of tetrachloroethylene throughout the A/M Area is illustrated on five contour maps (Plates 5-12 through 5-16). These maps were modified, by reduction and utilizing new nomenclature, from the report entitled "M-Area Hazardous Waste Management Facility Post Closure Care Permit, Groundwater Monitoring and Corrective Action Program", 1991 Fourth Quarter Report (WSRC, 1991c). Recent studies subdivide the Steed Pond Aquifer into the "M-Area" aquifer zone and the "Lost Lake" aquifer zone based on the presence of greater than 50 percent clay in the "green clay" confining zone. Because the "green clay" confining zone exhibits localized lateral variation in percent of clay-size particles, only a single aquifer, instead of two aquifer zones, is distinguished where less than 50 percent clay occurs in this aquitard. However, for the purpose of graphically displaying the horizontal distribution of tetrachloroethylene, the "M-Area" and "Lost Lake" aquifer zones are shown as continuous zones (Plates 5-12 through 5-16).

5.4.1.1 "M-Area" Aquifer Zone

Plate 5-12 is an isoconcentration contour map of the "M-Area" aquifer zone for tetrachloroethylene. The map shows a large area of tetrachloroethylene within the central portion of the A/M Area, which corresponds to known source areas, including the M-Area Solvent Handling/Storage Area, the Process Sewer Line, the M-Area Settling Basin Area, and the A-014 Outfall Area.

Within the SRL Complex Area, the horizontal distribution of tetrachloroethylene occupies a relatively smaller area than trichloroethylene. Two factors that affect the distribution of tetrachloroethylene include solubility and the time period in which the solvents were used. Tetrachloroethylene is one-tenth as soluble as trichloroethylene, and tetrachloroethylene was used later in time and replaced trichloroethylene as a degreaser solvent. As previously discussed, within the northern portion of the A/M Area, the dominant solvent contamination appears to be trichloroethylene. Conversely, the dominant solvent contamination within the central to southern portions of the A/M Area appears to be tetrachloroethylene.

Low levels (<50 ppb) of tetrachloroethylene are reported in the vicinity of the Miscellaneous Chemical Basin. Refer to Section 5.2.3 for further information on the Miscellaneous Chemical Basin.

5.4.1.2 Upper "Lost Lake" Aquifer Zone

Plate 5-13 is an isoconcentration contour map of the upper "Lost Lake" aquifer zone for tetrachloroethylene. The plume outline on the map is similar to that in the overlying "M-Area" aquifer zone. However, in the upper "Lost Lake" aquifer zone, horizontal contaminants are spreading south-southwest in response to hydraulic gradients.

Monitoring wells adjacent to the Miscellaneous Chemical Basin and the A-Area Metal Burning Pit show limited (<25 ppb) tetrachloroethylene contamination.

Within the northern portion of the A/M Area, the observed distribution of tetrachloroethylene, associated with the SRL Complex Area and the A-001 Outfall Area, suggests minor horizontal migration, compared to trichloroethylene, within the upper "Lost Lake" aquifer zone.

5.4.1.3 Lower "Lost Lake" Aquifer Zone

Plate 5-14 is an isoconcentration contour map of the lower "Lost Lake" aquifer zone for tetrachloroethylene. The map shows horizontal migration of tetrachloroethylene within the northern portion of the A/M Area. Both the upper and lower "Lost Lake" aquifer zones illustrate similar distributions of tetrachloroethylene within the central to southern portions of the A/M Area. High values of tetrachloroethylene correspond to the M-Area Settling Basin.

5.4.1.4 "Middle Sand" Aquifer Zone

Plate 5-15 is an isoconcentration contour map of the "middle sand" aquifer zone for tetrachloroethylene. The map shows tetrachloroethylene concentrated around the primary source areas within the central to southern portions of the A/M Area, which includes the M-Area Settling Basin, the Process Sewer Area, the M-Area Solvent Handling/Storage Area, and the A-014 Outfall Area (refer to Plate 5-1 for locations). The detection of tetrachloroethylene within the "middle sand" aquifer zone indicates vertical migration through the "upper clay" confining zone of the Crouch Branch Confining Unit.

Although tetrachloroethylene is not observed in the northern portion of the A/M Area, near the SRL Complex Area, or in the A-001 Outfall Area, tetrachloroethylene has migrated in and through the "middle sand" aquifer zone as evidenced by the detection of tetrachloroethylene in the underlying Crouch Branch Aquifer (Plate 5-16).

5.4.1.5 Crouch Branch Aquifer

Plate 5-16 is an isoconcentration contour map of the Crouch Branch Aquifer for tetrachloroethylene. The map shows that contamination has migrated down to the Crouch Branch Aquifer (wells MSB-66TA and MSB-37A). Detection of tetrachloroethylene in

conjunction with hydrostratigraphic interpretations indicate that the "lower clay" confining zone of the Crouch Branch Confining Unit lacks lateral and vertical continuity within the northern portion of the A/M Area. Plate 5-17 illustrates the flow path of tetrachloroethylene from the source area to the screened portion of well MSB-37A.

In the central and southern portions of the A/M Area, the "lower clay" confining zone of the Crouch Branch Confining Unit appears to be both laterally and vertically extensive, restricting tetrachloroethylene migration into the Crouch Branch Aquifer.

5.4.2 Vertical Distribution

Analytical data used to construct the concentration contour maps are taken primarily from the report "M-Area Hazardous Waste Management Facility Post Closure Care Permit, Groundwater Monitoring and Corrective Action Program, 1991 Third Quarter Report" (WSRC, 1991b). However, in the course of data compilation for use in this report, it was found that key well cluster locations did not have analytical results. These wells were known to have constituent concentrations which exceeded the Toxicity Characteristic Leaching Procedure (>TCLP) values.

To provide a more complete data representation, fourth quarter 1991 (4Q91) data (WSRC, 1991c) were used. The combined data sets (3Q91 and 4Q91) for each of the cross sections A-A' through E-E' are presented in Tables 5-7 through 5-11, respectively. Because of the combination of the two quarters, the position of the concentration contours shown on the cross sections are similar to but do not match exactly the contours shown on the concentration contour maps for the individual aquifer zones (Plates 5-12 through 5-16) which were constructed using only fourth quarter 1991 data.

In preparing the tetrachloroethylene concentration contour cross sections, the analytical data were posted at the corresponding monitoring well screened interval. The contours were then drawn to include data within the indicated range of concentration and, to the extent practical, the contours were drawn to illustrate both the horizontal components of contaminant transport in the aquifers and the spatial association of known or probable source areas. The resulting figures are interpretations of the available data and do not represent the results of a detailed flow and transport model calculation.

5.4.2.1 Cross Section A-A'

Plate 5-17 is an isoconcentration contour map of Cross Section A-A' for tetrachloroethylene. The south-north cross section is oriented parallel to groundwater flow and therefore accurately depicts the direction of contaminant migration. Groundwater generally flows in a southerly direction for all water-bearing sediments, except within the northern portion of the A/M Area where radial flow occurs within the Steed Pond Aquifer.

Similar to the trichloroethylene distribution (Plate 5-7), tetrachloroethylene appears as two distinct plumes. The plume originating from the A-014 Outfall Area (between well clusters MSB-36 and MSB-35) has moved through the "M-Area" aquifer zone and "green clay"

Table 5-7. Cross Section A-A' Monitoring Wells Showing Tetrachloroethylene Concentrations

Page 1 of 2

Monitoring Wells	Hydrostratigraphic Interval	Tetrachloroethylene (ppb) 3Q91	Tetrachloroethylene (ppb) 4Q91
MSB-40A	"middle sand" aquifer zone	<1.0	
MSB-40B	"Lost Lake" aquifer zone	>TCLP	2.8
MSB-40C	"Lost Lake" aquifer zone	<1.0	
MSB-40D	"M-Area" aquifer zone	<1.0	
MSB-40TA	Crouch Branch Aquifer	<1.0	
MSB-75B	"Lost Lake" aquifer zone	<10.0	
MSB-75C	"Lost Lake" aquifer zone	<1.0	
MSB-36A	"middle sand" aquifer zone	<1.0	
MSB-36B	"Lost Lake" aquifer zone	>TCLP	<1.0
MSB-36C	"Lost Lake" aquifer zone	13.7	
MSB-36D	"M-Area" aquifer zone	<1.0	
MSB-36TA	Crouch Branch Aquifer	1.2	
MSB-35A	"middle sand" aquifer zone	<1.0	
MSB-35B	"Lost Lake" aquifer zone	<1.0	
MSB-35D	"M-Area" aquifer zone	DRY	
MSB-35TA	Crouch Branch Aquifer	<1.0	
MSB-44A	"middle sand" aquifer zone	<1.0	
MSB-44B	"Lost Lake" aquifer zone	<1.0	
MSB-44C	"M-Area" aquifer zone	<1.0	
MSB-42A	"middle sand" aquifer zone	>TCLP	135.0
MSB-42B	Steed Pond Aquifer	<2.0	
MSB-42C	Steed Pond Aquifer	4.2	
MSB-42D	Steed Pond Aquifer	DRY	
MSB-42TA	Crouch Branch Aquifer	4.4	
MSB-37A	Crouch Branch Aquifer	<10.0	
MSB-37B	"middle sand" aquifer zone	11.2	
MSB-37C	Steed Pond Aquifer	211.0	
MSB-37D	Steed Pond Aquifer	NOT SAMPLED	
MSB-37TA	Crouch Branch Aquifer	>TCLP	77.4
MSB-47B	Steed Pond Aquifer	>TCLP	<25.0
MSB-47BB	"middle sand" aquifer zone	<1.0	
MSB-47C	Steed Pond Aquifer	>TCLP	<200.0
MSB-47D	Steed Pond Aquifer	<1.0	
MSB-47TA	Crouch Branch Aquifer	>TCLP	<10.0
MSB-69B	"middle sand" aquifer zone	<5.0	
MSB-69C	Steed Pond Aquifer	<1.0	
MSB-69D	Steed Pond Aquifer	<5.0	

Table 5-7. Cross Section A-A' Monitoring Wells Showing Tetrachloroethylene Concentrations

Page 2 of 2

Monitoring Wells	Hydrostratigraphic Interval	Tetrachloroethylene (ppb) 3Q91	Tetrachloroethylene (ppb) 4Q91
MSB-69TA	Crouch Branch Aquifer	<5.0	
MSB-54B	"middle sand" aquifer zone	<1.0	
MSB-54C	Steed Pond Aquifer	<1.0	
MSB-54D	Steed Pond Aquifer	<1.0	
MSB-54TA	Crouch Branch Aquifer	<1.0	

NOTE: >TCLP Greater than Toxicity Characteristic Leaching Procedure quantitative limits

Table 5-8. Cross Section B-B' Monitoring Wells Showing Tetrachloroethylene Concentrations

Monitoring Wells	Hydrostratigraphic Interval	Tetrachloroethylene (ppb) 3Q91	Tetrachloroethylene (ppb) 4Q91
MSB-71B	"Lost Lake" aquifer zone	<5.0	
MSB-78D	Steed Pond Aquifer	DRY	
MSB-20A	Steed Pond Aquifer	>TCLP	<20.0
MSB-20C	Steed Pond Aquifer	<5.0	
MSB-21A	Steed Pond Aquifer	1.4	
MSB-21B	Steed Pond Aquifer	<10.0	
MSB-21C	Steed Pond Aquifer	<1.0	
MSB-21TA	Crouch Branch Aquifer	<1.0	
MSB-26	"M-Area" aquifer zone	>TCLP	31.4
MSB-26A	"Lost Lake" aquifer zone	>TCLP	403.0
MSB-26B	"Lost Lake" aquifer zone	<2.0	
MSB-27	"M-Area" aquifer zone	<5.0	
MSB-27A	"M-Area" aquifer zone	>TCLP	7010.0
MSB-27B	"Lost Lake" aquifer zone	<20.0	
MSB-27TA	Crouch Branch Aquifer	<5.0	
MSB-34A	"middle sand" aquifer zone	>TCLP	338.0
MSB-34B	"Lost Lake" aquifer zone	>TCLP	16.7
MSB-34C	"M-Area" aquifer zone	18.6	
MSB-34TA	Crouch Branch Aquifer	<1.0	
MSB-34TB	Crouch Branch Aquifer	<1.0	
MSB-42A	"middle sand" aquifer zone	>TCLP	135.0
MSB-42B	Steed Pond Aquifer	<2.0	
MSB-42C	Steed Pond Aquifer	4.2	
MSB-42D	Steed Pond Aquifer	DRY	
MSB-42TA	Crouch Branch Aquifer	4.4	
MSB-52B	Steed Pond Aquifer	3.5	
MSB-52D	Steed Pond Aquifer	<1.0	
MSB-41A	"middle sand" aquifer zone	1.1	
MSB-41B	"middle sand" aquifer zone	9.5	
MSB-41C	"Lost Lake" aquifer zone	<1.0	
MSB-41D	"M-Area" aquifer zone	DRY	
MSB-41TA	Crouch Branch Aquifer	<1.0	

NOTE: >TCLP Greater than Toxicity Characteristic Leaching Procedure quantitative limits

Table 5-9. Cross Section C-C' Monitoring Wells Showing Tetrachloroethylene Concentrations

Monitoring Wells	Hydrostratigraphic Interval	Tetrachloroethylene (ppb) 3Q91	Tetrachloroethylene (ppb) 4Q91
MSB-43A	Steed Pond Aquifer	<1.0	
MSB-43B	Steed Pond Aquifer	<1.0	
MSB-43D	Steed Pond Aquifer	<1.0	
MSB-43DD	Steed Pond Aquifer	PIEZ	
MSB-43TA	Crouch Branch Aquifer	<1.0	
MSB-29A	"middle sand" aquifer zone	<1.0	
MSB-29B	Steed Pond Aquifer	<1.0	
MSB-29C	Steed Pond Aquifer	<1.0	
MSB-29D	Steed Pond Aquifer	<1.0	
MSB-29DD	Steed Pond Aquifer	PIEZ	
MSB-29TA	Crouch Branch Aquifer	<1.0	
MSB-82A	"middle sand" aquifer zone	<1.0	
MSB-82B	"middle sand" aquifer zone	<1.0	
MSB-82C	Steed Pond Aquifer	<5.0	
MSB-82D	Steed Pond Aquifer	<1.0	
MSB-82TA	Crouch Branch Aquifer	<1.0	
MSB-69B	"middle sand" aquifer zone	<5.0	
MSB-69C	Steed Pond Aquifer	<1.0	
MSB-69D	Steed Pond Aquifer	<5.0	
MSB-69TA	Crouch Branch Aquifer	<5.0	
MSB-85B	Crouch Branch Aquifer	<1.0	
MSB-85C	Steed Pond Aquifer	6.8	
MSB-85D	Steed Pond Aquifer	<1.0	
MSB-85TA	Crouch Branch Aquifer	<1.0	
MSB-48A	"middle sand" aquifer zone	<1.0	
MSB-48B	"Lost Lake" aquifer zone	>TCLP	<1.0
MSB-48C	"Lost Lake" aquifer zone	<2.0	
MSB-48D	"M-Area" aquifer zone	DRY	
MSB-48TA	Crouch Branch Aquifer	8.6	

NOTE: >TCLP Greater than Toxicity Characteristic Leaching Procedure quantitative limits
PIEZ Piezometer

Table 5-10. Cross Section D-D' Monitoring Wells Showing Tetrachloroethylene Concentrations

Page 1 of 2

Monitoring Wells	Hydrostratigraphic Interval	Tetrachloroethylene (ppb) 3Q91	Tetrachloroethylene (ppb) 4Q91
MSB-71B	"Lost Lake" aquifer zone	<5.0	
MSB-76C	"Lost Lake" aquifer zone	>TCLP	1830.0
MSB-17A	Steed Pond Aquifer	261.0	
MSB-17B	Steed Pond Aquifer	>TCLP	1200.0
MSB-17BB	Steed Pond Aquifer	>TCLP	288.0
MSB-17C	Steed Pond Aquifer	NOT SAMPLED	
MSB-17D	Steed Pond Aquifer	<5.0	
MSB-12A	"Lost Lake" aquifer zone	>TCLP	7.0
MSB-12B	"Lost Lake" aquifer zone	>TCLP	4700.0
MSB-12C	"Lost Lake" aquifer zone	>TCLP	1300.0
MSB-12D	"M-Area" aquifer zone	DRY	
MSB-12TA	Crouch Branch Aquifer	<1.0	
MSB-12TB	Crouch Branch Aquifer	2.3	
MSB-62B	"Lost Lake" aquifer zone	3.0	
MSB-62C	"Lost Lake" aquifer zone	70.0	
MSB-62D	"M-Area" aquifer zone	153.0	
MSB-4A	Steed Pond Aquifer	STANDBY STATUS	
MSB-4B	Steed Pond Aquifer	<25.0	
MSB-4C	Steed Pond Aquifer	500.0	
MSB-4D	Steed Pond Aquifer	61.0	
MSB-3A	"M-Area" aquifer zone	STANDBY STATUS	
MSB-3B	"Lost Lake" aquifer zone	34.0	
MSB-3C	"Lost Lake" aquifer zone	<250.0	
MSB-3D	"M-Area" aquifer zone	1250000.0	
MSB-2A	"M-Area" aquifer zone	STANDBY STATUS	
MSB-2B	"middle sand" aquifer zone	62.0	
MSB-2C	"Lost Lake" aquifer zone	14000.0	
MSB-2D	"M-Area" aquifer zone/ "Lost Lake" aquifer zone	1630.0	
MSB-31A	Crouch Branch Aquifer	<1.0	
MSB-31B	Steed Pond Aquifer	318.0	
MSB-31C	Steed Pond Aquifer	>TCLP	387000.0
MSB-31CC	Steed Pond Aquifer	19.3	
MSB-19A	"middle sand" aquifer zone	8.1	
MSB-19B	"Lost Lake" aquifer zone	<1.0	
MSB-19C	"M-Area" aquifer zone	9.9	
MSB-74B	"Lost Lake" aquifer zone	>TCLP	4.5
MSB-74C	"Lost Lake" aquifer zone	<1.0	

Table 5-10. Cross Section D-D' Monitoring Wells Showing Tetrachloroethylene Concentrations

Page 2 of 2

Monitoring Wells	Hydrostratigraphic Interval	Tetrachloroethylene (ppb) 3Q91	Tetrachloroethylene (ppb) 4Q91
MSB-74D	"M-Area" aquifer zone	39.3	
MSB-33	"M-Area" aquifer zone	NOT SAMPLED	
MSB-33A	"middle sand" aquifer zone	<1.0	
MSB-33B	"Lost Lake" aquifer zone	28.3	
MSB-33C	"Lost Lake" aquifer zone	NOT SAMPLED	
MSB-33TA	Crouch Branch Aquifer	<1.0	
MSB-51B	"Lost Lake" aquifer zone	<1.0	
MSB-51D	"M-Area" aquifer zone	<1.0	
MSB-51DD	"M-Area" aquifer zone	PIEZ	

NOTES: >TCLP Greater than Toxicity Characteristic Leaching Procedure quantitative limits

PIEZ Piezometer

STANDBY STATUS To be used later with Soil Vacuum Extraction Systems

Table 5-11. Cross Section E-E' Monitoring Wells Showing Tetrachloroethylene Concentrations

Page 1 of 2

Monitoring Wells	Hydrostratigraphic Interval	Tetrachloroethylene (ppb) 3Q91	Tetrachloroethylene (ppb) 4Q91
MSB-73B	"Lost Lake" aquifer zone	<5.0	
MSB-49A	"middle sand" aquifer zone	<1.0	
MSB-49B	"middle sand" aquifer zone	<2.0	
MSB-49D	"M-Area" aquifer zone	<1.0	
MSB-18A	"Lost Lake" aquifer zone	10.5	
MSB-18B	"Lost Lake" aquifer zone	26.2	
MSB-18C	"M-Area" aquifer zone	<1.0	
MSB-8A	"M-Area" aquifer zone	DRY	
MSB-8B	"Lost Lake" aquifer zone	3.7	
MSB-8C	"Lost Lake" aquifer zone	205.0	
MSB-63B	"Lost Lake" aquifer zone	<1.0	
MSB-63C	"Lost Lake" aquifer zone	5.0	
MSB-63D	"M-Area" aquifer zone	261.0	
MSB-1A	Steed Pond Aquifer	STANDBY STATUS	
MSB-1B	Steed Pond Aquifer	<1.0	
MSB-1C	Steed Pond Aquifer	65.0	
MSB-1CC	Steed Pond Aquifer	26.0	
MSB-1D	Steed Pond Aquifer	8.0	
MSB-4A	Steed Pond Aquifer	STANDBY STATUS	
MSB-4B	Steed Pond Aquifer	<25.0	
MSB-4C	Steed Pond Aquifer	500.0	
MSB-4D	Steed Pond Aquifer	61.0	
MSB-3A	"M-Area" aquifer zone	STANDBY STATUS	
MSB-3B	"Lost Lake" aquifer zone	34.0	
MSB-3C	"Lost Lake" aquifer zone	<250.0	
MSB-3D	"M-Area" aquifer zone	1250000.0	
MSB-11A	"Lost Lake" aquifer zone	<1.0	
MSB-11B	"Lost Lake" aquifer zone	6.9	
MSB-11C	"Lost Lake" aquifer zone	>TCLP	10800.0
MSB-11D	"M-Area" aquifer zone	>TCLP	64.0
MSB-11E	"M-Area" aquifer zone	DRY	
MSB-11F	"M-Area" aquifer zone	>TCLP	251.0
MSB-15A	"Lost Lake" aquifer zone	>TCLP	103.0
MSB-15AA	"Lost Lake" aquifer zone	<2.0	
MSB-15C	"M-Area" aquifer zone	>TCLP	6200.0
MSB-15D	"M-Area" aquifer zone	>TCLP	1530.0
MSB-16A	"Lost Lake" aquifer zone	>TCLP	381.0
MSB-16C	"M-Area" aquifer zone	>TCLP	194.0

Table 5-11. Cross Section E-E' Monitoring Wells Showing Tetrachloroethylene Concentrations

Page 2 of 2

Monitoring Wells	Hydrostratigraphic Interval	Tetrachloroethylene (ppb) 3Q91	Tetrachloroethylene (ppb) 4Q91
MSB-23	"M-Area" aquifer zone	DRY	
MSB-23B	"Lost Lake" aquifer zone	156.0	
MSB-23TA	Crouch Branch Aquifer	3.0	
MSB-34A	"middle sand" aquifer zone	>TCLP	338.0
MSB-34B	"Lost Lake" aquifer zone	>TCLP	16.7
MSB-34C	"M-Area" aquifer zone	18.6	
MSB-34TA	Crouch Branch Aquifer	<1.0	
MSB-34TB	Crouch Branch Aquifer	<1.0	
MSB-37A	"middle sand" aquifer zone	<10.0	
MSB-37B	"middle sand" aquifer zone	11.2	
MSB-37C	Steed Pond Aquifer	211.0	
MSB-37D	Steed Pond Aquifer	NOT SAMPLED	
MSB-37TA	Crouch Branch Aquifer	>TCLP	77.4
ASB-6A	Steed Pond Aquifer	2.6	
ASB-6AA	"middle sand" aquifer zone	>TCLP	24.8
ASB-6C	Steed Pond Aquifer	72.6	
ASB-6TA	Crouch Branch Aquifer	65.5	
ASB-8	Steed Pond Aquifer	3.1	
ASB-8A	"middle sand" aquifer zone	<5.0	
ASB-8B	"middle sand" aquifer zone	>TCLP	26.1
ASB-8C	Steed Pond Aquifer	>TCLP	105.0
ASB-8TA	Crouch Branch Aquifer	<5.0	
MSB-77B	Steed Pond Aquifer	<1.0	
MSB-77C	Steed Pond Aquifer	<10.0	
MSB-77D	Steed Pond Aquifer	<1.0	
MSB-77TA	Crouch Branch Aquifer	<1.0	
MSB-48A	"middle sand" aquifer zone	<1.0	
MSB-48B	"Lost Lake" aquifer zone	>TCLP	<1
MSB-48C	"Lost Lake" aquifer zone	<2.0	
MSB-48D	"M-Area" aquifer zone	DRY	
MSB-48TA	Crouch Branch Aquifer	8.6	
MSB-86C	"Lost Lake" aquifer zone	<1.0	

NOTE: >TCLP Greater than Toxicity Characteristic Leaching Procedure quantitative limits

STANDBY STATUS To be used later with Soil Vacuum Extraction Systems

confining zone and has migrated laterally within the upper portion of the "Lost Lake" aquifer zone. As discussed in Section 5.2.1, trichloroethylene was used during the early years of A/M Area operation while tetrachloroethylene was used in the later years of operation. It is apparent, by comparing the migration patterns for trichloroethylene and tetrachloroethylene, that trichloroethylene has migrated a greater distance, both vertically and horizontally, due to a longer residence time within the groundwater flow system.

Another plume exists in the vicinity of well cluster MSB-47 and appears to originate from the SRL Complex Area extending from the water table surface down to the Crouch Branch Aquifer. The tetrachloroethylene and trichloroethylene distributions, within this portion of the A/M Area, have the same general geometric shape; however, the trichloroethylene plume contains higher contaminant levels. This observation is consistent with all cross sections depicting plumes originating from the SRL Complex Area and the A-001 Outfall Area. Apparently, trichloroethylene, as a degreasing solvent, was used and disposed of in larger quantities than tetrachloroethylene within the northern portion of the A/M Area. There is, however, a lack of documentation to support this observation.

5.4.2.2 Cross Section B-B'

Plate 5-18 is an isoconcentration contour map of Cross Section B-B' for tetrachloroethylene. The west-east cross section is positioned perpendicular to groundwater flow and therefore does not accurately depict the direction of contaminant migration. The cross section runs through the M-Area Solvent Handling/Storage Area (well clusters MSB-27 and MSB-34) and continues downgradient of the SRL Complex Area and A-001 Outfall Area. Vertical migration has reached the "middle sand" aquifer zone and may have entered the zone, in an upgradient area, where the overlying "upper clay" confining zone becomes discontinuous. The "lower clay" confining zone of the Crouch Branch Confining Unit apparently has restricted vertical migration.

Relatively high values (7,010 ppb) of tetrachloroethylene have been detected at well cluster MSB-27.

5.4.2.3 Cross Section C-C'

Plate 5-19 is an isoconcentration contour map of Cross Section C-C' for tetrachloroethylene. The west-east cross section is oriented perpendicular to groundwater flow and therefore does not accurately depict the direction of contaminant migration. Tetrachloroethylene concentration (7-9 ppb) has been detected within the basal portion of the Steed Pond Aquifer undifferentiated and within the Crouch Branch Aquifer, respectively. Due to a component of radial flow, isolated portions of the tetrachloroethylene plume extend in a northerly direction. (Refer to Plates 5-17 and 5-21 for a longitudinal view.)

Consistent with previous discussions, the thin and sporadic characteristics of the Crouch Branch Confining Unit have had a limited effect on restricting the downward migration of contaminants.

5.4.2.4 Cross Section D-D'

Plate 5-20 is an isoconcentration contour map of Cross Section D-D' for tetrachloroethylene. The northwest-southeast cross section is oriented perpendicular to groundwater flow and therefore does not accurately depict the direction of contaminant migration. The overall shape of the tetrachloroethylene plume is very similar to the shape of the trichloroethylene plume, as shown on Plate 5-10.

Four source areas can be defined, including the M-Area Solvent Handling/Storage Area, the Process Sewer Line Area, M-Area Settling Basin Area, and A-014 Outfall Area, that have contributed both trichloroethylene and tetrachloroethylene to the groundwater system (i.e., Steed Pond Aquifer undifferentiated). Consistent with other cross sections, the vertical distribution of tetrachloroethylene indicates that the "green clay" confining zone has a limited effect on restricting vertical migration. The Crouch Branch Confining Unit within this portion of the A/M Area has restricted vertical migration of contaminants into the Crouch Branch Aquifer.

Wells with maximum values for tetrachloroethylene include MSB-3D (1,250,000 ppb) and MSB-31C (387,000 ppb). These values also represent the highest levels of solvents within the A/M Area. Tetrachloroethylene was used as a degreasing solvent after the use of trichloroethylene in the M-Area Solvent Handling/Storage Area and was also used and released to the environment in greater quantities than trichloroethylene (Table 5-1). Approximately 1 million pounds of tetrachloroethylene were released to Tim's Branch (A-014 Outfall Area), and approximately 1.8 million pounds of tetrachloroethylene were released to the M-Area Settling Basin.

Several monitoring wells are located adjacent to the M-Area Settling Basin, including well cluster MSB-3. DNAPLs have been observed in monitoring well MSB-3D, representing the first occurrence in the A/M Area. Analytical results for samples collected on April 5, 1991, indicate that the DNAPLs consist mainly of tetrachloroethylene, with concentrations of trichloroethylene. The hydrostratigraphic setting surrounding well cluster MSB-3 (M-Area Settling Basin) and well MSB-31 (A-014 Outfall Area) is atypical for this south-central portion of the A/M Area. The atypical characteristic of this area is due to the absence of the "green clay" confining zone, which is relatively thick and continuous along the eastern portion of Cross Section D-D' and thins in the western portion.

5.4.2.5 Cross Section E-E'

Plate 5-21 an isoconcentration contour map of Cross Section E-E' for tetrachloroethylene. The northeast-southwest cross section is oriented parallel to groundwater flow and therefore accurately depicts the direction of contaminant migration.

Along the southern end of the cross section, in the vicinity of well cluster MSB-63, tetrachloroethylene (261 ppb) appears to be migrating from the Lost Lake area in a southerly direction.

As discussed in Section 5.4.2.4, a concentrated plume of tetrachloroethylene underlies the M-Area Settling Basin. Cross Section E-E' provides a different view, parallel to groundwater flow, which illustrates the direction of migration. Refer to Section 5.4.2.4 for details and a discussion of DNAPL occurrence.

In the vicinity of well cluster MSB-15, another distinct plume is shown on Cross Section E-E'. The source of tetrachloroethylene appears to be the Process Sewer Line Area. A maximum tetrachloroethylene value for this area is 10,800 ppb.

Cross Section E-E' traverses through the M-Area Solvent Handling/Storage Area between well clusters MSB-16 and MSB-34. The concentrations of tetrachloroethylene within this area are fairly consistent ranging from 103 to 381 ppb.

Within the northern portion of the A/M Area, between well clusters MSB-34 and MSB-86, relatively low levels of tetrachloroethylene are observed from the Steed Pond Aquifer down to the Crouch Branch Aquifer. This and other supporting data on the cross sections indicate that tetrachloroethylene within the northern portion of the A/M Area, although present in the form of a contaminant plume, does not have distinct boundaries and has relatively low tetrachloroethylene values (338 ppb) as compared to the trichloroethylene values (3,240 ppb). These observations suggest limited use and disposal of tetrachloroethylene effluent within the northern portion of the A/M Area.

5.5 Time/Concentration Graphs

The effect of the recovery system on water quality may be indicated by the amount of solvent removed by each of the recovery wells and by the total amount removed through the air stripper. Time/concentration graphs for the recovery wells during calendar year 1991 show a pattern of solvent recovery. The concentration trends in wells RWM-1, -2, -3, -4, -5, -6, and -11 indicate a steady state to steady decrease in total solvent. Wells RWM-7, -8, -9, and -10 indicate some peaks in concentration as plume fronts approach the recovery well. Some irregularity is to be expected since the contaminants were not introduced into the groundwater system in a continuous manner. In addition, variations due to analysis may cause occasional irregularity.

Time/concentration graphs for several monitoring wells also show the influence of the recovery well network. Time/concentration graphs for several monitoring wells are included in Appendix B.

Significant changes in contaminant detection are evident on time/concentration graphs for monitoring wells from three general areas of pumpage: the pumping center north of the M-Area HWMF in proximity to recovery wells RWM-1, -8, and -10; the pumping center at the north end of the M-Area in proximity to recovery wells RWM-2, -3, -4, -5, -9, and -11; and the pumping center to the south of the M-Area near the A-014 Outfall Area in proximity to recovery wells RWM-6 and -7.

Monitoring wells at the MSB-9, -10, -11, -12, and -13 clusters show the influence of recovery wells RWM-1, -8, and -10. The plots for monitoring wells MSB-9B, -9C, -10C, -12B, and -12C show overall trends of increasing trichloroethylene. At MSB-11C, the increase and rapid decline from the peak concentration of nearly 160,000 ppb may indicate that water with the highest concentration has passed this well. Well MSB-12A also shows an overall trend of increasing trichloroethylene. At well MSB-12A, trichloroethylene concentration began declining or leveling in mid-1989. This well is within the 5-year zone of capture of recovery wells RWM-1 and -10; the more highly contaminated groundwater has presumably been removed.

Because concentrations are low at some wells, such as MSB-13A and -13C, observed increases may reflect only normal fluctuations due to sampling and analysis. Concentrations at the MSB-12 well cluster have been rising, indicating both the flow direction and the influence of the 5-year capture zone from recovery well RWM-8.

Concentrations at well MSB-16A have been steadily rising to a possible plateau. This trend is indicative of pumpage from nearby recovery wells RWM-4 and -5, which are receiving water from the center of the main M-Area plume. However, concentrations in well MSB-16C are declining as a result of recovery and vertical movement of contaminants in the more shallow zones.

Farther north, monitoring wells MSB-23B, -24A, -26A, -27A, and -28A may be used to describe the influence of recovery wells in the area. Concentrations at well MSB-23B have declined indicating that it was once in the center of the plume in this area (above 10,000 ppb) but now occupies a more peripheral location (less than 1,000 ppb). Concentrations at well MSB-24A decreased through 1987 but have been increasing slightly since that time. As occurred at well MSB-23B, the trichloroethylene concentration at well MSB-27A has decreased more than one order of magnitude from about 90,000 ppb to below 10,000 ppb since 1985. Wells MSB-26A and -27A have continued to show declining trends, although some leveling has occurred. More highly contaminated water in the Upper "Lost Lake" aquifer zone has passed well MSB-26A within the flow path to recovery wells RWM-2 and -3. Contaminant concentrations peaked in 1990 and have been decreasing since then.

The flow pattern, as observed by comparing potentiometric maps through time, in the Steed Pond Aquifer has been altered significantly since startup. For instance, well MSB-27A is no longer located on a water elevation high. Prior to operation of the recovery system, water flowed from well MSB-27A to the southwest. Now the location of well MSB-27A receives water from the northeast. The recovery system may have affected water quality at well MSB-28A even though it is outside the zone of capture. This well showed a trend of increasing concentration prior to system startup. Since startup, as flow changed in the Steed Pond Aquifer, concentrations have stopped increasing at well MSB-28A.

In the vicinity of the A-014 Outfall Area, the effect of recovery well RWM-6 on water quality is apparent from using data collected from the MSB-31 well cluster. Time series plots from well MSB-31 indicate the significant influence that pumping of well RWM-6 has in this area. When well RWM-6 was inoperative during August 1986, levels quickly rose in the MSB-31B well

screened in the base of the Steed Pond Aquifer. Well RWM-6 is helping to prevent contamination from reaching the downgradient MSB-31 well location.

In the vicinity of recovery wells RWM-9 and -11, the time/concentration graphs for monitoring well clusters MSB-34 and -37 illustrate concentration patterns. There has been a four-fold decrease in concentration levels at well MSB-34B. The same interpretation may be used for wells at the MSB-37 cluster, except the concentrations are lower.

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6.0 SUMMARY

The hydrostratigraphic units underlying the A/M Area of the SRS are described in this characterization report utilizing the most current hydrostratigraphic classification of aquifers and aquitards (Aadland et al., 1990a). The hydrostratigraphic interpretation of the sediments underlying the A/M Area, as presented in this report, is consistent with both previous works related to the A/M Area and regional SRS studies.

Development of detailed hydrogeologic cross sections has provided the basic framework to evaluate the hydrogeologic flow system and contaminant migration for trichloroethylene and tetrachloroethylene, the primary contaminants within the groundwater system. This hydrostratigraphic evaluation, coupled with hydraulic and contaminant data, has provided insight concerning past and current contaminant migration pathways and is summarized as follows:

- The Steed Pond Aquifer and the Crouch Branch Aquifer are separated by the Crouch Branch Confining Unit within the A/M Area. Immediately north of the northern SRS boundary, the Crouch Branch Confining Unit pinches out, and the Steed Pond Aquifer and Crouch Branch Aquifer coalesce to form the Hollow Creek Aquifer.
- The Crouch Branch Confining Unit, within the southern portion of the A/M Area, is divided into the "upper clay" and "lower clay" confining zones, separated by the "middle sand" aquifer zone.
- Within the southern portion of the A/M Area, the Steed Pond Aquifer is divided into the "M-Area" aquifer zone and the "Lost Lake" aquifer zone, separated by the "green clay" confining zone. The "green clay" confining zone thins in a northerly direction and becomes absent within the northern portion of the A/M Area.
- In general, the confining units and zones within the A/M Area thin and become discontinuous in a northerly direction. As a result, the migration of solvents within the groundwater flow system (trichloroethylene and tetrachloroethylene) have entered the Crouch Branch Aquifer in the northern portion of the A/M Area.
- Third and fourth quarter 1991 analytical data show tetrachloroethylene to be the dominant solvent contaminant within the central and southern portions of the A/M Area. Conversely, trichloroethylene appears to be the dominant solvent contaminant within the northern portion of the A/M Area.
- From observations of solvent contaminants, within the groundwater flow system, the "Lost Lake" aquifer zone (lower portion of the Steed Pond Aquifer) appears to be the primary hydrostratigraphic unit in which horizontal contaminant migration occurs due to the hydraulic characteristics of the Crouch Branch Confining Unit. In addition, horizontal transport occurs within the "middle sand" aquifer zone and the Crouch Branch Aquifer due to the thin and discontinuous nature of the Crouch Branch Confining Unit within the northern portion of the A/M Area.

- Generally, throughout the A/M Area, the "lower clay" confining zone of the Crouch Branch Confining Unit appears to be the most effective confining zone in restricting groundwater flow and contaminant migration.

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