AIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910

301/587-8202

Centimeter

Inches

MANUFACTURED TO AIM STANDARDS
BY APPLIED IMAGE, INC.

1 of 2

2

WSRC-TR-93-008

Dan Moore-Shedrow
Derivative Classifier

**DEMONSTRATION OF A UTILITY
INDUSTRY HORIZONTAL DRILLING
SYSTEM: HORIZONTAL WELL AMH-5
INSTALLATION REPORT**

Approved by:

Dan Moore-Shedrow
D. B. Moore-Shedrow, Manager
Environmental Sciences Section

December 1992

Westinghouse Savannah River Company
Savannah River Technology Center
Aiken, South Carolina 29808

Prepared for the Department of Energy under Contract DE-AC09-89SR18035

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Disclaimer

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

**DEMONSTRATION OF A UTILITY INDUSTRY
HORIZONTAL DRILLING SYSTEM:
HORIZONTAL WELL AMH-5 INSTALLATION
REPORT**

December 31, 1992

**Westinghouse Savannah River Company
Savannah River Site
Aiken, South Carolina 29808**

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

THIS PAGE INTENTIONALLY LEFT BLANK

CONTENTS

TABLE OF CONTENTS	i
LIST OF FIGURES	iii
LIST OF PLATES	iv
LIST OF ABBREVIATIONS AND ACRONYMS	iv
 1.0 EXECUTIVE SUMMARY	 1
 2.0 INTRODUCTION	 3
2.1 M-Area Basin Background and Project Description	3
2.2 TNX Area Background and Project Description	4
2.3 Objectives	5
 3.0 GEOLOGIC SETTING	 11
3.1 Regional Setting	11
3.2 A/M Area Hydrogeologic and Hydrostratigraphic Setting	11
3.2.1 Santee Formation	12
3.2.2 Dry Branch Formation	13
3.2.3 Tobacco Road Formation	13
3.2.4 "Upland Unit"	14
 4.0 DRILLING SYSTEM	 19
4.1 Drilling Fluid System	19
4.2 Down-Hole Drilling Assembly	19
 5.0 TECHNICAL APPROACH	 27
 6.0 CONSTRUCTION SUMMARY	 31
6.1 Preliminary Work	31
6.2 Drilling the Borehole	31
6.3 First Well Completion Attempt	32
6.4 Redrilling the Borehole	33
6.5 Second Well Completion Attempt	33
6.6 Attempt at Drilling a New Borehole	34
6.7 Third Well Completion Attempt	35
 7.0 DISCUSSION	 43
7.1 Analysis of the Drilling Program	43
7.2 Analysis of the Well Completion Method	44
 8.0 CONCLUSIONS	 47
 9.0 RECOMMENDATIONS AND SUGGESTIONS FOR FUTURE ACTIVITIES	 49
9.1 Recommendations	49
9.2 Suggestions For Future Activities	50

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

REFERENCES	51
Appendix A	TNX Area Horizontal Drilling Program A-1
Appendix B	Proposed Drilling Plans for a Horizontal Well at the Integrated Demonstration Site Adjacent to the M-Area Basin, Savannah River Site . . . B-1
Appendix C	Daily Activity Reports C-1
Appendix D	M-Area Horizontal Drilling Photographs D-1
Appendix E	Secondary Survey of Horizontal Well AMH-5 E-1

LIST OF FIGURES

2-1	Location of the SRS in South Carolina	6
2-2	Location of M-Area Basin Hazardous Waste Management Facility	7
2-3	Location of M-Area Drilling Site and Process Sewer Line	8
2-4	Location of the TNX Area in the SRS	9
2-5	Location Map for Proposed Horizontal Wells at the TNX Area	10
3-1	Physiographic Provinces of the Eastern United States	15
3-2	Physiographic Subprovinces of the South Carolina Coastal Plain	16
3-3	Comparison of Chronostratigraphic, Lithostratigraphic, and Hydrostratigraphic Units at the SRS	17
3-4	Hydrostratigraphic Chart for the A/M Area	18
4-1	Oblique View of X-810 Experimental Drilling Rig	21
4-2	Down-Hole Assembly	23
4-3	Patented Directional Drilling Tool	25
5-1	Schematic Diagram of M-Area Installation and Description of Completion	28
5-2	Proposed Path (Plan View) of Horizontal Well in M Area	29
5-3	Proposed Path (in Cross Section) of Horizontal Well in M Area	30
6-1	AMH-5 Borehole Path as Surveyed by Drill Scout™ Steering Tool – Plan View	37
6-2	Longitudinal Cross Section of the M-Area Borehole Path as Drilled in June 1992	38
6-3	Pulling Device Used During Completion Attempts 1 and 2	39
6-4	Pulling Device Used During the Third Completion Attempt	41
A-1	Location of the TNX Area in the SRS	A-5
A-2	Proposed Horizontal Well Schematic for the TNX Area	A-6
A-3	Proposed Locations of Horizontal Wells in the TNX Area	A-7
D-1	X-810 Drilling Rig Held in Place by a Wheeled Backhoe	D-3
D-2	X-810 Drilling Rig	D-5
D-3	Surface Launch of Borehole	D-7
D-4	Surface Launch of Borehole	D-9
D-5	Drilling Tool Exiting Ground Surface	D-11
D-6	Down-Hole Assembly Exiting Ground Surface	D-13
D-7	Exit Pit with Down-Hole Assembly Exiting Ground Surface During Second Completion Attempt	D-15
D-8	Cable Tension Device Used During First and Second Completion Attempts	D-17
D-9	Drilling Rig Set Up for Pit-Launched Third Completion Attempt	D-19
D-10	Side View of Drilling Pit	D-21
D-11	Down-Hole View of Pit-Launch Drilling During Third Completion	D-23
D-12	Crew Adding Drill Stem while Drilling During Third Completion Attempt	D-25
D-13	Oblique View of Drilling Pit	D-27
D-14	Down-Hole Assembly Exiting Ground Surface During Third Completion Attempt	D-29
D-15	Steel Collar Used to Attach Fiberglass Well Materials to Pulling Device During Third Completion Attempt	D-31
D-16	Steel Collar Being Connected to Fiberglass Well Materials During Third Completion Attempt	D-33

LIST OF FIGURES (cont'd)

D-17	Steel Collar Attached to Pulling Device Used During Third Completion Attempt	D-35
D-18	O-Ring at Open End of Fiberglass Pipe	D-37
D-19	Fiberglass Casing Being Pulled into Borehole During Third Completion Attempt	D-39
D-20	Fiberglass Casing Extending Out of Exit Hole After Successful Third Well Completion Attempt	D-41

LIST OF PLATES

1	Integrated Demonstration Site Hydrogeologic Cross Section	(in pocket)
---	---	-------------

LIST OF ABBREVIATIONS AND ACRONYMS

bgs	below ground surface
CDM Federal	CDM Federal Programs Corporation
Ditch Witch®	Charles Machine Works
DOE	Department of Energy
ft-lb	foot-pound
gpm	gallons per minute
ID	inside diameter
lb	pound
MD	measured depth
OD	outside diameter
psi	pounds per square inch
PVC	polyvinyl chloride
RF	radio frequency
SNL	Sandia National Laboratory
SRS	Savannah River Site
SRTC	Savannah River Technology Center
SVE	soil vapor extraction
TNX	trinitroxyene
TVD	true vertical depth
VOCs	Volatile Organic Compounds

1.0 EXECUTIVE SUMMARY

The objective of this project was to demonstrate an innovative directional drill system. The system is an experimental compaction/dry drilling technique developed by Charles Machine Works (Ditch Witch®) of Perry, Oklahoma.

A horizontal well was installed in the M Area of the Savannah River Site (SRS) below and parallel to an abandoned tile process sewer line. Documented releases from the process sewer line have contaminated the underlying vadose zone and groundwater with volatile organic compounds (VOCs). A low permeability clay stratum located 30-40 feet below ground surface (bgs) has retained a large portion of the VOCs and now acts as a secondary source of contamination.

The horizontal well was installed in the clay stratum to be used as part of a radio frequency (RF) heating enhanced soil vapor extraction (SVE) system demonstration. An antenna that emits RF electromagnetic radiation will be placed in the horizontal well. The radio waves will be used to heat the surrounding clay for the purpose of volatilizing the contaminants. Once volatilized, the contaminants will be extracted through the horizontal well screen by applying a vacuum in the well. The performance of the thermally enhanced system will be compared to the baseline vapor extraction technology.

The installation of the horizontal well was a two-part process. Part one consisted of drilling the borehole, and part two was the horizontal well completion. The borehole was drilled with relatively few modifications to the drilling plan. The most noteworthy modifications were: (1) a more aggressive drilling tool was needed to drill through the clay strata encountered at the site; (2) water was used as a drilling fluid for the purpose of lubricating and cooling the drilling tool; and (3) the drilling rig was placed in a pit in order to establish a more competent anchorage. The borehole was successfully drilled in the stratum and area of interest without any major problems.

The first two attempts at installing the horizontal well materials were unsuccessful due to the failure of the well string to maintain its integrity. The well string consisted of polyvinyl chloride (PVC) casing and a Teflon™ screen interval. In both instances the PVC pipe parted during the installation attempt. The PVC casing was designed for use in constructing vertical wells and could not withstand the pulling forces applied to the well string during horizontal well installation. The third attempt at horizontal well installation was successful because the well materials were constructed from a durable fiberglass and were designed to withstand the physical stresses of the well installation.

The following conclusions were reached as a result of the horizontal drilling demonstration.

1. The demonstration showed that horizontal wells can be drilled with a compaction drilling method designed to minimize the amount of drilling fluid required. However, the method requires some drilling fluid to lubricate and cool the drilling tool.
2. The steering system used during the demonstration is adequate only where accuracy in an azimuth along a north-south line is not required. The use of a secondary, one-shot survey is recommended when using this system. A secondary survey is included in Appendix E.

3. A surface borehole launch requires an improved drilling rig anchor system to allow maximum pushing and pulling capacity.
4. Well materials must be designed for the physical stresses of horizontal well installation. Standard vertical well materials are not adequate for horizontal wells.

An ancillary demonstration was planned at the SRS TNX Area. However, that demonstration was not completed due to incompatibilities between the drilling technology and the geologic conditions found at the TNX Area. Specifically, the compaction drilling technique was not able to maintain an open borehole in the saturated sand underlying the TNX Area. A description of this aborted demonstration is presented in Appendix A.

2.0 INTRODUCTION

The SRS is part of the United States Department of Energy (DOE) Nuclear Weapons Complex. Its main function is to produce nuclear materials for national defense.

The SRS is located in south-central South Carolina and occupies an area of approximately 300 square miles (192,000 acres) (Fig. 2-1). 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 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.

The Department of Energy's Office of Technology Development initiated an integrated demonstration of innovative technologies and systems for cleanup of VOCs in soils and groundwater at the SRS in 1989. The overall goal of the program is demonstration of multiple technologies and systems in the fields of drilling, characterization, monitoring, and remediation at a single test bed. Innovative technologies are compared to one another and to baseline technologies in terms of technical performance and cost effectiveness. Transfer of successfully demonstrated technologies and systems to DOE environmental restoration organizations, to other government agencies, and to industry is a critical part of the program.

Directional drilling has been shown to be a successful technique for enhancing access to the subsurface, thus improving remediation systems, especially remediation systems which perform *in situ*. Demonstration of an innovative directional drilling system at the Integrated Demonstration Site at the SRS, Aiken, South Carolina, was initiated in June of 1992. The directional drilling system was designed to install an *in situ* remediation system described below.

2.1 M-Area Basin Background and Project Description

The M Area (3/700 Area), located in the northwestern portion of the SRS (Fig. 2-1), is the site of the metals fabrication facility where fuel targets for the reactors were fabricated. Hydrologic investigations at the SRS have shown that M-Area operations have resulted in the contamination of the groundwater with VOCs near the M-Area Settling Basin (Fig. 2-2). The contamination at this site resulted from the leakage of waste solvents from the now abandoned tile process sewer line and from the basin itself into the vadose zone with subsequent gravity driven migration of the contaminants into the groundwater. The layout of the site and the process sewer line are shown in Figure 2-3. A remedial action program consisting of groundwater pumping from eleven recovery wells followed by above-ground air-stripping in a central tower has been implemented since 1985 to address groundwater contamination in M Area.

In order to test new remediation technologies, the Environmental Sciences Section of the Savannah River Technology Center (SRTC) installed a below-ground SVE system in M Area to supplement the pump and treat system. The below-ground system consists of two horizontal wells, one installed above the water table for vapor extraction and one below the water table for air injection. The deeper well (AMH-1), installed below the water table, was designed to inject air under high pressure, inducing volatilization of VOCs. The shallow well

(AMH-2) was designed to extract the vapor phase VOCs from the vadose zone. Acting together, these wells were designed to strip VOCs from the groundwater through air-injection and remove them from the subsurface with vapor extraction. However, residual concentrations of VOCs continue to persist in the vadose zone in low permeability clay strata and provide a continuous source of contaminants to the groundwater.

The SRTC devised a plan to remove the VOCs from a clay stratum found approximately 30 to 40 feet bgs. The plan is to: (1) install a horizontal well beneath and parallel to the abandoned tile sewer line in the clay stratum, (2) insert an RF antenna into the well, (3) heat the clay stratum with radio waves, and (4) extract the volatilized VOCs from the stratum using the well as an SVE well. This report will deal exclusively with the drilling of the horizontal borehole and the installation of the horizontal well.

Demonstration of an innovative directional drilling technology modified from the utility industry has been made possible through a three-year industrial partnership between Sandia National Laboratory (SNL) and Ditch Witch®. A patented directional drilling rig operating on a compaction principle, thus minimizing drill cuttings and fluids, was brought to the SRS for the first full-scale demonstration involving installation of well casing.

A drilling team was retained by SRTC for the design, drilling, and installation of the horizontal well. Drilling experts from the SNL, Geothermal Drilling Division (Albuquerque, NM) designed the borehole. Ditch Witch® (Perry, OK) provided experimental equipment and drilling experts for borehole construction and pipe installation. Environmental Monitoring and Testing Corp. (New Ellenton, SC) provided a South Carolina-certified driller. CDM Federal Programs Corporation (CDM Federal) (Aiken, SC) was retained to: (1) provide technical oversight, (2) document project activities, and (3) generate the horizontal well completion report. SRTC provided program management and materials to construct the horizontal well.

2.2 TNX Area Background and Project Description

The TNX Area is located in the western portion of the SRS and is adjacent to the Savannah River (Fig. 2-4). The TNX Area has been the site of pilot plant operations since the early 1950s. The mission of the TNX pilot facility is to perform pilot scale tests on operations developed in the laboratory before they are implemented in the SRS operations.

The TNX Area is located next to a wetland that lies in the Savannah River flood plain. Site operations have lead to VOC releases to groundwater. The groundwater flows towards the Savannah River beneath the wetlands. A horizontal well constructed perpendicular to and downgradient of the VOC plume was proposed as an interim action to prevent further migration of contaminants downgradient towards the hydrologic boundaries along the Savannah River.

The proposed horizontal well was planned to be installed at a depth of 15-25 feet bgs in the area southwest of the terrace on which the TNX facilities are situated (Fig. 2-5). A test well was planned to be installed outside the contaminant plume to initially test the drilling method. The two proposed horizontal well locations are shown on Figure 2-5. The drilling method utilized a Jet-Trak 4/40 drilling rig with a fluid-assisted guided boring system and a patented directional drilling tool. The drilling produces no drill cuttings and uses approximately two gallons of water per minute of drilling.

The test well was attempted at the TNX Area, and the drilling method was ineffective in the geologic conditions found at that site. A description of the drilling activities is presented in Appendix A. No further discussion of the TNX Area demonstration will be included in the main body of this report.

2.3 Objectives

The objectives of the M-Area demonstration were: (1) to test and evaluate the feasibility of horizontal directional drilling technology, adapted from the utility industry, to drill boreholes in unconsolidated sediments (sands, gravels, and silts) and semi-consolidated clay units; and (2) to install a well in a vadose zone clay stratum to evaluate the effectiveness of RF heating combined with SVE.

Figure 2-1. Location of the SRS in South Carolina

Figure 2-2. Location of M-Area Basin Hazardous Waste Management Facility

Figure 2-3. Location of M-Area Drilling Site and Process Sewer Line

Figure 2-4. Location of the TNX Area in the SRS

Figure 2-5. Location Map for Proposed Horizontal Wells at the TNX Area

3.0 GEOLOGIC SETTING

3.1 Regional Setting

The SRS is located in the Upper Atlantic Coastal Plain Physiographic Province (Fig. 3-1). Within the Coastal Plain Province, the SRS lies on the Aiken Plateau (Fig. 3-2), which is bounded by the Savannah and Congaree Rivers. The surface of the Aiken Plateau is dissected by streams and is characterized by broad interfluvial areas with narrow steep-sided valleys.

The Atlantic Coastal Plain is comprised of a wedge of southeast-dipping unconsolidated and semiconsolidated sediments, which increase in thickness from zero at the Fall Line to more than 4,000 feet near the Atlantic Coast. These sediments range from Late Cretaceous (100 million years) to Holocene (present) in age and extend to the seaward edge of the Continental Shelf. The Coastal Plain sediments generally consist of strata of gravel, sand, silt, clay, and limestone, which were deposited in a variety of fluvial, deltaic, and marine depositional environments. The base of the Coastal Plain sediments lies unconformably on top of crystalline, metamorphic rocks and granitic rocks in the northern portion of the SRS and on top of Triassic sediments, deposited in a rift basin, in the southern part of the SRS. The Atlantic Coastal Plain sediments have been extensively studied at the SRS, and many lithologic and hydrostratigraphic names have been applied to these sediments. Figure 3-3 illustrates a comparison of chronostratigraphic, lithostratigraphic, and hydrostratigraphic units. For the purpose of this report the M-Area hydrogeologic setting is described using hydrostratigraphic nomenclature, and the vadose zone, where the horizontal drilling occurred, will be described using lithostratigraphic nomenclature.

3.2 A/M Area Hydrogeologic and Hydrostratigraphic Setting

Drilling activities (horizontal well AMH-5) occurred within the Integrated Demonstration Site located within the central portion of the A/M Area.

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. 3-4).

The majority of the monitoring wells within the A/M Area are constructed in water-bearing sediments overlying the McQueen Branch Confining Unit. The Crouch Branch Aquifer, which overlies the McQueen Branch Confining Unit, is continuous beneath most of the A/M Area. Beneath the Integrated Demonstration Site at MSB-2, the top of the Crouch Branch Aquifer lies 275 feet below land surface. The Crouch Branch Aquifer is characterized by tan, gray, white, and yellow, very poorly sorted to well-sorted, medium to coarse-grained, locally pebbly sand. Based on third quarter 1991 water level data, horizontal hydraulic gradients show a southwesterly direction of groundwater flow in the vicinity of the Integrated Demonstration Site. 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. 3-4).

The Crouch Branch Confining Unit separates the underlying Crouch Branch Aquifer from the overlying Steed Pond Aquifer. Within the central and southern portions of the A/M Area,

including the Integrated Demonstration Site, the Crouch Branch Confining Unit, from its base to the top of the unit, can be subdivided as follows:

<u>Hydrostratigraphic Zone</u>	<u>Depth (in feet) to Top of Zone at MSB-2</u>	<u>Thickness (in feet) of Zone at MSB-2</u>
"lower clay" confining zone	238	37
"middle sand" aquifer zone	220	18
"upper clay" confining zone	211	9

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 north of the Integrated Demonstration Site. Within the southern to central portions of the A/M Area, including the Integrated Demonstration Site, the Steed Pond Aquifer, from its base to the top of the aquifer, includes the following:

<u>Hydrostratigraphic Zone</u>	<u>Depth (in feet) to Top of Zone at MSB-2</u>	<u>Thickness (in feet) of Zone at MSB-2</u>
"Lost Lake" aquifer zone	145	66
"green clay" confining zone	143	2
"M-Area" aquifer zone	122	21

The Steed Pond Aquifer is characterized by yellow, tan, orange, and brown, loose to slightly indurated, fine to coarse-grained, moderately to well-sorted pebbly sand interbedded with occasional clay and clayey sand beds. Based on third quarter 1991 water level data, horizontal hydraulic gradients show a southerly to southwesterly direction of groundwater flow in the vicinity of the Integrated Demonstration Site.

In the central and northern portion of the A/M Area, the "green clay" confining zone thins and grades from a clay to a clayey silty sand. The "green clay" confining zone has also been referred to as the "200-ft clay" by Eddy and others (1991). The overlying "M-Area" aquifer zone and the underlying "Lost Lake" aquifer zone combine to form the undifferentiated Steed Pond Aquifer north of the Integrated Demonstration Site. Plate 1 (Integrated Demonstration Site Hydrogeologic Cross Section) depicts the hydrogeologic conditions from the vadose zone to the upper portion of the Steed Pond Aquifer, underlying the Integrated Demonstration Site.

Overlying the "M-Area" aquifer zone is the vadose zone. The vadose zone underlying the M-Area Settling Basin includes portions of the Santee Formation, the Dry Branch Formation, Tobacco Road Formation, and the "Upland unit". These formations are described, from the base of the vadose zone (water table) to land surface.

3.2.1 Santee Formation

In the A/M Area, the Santee Formation varies in thickness from 30 to 45 feet. Within the Integrated Demonstration Site the Santee Formation is 43 feet thick at MHT-3C, and the top of the formation lies 103 feet below land surface. It is composed of brown, tan, and yellowish orange, fine to coarse, poorly to well-sorted sands and interbedded with clayey sand, sandy clay, and clay. It is distinguished from the cleaner sands of the overlying Dry Branch

Formation by a higher gamma-ray count on geophysical logs. Underlying the Integrated Demonstration Site, the Santee Formation is partially saturated with a static water level of approximately 130 feet below land surface.

3.2.2 Dry Branch Formation

The Dry Branch Formation crops out in stream valleys, and the thickness varies from 0 to 110 feet in A/M Area wells. Within the Integrated Demonstration Site, the Dry Branch Formation is 35 feet thick at MHT-3C, and the top of the formation lies 68 feet below land surface. Sand of the Dry Branch Formation probably accumulated in a shallow marine environment. Jacksonian (Late Eocene) fossils have been found in the formation in downdip SRS wells, and the specific unit was traced into the A/M Area by correlating it with lithologic and geophysical logs.

The Dry Branch Formation is composed of orange, brown, tan, and yellow, fine to coarse, poorly to well-sorted quartz sand. Pebbly layers are common, and induration is slight to moderate. The Twiggs Clay Member of the Dry Branch Formation is difficult to map 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 interbedded with sand and clayey sand, which is characterized as tan, light gray, and brown, ranges from 12 to 34 feet beneath the Integrated Demonstration Site (Science Applications International Corporation [SAIC], 1992) but is not laterally continuous over long distances. It has been referred to as the "tan clay" in previous SRS reports and as the "270-ft clay" by Eddy and others (1991). The top of the Dry Branch Formation is identified on geophysical logs where a low gamma ray count in the cleaner sand of the Dry Branch Formation sharply increases in the more argillaceous sand of the Tobacco Road Formation. On most lithologic logs, the contact, which is probably conformable, is marked by an increase in silt and clay percentage. The Dry Branch Formation and the overlying formations are unsaturated beneath the Integrated Demonstration Site.

3.2.3 Tobacco Road Formation

The Tobacco Road Formation crops out in several places in the A/M Area. The formation has a higher silt and clay content and thus a lower permeability than the Dry Branch Formation. The Tobacco Road Formation was probably deposited in a shallow marine environment and has been dated as late Jacksonian (late Late Eocene) downdip from the SRS in Georgia (Huddleston and Hetrick, 1985). Nystrom and Willoughby (1982) have traced the formation into the vicinity of the A/M Area by correlation of outcrops and have dated it as Claibornian, not Jacksonian.

Beneath the Integrated Demonstration Site, the Tobacco Road Formation is 15 feet thick at MHT-3C, and the top of the formation lies 50 feet below land surface. The top of the Tobacco Road Formation is identified where comparatively well-sorted sand is overlain by more poorly sorted sand, pebbly sand, and clay of the "Upland unit". The Tobacco Road Formation is orange, red, brown, yellow, tan, and purple. Fine to coarse, poorly to well-sorted sands compose almost the entire formation. Pebbly layers are common, especially near the base. Clay clasts are fairly common, and clay layers ranging from 2 to 10 feet thick have been identified underlying the Integrated Demonstration Site (SAIC, 1992). This unit is referred to as the "300-ft clay" by Eddy and others (1991).

3.2.4 "Upland Unit"

The "Upland unit" unconformably overlies the Tobacco Road Formation. The South Carolina Geological Survey has been mapping it as the informally named "Upland unit" (Nystrom and Willoughby, 1982). It partially corresponds to sediments previously mapped at the SRS as the Hawthorn Formation (Siple, 1967). The unit caps higher areas in much of the southwestern Coastal Plain of South Carolina and is a deposit of poorly-sorted, clayey, silty, pebbly, and cobbly quartz sand, conglomerate, and clay which show significant lateral and vertical variation.

In the A/M Area, these sediments are yellow, orange, purple, red, brown, and tan, mostly fine to very coarse, clayey, silty quartz sand beds. They are locally pebbly with layers of conglomerate, and are very poorly to poorly-sorted, moderately indurated. Weathered feldspar grains are abundant in places. Clay lenses interbedded with these sands are up to 50 feet thick. Thickness varies from 0 to approximately 60 feet. The sediments, which have low permeability, were probably deposited in high energy fluvial channels, point bars, floodplains, and abandoned channels. The "Upland unit" has not been dated paleontologically, but it may correlate with the Miocene Altamaha Formation in Georgia (Nystrom et al., 1986).

Underlying the Integrated Demonstration Site, the "Upland unit" is 50 feet thick at MHT-3C. Locally the "Upland unit" is characterized as a reddish orange, brown, and purple, poorly-sorted gravelly sand and clay. The sandy units have a speckled appearance (SAIC, 1992). The target zone for the horizontal drilling lies within the "Upland unit" and is referred to as the "clay stratum" in this report. This unit also corresponds to the "325-ft clay" by Eddy and others (1991). The depth of this unit, at the AMH-5 drill site, is approximately 32 to 40 feet below land surface. It is characterized as a clayey sand, sandy clay, and clay with subordinate sand layers. Only a few clay layers exceed one foot in thickness. Textural evidence exists indicating that many of the one-foot intervals logged as clay and sandy clay, in the lower portions of this unit, are cobble to boulder-sized clasts of clay eroded from the underlying sediments or small lenticular clay lenses (SAIC, 1992).

Although the clay stratum (325-ft clay) has been placed in the lower portion of the "Upland unit" based on geophysical logs, the lithologic characteristics (pale purple, silty clay) are indicative of the underlying Tobacco Road Formation (personal communication with Andrew D. Smits, 1992).

Figure 3-1. Physiographic Provinces of the Eastern United States

Figure 3-2. Physiographic Subprovinces of the South Carolina Coastal Plain

Figure 3-3. Comparison of Chronostratigraphic, Lithostratigraphic, and Hydrostratigraphic Units at the SRS

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

4.0 DRILLING SYSTEM

The drilling of the horizontal borehole was performed by Charles Machine Works (Ditch Witch®) of Perry, Oklahoma. An experimental drilling rig (Fig. 4-1) with a patented directional drilling tool was used during the project. The drilling rig, designated X-810, is a top drive hydraulic rotary rig with an 80 horsepower motor pack and a high thrust and rotational torque capacity.

4.1 Drilling Fluid System

The patented directional drilling tool was designed to drill with or without drilling fluids. Drilling boreholes with this drilling tool offers an advantage because drilling fluids may not be required. All other existing directional drilling techniques require a drilling fluid to maintain borehole stability and to remove drill cuttings from the borehole. When drilling through contaminated areas, the drilling fluid becomes contaminated and, therefore, requires the same costly handling and disposal costs as drill cuttings. Compaction drilling maintains borehole stability by compacting drill cuttings into the borehole sidewall; therefore, no cuttings are created and the borehole remains stable.

The one disadvantage to the compaction drilling method is the resulting skin damage done to the borehole side wall. The skin damage is a compacted, decreased permeability zone immediately adjacent to the borehole.

The X-810 experimental drilling rig is capable of advancing a borehole with or without the use of drilling fluid. During this project, water was used as a drilling fluid to lubricate the drilling tool, cool the steering tool, and to lubricate the borehole. The drilling fluid system consisted of a water reservoir, a water pump, and a delivery system. Water was pumped at a flow rate of 1-3 gallons per minute (gpm) at 350 to 450 pounds per square inch (psi). The drilling fluid never returned to the surface and is assumed to have been lost to the formation; a total of 1500 to 2000 gallons of water is estimated to have been used in drilling the borehole.

4.2 Down-Hole Drilling Assembly

The down-hole assembly consists of the directional drilling tool, the steering tool contained in a housing, and a flexible sub-assembly (Fig. 4-2). The total length of the down-hole assembly is approximately 5 feet. All components of the down-hole assembly, including the closest three pieces of drill stem, are constructed of non-magnetic steel to prevent magnetic interferences with the steering tool.

The patented directional drilling tool was supplied by Ditch Witch® (Fig. 4-3). The tool is wedge shaped, approximately 15 inches long, 6 inches wide, and hexagonal in cross-section. Carbide cutting pieces are located at the top and base of the wedge. An initial test of the tool during the drilling program led to the addition of carbide cutting pieces to the side edges of the wedge or tool face. The wedge-shaped tool face provides the impetus for the drilling tool to deviate from a linear path in order to drill the curved sections of the borehole. When the drilling tool is pushed forward without rotation, the tool deviates in the direction of the slant of the tool face. To drill without deviation the drilling tool is rotated as it is pushed forward; in this way the tool face does not have a preferred orientation, and the drilling tool advances along

a straight path, as in the slant or horizontal sections of the borehole. The tool face orientation is monitored by the steering system.

The steering system (located just behind the drilling tool) was supplied by SNL and is commercially available from Survey Technology of Santa Ana, California under the trade name of Drill Scout™. The down-hole steering tool weighs 22 pounds (lb), is 20 inches long and 1.625 inches in diameter. The steering tool monitors drilling tool face orientation (roll) from 0° to 360° in 5° increments, uses a magnetometer to determine azimuth (magnetic heading) from 0° to 360° in 1° increments, and has an accelerometer to determine inclination ($\pm 30.0^\circ$ from horizontal). The azimuth measurements of the steering tool are sensitive to the tool's orientation in the earth's magnetic field. The tool is less accurate when taking azimuth measurements when it is oriented parallel to the earth's magnetic field than when the tool is oriented perpendicular to the earth's magnetic field. The down-hole tool receives power from, and sends information to, a surface control unit through a standard wireline. The surface control unit displays tool face orientation, azimuth, and inclination readings. Knowledge of the tool face orientation allows the driller to control the borehole deviation. Knowledge of the measured depth (MD) of the drill stem, the azimuth along the borehole, and inclination along the borehole allows the driller to accurately locate the drilling tool in the subsurface.

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

Oblique view of X-810 experimental drilling rig with M-Area Settling Basin in the background.

Figure 4-1. Oblique View of X-810 Experimental Drilling Rig

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

THIS PAGE INTENTIONALLY LEFT BLANK

The down-hole assembly is in the foreground. The patented drilling tool is to the left, the steering tool is located in the housing just behind the drilling tool, and the flexible sub-assembly is to the right.

Figure 4-2. Down-Hole Assembly

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

THIS PAGE INTENTIONALLY LEFT BLANK

This patented directional drilling tool was used during the third completion attempt. Note: (1) carbide cutters at the top, sides, and base of the wedge face, and (2) the water jet port is in the center of the wedge face.

Figure 4-3. Patented Directional Drilling Tool

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

THIS PAGE INTENTIONALLY LEFT BLANK

5.0 TECHNICAL APPROACH

SNL and SRTC devised the initial plans for borehole drilling and for installation of the horizontal well materials. Slotted Teflon™ pipe, capable of withstanding elevated temperatures, was chosen for the screen in the horizontal section, and solid PVC pipe was chosen for the riser to the surface by SRTC personnel. The detailed well plans that were prepared prior to startup are included in Appendix B.

The target zone for the horizontal well was a clay stratum located at a depth of 32-46 feet bgs, beneath, and parallel to the abandoned process sewer (Figs. 2-3 and 5-1). The low permeability clay stratum has become a reservoir/secondary source for downward percolating VOCs. The technical approach included drilling a horizontal borehole through the center of the clay stratum using a dry drilling, compaction technique. A slotted pipe would then be installed in the horizontal section of the borehole. The horizontal well would provide a conduit to the surface for radio frequency heating and SVE equipment.

The original plan was to enter the ground at a 20° angle from the horizontal at a point approximately 50 feet north of the M-Area Basin, drill at a constant angle to 25 feet true vertical depth (TVD) below the elevation of the entry point, and then begin to "build angle" by 1.15° per 5-foot drill stem until the drilling tool becomes horizontal at a 35.5 foot TVD below the elevation of the entry point. The drilling would continue with a constant inclination of 0.8° from the horizontal in order to follow the dip of the clay stratum. The constant inclination would continue for 230 feet, and the drilling would then begin to build angle by 2.3° per 5-foot drill stem until a constant angle of 23.8° from horizontal would be attained. That angle would be maintained until the drilling tool exited the ground surface. Figs. 5-2 and 5-3 show the planned path of the borehole.

Once the borehole was drilled, the well completion materials would be attached to the drill stem and pulled from the exit hole to the entrance hole. The advantage of this method is that there is always drill stem or well materials in the borehole. This enhances the integrity of the borehole by keeping communication open between the entrance and exit points of the borehole. The well would consist of a 3-inch inside diameter (ID) PVC riser pipe on the entrance side, 3-inch ID Teflon™ slotted pipe in the horizontal section, and 3-inch ID PVC riser pipe on the exit side.

The original plan was essentially followed to the point of well installation. As described in Section 6.0 the installation of the well materials failed, and the hole was temporarily abandoned (but not plugged). A Phase II drilling program was planned and followed the original (now Phase I) plan with the following modifications:

- The borehole would be launched from a 4.5-foot deep pit rather than launched from the surface. The purpose of the pit was to anchor the drilling rig to earth to allow for a greater pushing and pulling pressure.
- The well was to be constructed of fiberglass instead of PVC and Teflon™. The fiberglass pipe is stronger and able to withstand the tensile stress applied during installation.

Figure 5-1. Schematic Diagram of M-Area Installation and Description of Completion (Vertically Exaggerated)

Figure 5-2. Proposed Path (Plan View) of Horizontal Well in M Area

The dashed and dotted lines represent the vertical margins of error for the well path. Average grade represents average land surface conditions at the drill site.

**Figure 5-3. Proposed Path (in Cross Section) of Horizontal Well in M Area
(Vertical Exaggeration $\times 10$)**

6.0 CONSTRUCTION SUMMARY

Refer to Appendices C and D for Daily Activity Reports for the period of 6-16-92 to 9-24-92 and for M-Area photographs.

6.1 Preliminary Work

A line of sight survey of the proposed borehole path was done prior to drilling. The path of the borehole came close to several monitoring wells, and it was imperative that the monitoring wells not be damaged during drilling. The drilling rig was set up on the surveyed line, and the Drill Scout™ steering tool was calibrated to the surveyed line. During this calibration SNL personnel noticed that the steering tool demonstrated hysteresis error in the azimuth readings. The error was $\pm 5^\circ$ and observed only when the steering tool was placed in a north-south orientation, not in an east-west orientation. A similar error was observed in a second steering tool, and SNL personnel concluded that the error was generic to the design of the steering tool. However, it was determined that by rolling the steering tool at least one revolution between azimuth readings, acceptable ($<5^\circ$ error) readings could be obtained.

6.2 Drilling the Borehole

Drilling commenced with the experimental drill rig and directional drilling tool on June 17, 1992. Initially no drilling fluid was used; however, a stiff, resistant clay stratum was met at approximately 9 feet TVD. The drilling tool met refusal at this point and eventually heated to a temperature that caused the steering tool to fail. To be able to drill through the clay stratum, a more aggressive (larger carbide cutters) model of the drilling tool was utilized. The failed steering tool was replaced with a spare tool which was calibrated prior to use. In addition, water was added as a drilling fluid. The purpose of the water was to cool the drilling tool (and therefore the steering tool) and to lubricate the borehole (lessen the friction on the drill stem). The water was placed under 350-450 psi pressure with a flow of 1-3 gpm. The water flow was incapable of returning to the surface and did not carry cuttings out of the borehole. Water was used as a drilling fluid throughout the remainder of the project. These modifications to the drilling plan allowed the drilling to continue through the resistant clay stratum, which was approximately 10 feet thick.

Drilling pressures remained high while drilling from the entry point to the horizontal section. The thrust pressure was as high as 90,000 lb. While drilling in the horizontal (measured depth [MD] of 230 ft) the drill team decided to trip out of the borehole to inspect the drilling tool for wear. Inspection of the drilling tool found nothing out of the ordinary. The water port on the drilling tool was cleaned, and the drilling tool was tripped back into the borehole.

While tripping back in the borehole, the steering probe malfunctioned and was again tripped out of the borehole to check the steering probe. SNL personnel calibrated the sensor and decided to use the Ditch Witch® down-hole beacon and surface receiver to track the borehole to determine the borehole orientation. The survey indicated that the borehole was parallel to and about one foot to the west of the proposed line. During the trip back into the borehole, readings from the steering probe were taken at 5- and 10-foot intervals. The azimuth readings from the probe jumped between 001° and 332° (a difference of 29°). The drill team decided to

continue regardless of the azimuth readings, and generally the steering tool achieved the required accuracy.

Drilling became difficult (drilling torque about 4500-5000 ft-lb, straight push 60,000 lb) again at 250 feet MD. The water jet appeared blocked, and the drill team attempted to unblock the water port by backing the drilling tool out of the borehole about 10 feet and flushing with water. Drilling resumed, and the drilling continued to be very difficult. The borehole was extended to 280 feet MD before the drill crew decided to trip out of the borehole again to inspect the drilling tool. The drilling tool was excessively worn; at least 0.5 inch of steel was lost from the side of the drilling tool. A new drilling tool was installed, and the water port on the tool was enlarged to allow for the installation of a 500-psi water jet. Installation of the water jet aided drilling by cutting the formation. The quantity and pressure of the water was insufficient to cause drill cuttings or fluid to come to rise to the entrance of the borehole.

The drilling tool was tripped back into the hole, and drilling resumed. Drilling remained very difficult, and the drilling rig began pulling the rig anchors out of the ground. The borehole was extended to 485 feet MD before drilling was stopped to reset the anchors. A wheeled backhoe from SRS reset the anchors, and drilling resumed with minor delays until the borehole was completed. The drill bit exited the ground surface on June 23, 1992 approximately 30 feet to the west of the target stake. The total length of the borehole was 560 MD. Figures 6-1 and 6-2 illustrate the borehole path. An exit pit was excavated and filled with water to lubricate the borehole to facilitate installation of the well materials.

5.3 First Well Completion Attempt

The well completion materials consisted of:

- 30 pieces of 10-foot long, flush threaded, 3-inch nominal ID schedule 40 PVC pipe for the entrance and exit riser.
- 26 pieces of 10-ft long, flush threaded, 3-inch nominal ID, 0.010-inch slotted schedule 40 Teflon™ slotted pipe in the horizontal section.

The planned horizontal well was designed to have 160 feet of PVC entry riser casing, 260 feet of Teflon™ 0.010-inch slotted pipe, and 140 feet of PVC exit riser casing. Installation of the well materials was performed by attaching the well casing to a pulling device on the drill stem and then pulling the drill stem out the borehole from the entrance hole. The pulling device was a 6.5-inch outside diameter (OD) conical hole opener, a swivel joint, and a steel collar which the drill crew bolted onto the PVC pipe (Fig. 6-3). In addition a 0.25-inch steel cable was attached to the steel connector, run through the well material and attached to a cable tension device. The cable tensioner kept the cable taut and was used to provide additional strength to the well materials during pull-back.

Well installation began at 1900 hours on the same day the borehole was completed. Completion materials were attached in 10-foot joints with about 60 feet of casing attached and ready to enter the hole at any given time. The exit pit was kept about half full of water to assure that the borehole had a constant source of fluids to facilitate installation. Installation proceeded until 2050 hours. At that time all the PVC entry rise casing (160 feet) was in the borehole, and the Teflon™ slotted pipe was being attached to the casing. While attaching the

slotted pipe the drill crew observed that once the threaded flush joints of the Teflon™ pipe were screwed together the boxes and pins were coming apart under minor stresses. At 2116 hours it was decided to discontinue installation until a proper means of securing the Teflon™ joints was found.

The next day the drilling crew discussed the following options of securing the Teflon™ joints:

- Wrapping the joints with heavy-duty duct tape.
- Heat welding the joints together.
- Chemically bonding the joints together.
- Wrapping the joints with a heat shrink sleeve.

The SRS personnel experimented with heat welding the joints, and they located commercial sources for heat shrink and a chemical bonding agent. The heat welding did not work, and they decided to use a heavy-duty duct tape for securing the joints and proceeded with the installation at 1500 hours. It was observed that as the slotted pipe was pulled into the borehole, water in the exit pit drained into the pipe through the slots. After the 30 feet of slotted pipe were pulled into the borehole, the well string broke. The crew attempted to push the well materials out the exit hole, but this attempt was unsuccessful.

SRTC personnel and the drill crew decided on the following plan of action:

- The drill stem would be tripped out of the borehole.
- The borehole would be redrilled.
- New completion materials would be ordered, if necessary.
- The horizontal well would be completed.

6.4 Redrilling the Borehole

The drill crew pulled the drill stem out of the borehole on June 25, 1992, attached the down-hole assembly, and began redrilling the borehole. The borehole was completely redrilled by the end of the working day. Down-hole surveys were performed every 10 feet with the steering tool to assure that the drilling tool remained in the existing borehole. All surveys indicated that the original borehole had been maintained and redrilled.

6.5 Second Well Completion Attempt

WSRC personnel obtained 4-inch ID PVC pipe onsite and decided to use it to replace the 3-inch PVC entry riser lost during the first completion attempt. A 14.25-inch adapter was constructed to fit the 4-inch PVC pipe to the 3-inch PVC pipe. Furthermore, SRTC personnel decided to use the Teflon™ slotted pipe with tape-reinforced joints. The well configuration was planned as follows:

- Entry Riser – 178 feet of flush threaded, 4-inch nominal ID schedule 40 PVC pipe, 9 feet of flush threaded, 3-inch nominal ID schedule 40 PVC pipe. (These lengths include the 4-inch to 3-inch adapter.)

- Horizontal Section – 210 feet of 3-inch nominal ID, 0.010-inch slotted schedule 40 Teflon™ slotted pipe.
- Exit Riser – 160 feet of flush threaded, 3-inch nominal ID schedule 40 PVC pipe.

The drill crew decided to glue the PVC flush threads together in addition to screwing the joints together. A standard primer/adhesive system was used during the gluing process. The 0.25-inch steel cable and tensioner were also installed in the well materials to provide compressional strength to the well string.

The second attempt at installing the well began on June 26, 1992. Well completion materials were attached in 10-foot joints with about 60 feet of casing screen attached and ready to enter the hole at any given time. Each joint was treated with the primer/adhesive before the pin and box were screwed together. The exit pit was kept about half full of water to assure that the borehole had a constant source of fluids to ease installation. Initially, five 10-foot sections were connected to the pulling device; at least three 10-foot sections were connected above ground during the pull-back to maintain 60 feet of pipe ready to go in the borehole at any given time. The entire PVC entry riser (187 feet) was pulled into the borehole, and the Teflon™ slotted screen was screwed onto the PVC and secured with a heavy-duty duct tape. As the screen entered the borehole, water in the exit pit drained into the pipe through the slots. The water truck provided a constant flow of water to keep water in the exit pit. After 100 feet of Teflon™ slotted pipe entered the borehole the well string detached. A total of 187 feet of PVC casing and 100 feet of Teflon™ slotted screen were in the borehole at the time of failure.

The drill crew decided to continue pulling the drill stem out of the borehole to determine the location of the break in the conduit. The break occurred at the joint between the first and second PVC pipes connected to the pulling device. The pin of the second PVC pipe broke at the point where the O-ring groove was located.

The decision was made to abandon the borehole and make a third attempt at completing the well with new materials in a new borehole. The drill crew demobilized the drilling effort and planned to return to the site at a later date.

6.6 Attempt at Drilling a New Borehole

The drilling crew returned to the site on September 21, 1992, approximately 2.5 months after the second attempt. Modifications had been made to the drilling program, and new materials for the horizontal well had been obtained. The modifications were:

- A pit with dimensions of 16 feet by 16 feet by 4.5 feet deep was excavated to be used as the launching area for the drill rig. During the original drilling effort, the anchors on the drill rig worked loose due to the high pulling and pushing forces acting on the drill rig and rain-softened soils. The drill crew decided to place the drill rig in a pit and brace it between the walls of the pit. The drill rig would then be securely anchored to the earth and be able to push at maximum capacity. The pit would be excavated in a place that would allow the drill rig to drill the borehole 5 feet to the east and 5 feet below the original borehole.
- The carbide cutters on the drilling tool were enlarged. Additional carbide cutters were added to the sides of the wedge face of the drilling tool.

- New well materials were selected. The casing and well screen consisted of 30-foot, pin and box screw joints, 3.5-inch nominal OD Centron® fiberglass epoxy line pipe. This material is normally used in pipe line construction. For this application three rows of 0.010-inch slots were machined into the pipe to construct the well screen. The pipe joints had a larger OD for added strength.

The drill crew arrived on site and found the pit had been constructed to the exact size and specifications that had been requested. The drill rig was placed in the pit and braced both in front and in back with steel supports attached to the drill rig. The steering tool was calibrated but was damaged during installation into the down-hole assembly. The spare steering tool was then calibrated and installed in the down-hole assembly. The drilling fluid system was assembled. Water was once again used as the drilling fluid with no intention to produce fluid returns or drill cuttings at the surface. The water was under approximately 500 psi pressure and a flow rate of 1-3 gpm.

The drilling began at 1000 hours on September 22, 1992. The drilling plan was identical to the previous attempt with the exception of the true vertical depth to the horizontal section, which would be 5 feet greater (40 feet) (Fig. 5-3).

The drill crew had drilled 75 feet MD when they determined that the drill string had entered the previous borehole at about 25 feet MD. Their determination was based on the fact that drilling resistance was negligible (the drill string could virtually be turned by hand). An inspection of the pit location confirmed that the original borehole had been re-entered. SRTC personnel decided to re-drill the original borehole and complete the horizontal well in the original borehole. Concern was expressed by members of the drill crew that the PVC well string in the borehole left from the previous completion attempt may have detrimental effects on the RF heating system. SRTC personnel stated that the portion of the borehole that contained PVC pipe would not be affected during RF heating.

Drilling resumed in the original borehole, and the drill stem advanced with no resistance until 280 feet MD where the drilling torque increased to 5000 ft-lb. This measured depth corresponded with the location of the 4-inch PVC casing installed during the previous well completion attempt. The drill crew stopped rotating the drill stem while they advanced the drilling tool; pushing pressure was less than or equal to approximately 50,000 lb. At 530 feet MD the drilling tool momentarily met with refusal. The drill crew repositioned the drill stem on the drilling rig to get more push pressure applied to the drill stem and with maximum pressure, advanced the drilling tool past this obstacle. The obstacle was about 10 feet (two drill stem joints) in duration. The drilling tool exited the ground surface on June 23, 1992 at 550 feet MD at the original borehole exit point.

6.7 Third Well Completion Attempt

The well string was connected to a pulling device on the drill stem and pulled back through the borehole. The pulling device consisted of a conical-shaped hole opener, a universal joint connector, and a steel collar for attaching the well casing to the pulling device (Fig. 6-4). The well string consisted of:

- 150 feet of 3.5-inch OD fiberglass entry riser well casing.
- 300 feet of 3.5-inch OD 0.010 slotted fiberglass well screen.
- 137 feet of 3.5-inch OD fiberglass exit riser well casing.

The well completion was initiated on June 23, 1992 and proceeded smoothly until about 540 feet MD from the entrance hole. At that point the pulling pressure was at about 100,000 lb. This tight spot in the borehole corresponded with the obstacle met while advancing the drill stem. The high pulling pressure continued until completion activities stopped for the day. Activities were stopped because: (1) lightning in the area was threatening to postpone work, and (2) the projected time to well completion was past sunset for that day. When well completion activities resumed on June 24, 1992, the pulling pressure remained greater than 66,000 lb until 360 feet MD. The pulling pressure dropped from 66,000 lb to 33,000 lb from 360 feet MD to 250 feet MD, after which the pulling pressure was minimal and was attributed to the weight of the drill stem and well string only. The well completion continued with low pulling pressures until the well string was successfully installed. Approximately 10 feet of well casing was left above ground level at both the entrance and exit holes; surface completions of the horizontal well were completed at a later date.

Figure 6-1. AMH-5 Borehole Path as Surveyed by
 Drill Scout™ Steering Tool - Plan View

Figure 6-2. Longitudinal Cross Section of the M-Area Borehole Path as Drilled in June 1992 (Vertical Exaggeration $\times 10$)

Note the hose supplying water to the exit pit.

Figure 6-3. Pulling Device Used During Completion Attempts 1 and 2

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

THIS PAGE INTENTIONALLY LEFT BLANK

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

Figure 6-4. Pulling Device Used During the Third Completion Attempt

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

THIS PAGE INTENTIONALLY LEFT BLANK

7.0 DISCUSSION

The drilling program was experimental in nature and was expected to involve modifications to accommodate field conditions. However, the drilling plans generally worked well, and few changes were required. The problems that caused failures during the demonstration occurred during well installation and were related to the well completion materials.

7.1 Analysis of the Drilling Program

Overall drilling performance was controlled by several factors including:

- Specific geologic conditions (percentage of clay).
- Drilling tool lubrication.
- Steering tool accuracy.
- Drilling rig anchorage.

The specific geologic condition that created difficulties during drilling was an upper clay stratum that occurs at approximately 10-15 feet TVD. At the outset of drilling of the borehole, the clay stratum caused bit refusal. When the drilling tool was tripped out of the borehole, heat from drilling had turned the clay into a substance that resembled oven-baked pottery. The bit refusal and associated heat were overcome by using a more aggressive drilling tool (with more aggressive carbide cutters) and by adding water as a drilling fluid to cool and lubricate the drilling tool.

During the third drilling attempt the upper clay stratum again nearly caused refusal. In this case the drilling tool was pushing through PVC casing and Teflon™ screen abandoned in the original borehole from completion attempts 1 and 2. The clay stratum was resistant to the expansion of the PVC and Teflon™ into the sides of the borehole, and, therefore, friction on the drilling tool and drill stem increased to a point of bit refusal. Aggressive drilling pressures overcame this obstacle. However, during subsequent well installation the friction induced by the abandoned well materials and the upper clay stratum caused increased pulling pressures. The increased pulling pressures and associated stresses were mainly located on the pulling device, but the fiberglass well completion materials used in the third well completion attempt may have also been stressed.

The final drilling tool (as described in Section 4.2) used during the third drilling attempt was not tested in a rotating mode because it followed the original borehole. However, the final drilling tool was significantly more aggressive than the previous tools with carbide cutters along both sides of the wedge face as well as larger carbide cutters at the tip and base of the tool (Fig. 4-3). The final drilling tool was also fitted with a larger fluid port in order to deliver more drilling fluid for cooling and lubricating the drilling tool and to possibly aid in cutting the formation.

The steering system proved to be adequate for the requirements of this drilling program, but the system needs to be improved to provide more accurate results. Some suggested improvements are:

- A temperature sensor to prevent overheating of the down-hole tool.
- Improved azimuth resolution, especially when the tool is used along north-south lines.
- A computer link to the drilling console to provide better tracking of the borehole.
- A secondary survey method is needed to confirm the borehole path. A secondary survey is included in Appendix E.

During the drilling of the original borehole, the drilling rig anchors became loose to a point where they were not holding the drilling rig in place. At that time, a wheeled backhoe was used to anchor the drilling rig. During the third attempt, a pit was constructed in which the drilling rig was placed for bracing. While the pit provided excellent anchorage and allowed the drilling rig to push and pull at maximum capacity, a pit is not always desired or acceptable. Environmentally sensitive areas, such as the TNX Area, preclude the use of pit-launched drilling programs. The anchor system on the drilling rig should be improved so that a surface-launched borehole can provide maximum pushing and pulling capacity.

7.2 Analysis of the Well Completion Method

The well completion method is typical of the method used in the utility industry for installing cables, conduits, and pipes. The method requires an open borehole with entrance and exit holes and a drill stem for pulling the well materials into the borehole. While this method is intuitively simple, it does put stress on the well materials. At any given time each section or joint in the well string experiences the pulling force of the well string that follows. The components of the pulling force of the well string are:

- **Weight** – The weight of the well string is dependent on the mass of the well materials and upward or downward forces in the borehole. An example of upward force is buoyancy caused by fluid in the borehole. An example of a downward force is hydrostatic head differential. The latter force is caused by a greater hydrostatic head in the borehole than in the surrounding formation. This force differential can act to push the well materials into the sidewall of the borehole increasing the weight of the well string and the surface friction experienced by the well string.
- **Surface Friction** – Surface friction is a function of the weight of the well materials, the borehole sidewall materials, and the amount of surface area of the well materials in contact with the borehole sidewall. At certain points in the borehole, such as the curves, the well materials have a greater surface area in contact with the sidewall. Borehole collapse will also increase the surface friction of the well materials.
- **Key Setting** – Key setting is when the well materials are forced into the sidewall of the borehole. Key setting is generally due to borehole geometry and occurs along the upper part of the borehole at the curved sections.
- **Oblique Forces** – There are also oblique forces applied to the well materials as they are pulled through the curved sections of the borehole. The oblique forces act to deform the pipe and joints (specially at the O-ring groove on the joint pin).

The well materials must be able to maintain their integrity while experiencing the pulling forces described above. More importantly the joints in the well materials must survive these forces.

The well materials used during completion attempts 1 and 2 were not able to withstand the pulling pressures produced during well completion.

During the first well completion attempt it was obvious that the joints of the Teflon™ slotted pipe would not withstand the slightest pulling forces. These well materials were designed to be installed in a vertical well and were not designed to undergo the stresses of horizontal well completion. Similarly the PVC casing joints were also designed to be used in a vertical well. Attempts to improve the integrity of the Teflon™ joints by taping produced time delays during installation of well materials. It is likely that the borehole may have partially collapsed on the PVC casing, already in the borehole, during the time delays. This would have increased the surface friction and weight of the well materials in the borehole and put additional stress on the casing joints, especially those joints closest to the pulling device.

Another factor which may have increased the pulling force on the well materials is the amount of water that flowed into the well screen as it passed through the exit pit into the borehole. Two possible scenarios include:

- The conical-shaped hole opener pushed any water in the borehole in front of it and left a partial vacuum in its wake. The partial vacuum caused the borehole sidewall to come in on the well materials and blocked any water coming from the exit hole into the borehole; thus, the borehole became dry.
- As the well screen entered the exit pit it was observed that the water in the pit flowed into the well screen and casing. The water in the well casing was not buoyed by water in the borehole which was dry. The water increased the weight and friction of the well string, thus causing greater stress on the casing joints.

The well string likely failed at a joint very close to the pulling device because those joints experienced the greatest pulling forces. The well string was approximately 190 feet long. The first joints had passed through the first curved section and had experienced oblique forces which may have deformed the joints. The well string may have experienced key setting in the curved section which may have increased surface friction on the pipe. Water in the well casing may have increased the weight of the well materials. Partial collapse at the borehole may also have increased the weight and surface friction of the materials. Any one of these factors may not have caused failure of the well string, but the combination of all of them was too much for the casing joints to withstand.

The second completion attempt had the same factors working against the well materials as in the first attempt plus the factor of solvent/adhesive on the PVC casing joints. The solvent placed on the casing joints softened the PVC prior to application of the adhesive. This in itself would not have caused failure of the joints but the bonding of the joints was not allowed to cure. The joints may have been weakened as pulling forces were applied before the joints were fully hardened. An inspection of the break in the pin of the second PVC joint showed that the break occurred at the O-ring groove and that the PVC around the groove had been affected by the solvent/adhesive. The O-ring groove was machined between the threads on the pin and the straight pipe. The location of the groove created a weakness in the joint and the solvent/adhesive further weakened the joint.

The third completion attempt was successful even though the well materials may have experienced high pulling pressures. The fiberglass well materials had the following two advantages (aside from superior tensile strength) over the PVC well materials:

- The fiberglass well materials were in 30-foot lengths. Longer pipe lengths meant fewer joints to break and a greater capability to bend while going through the curved sections. Joints do not bend as readily as straight pipe.
- The joints of the fiberglass pipes had much thicker walls and consequently were much stronger. The pin and boxes of the joints had no inherent weak spots. For example, the O-ring groove on the fiberglass pin was between the threads and the end of the pin and did not provide a weak spot in the joint.

The successful completion of the horizontal well was directly dependent on the type of well materials used in the third attempt. The following criteria must be considered when choosing completion materials for a horizontal well:

- Compatibility of Materials – In this case it was necessary to use materials that could resist the heat generated during the proposed radio frequency heating demonstration. The Teflon™ screen fulfilled this criterion but failed to fulfill the following criteria.
- Flexibility of Materials – The radius of curvature of the borehole must be factored into selection of well materials. The well materials must be able to elastically deform and recover without detrimental effects while moving through the curved sections of the borehole.
- Strength of Materials (Joints) – The joints of the well materials must be able to withstand the pulling forces experienced during well completion. Joints designed for vertical well materials are not able to withstand horizontal well completion forces.

8.0 CONCLUSIONS

The following conclusions were reached upon completion of the drilling demonstration:

1. The demonstration showed that horizontal wells can be drilled with a compaction drilling method. It also showed that the method requires some sort of drilling fluid to lubricate and cool the drilling tool.
2. The magnetometer/accelerometer steering system used during the demonstration, Drill Scout™, is adequate only where accuracy in azimuth along a north-south line is not required. The use of a secondary survey is recommended when using this type of steering tool. A secondary survey is included in Appendix E.
3. A surface borehole launch requires an improved drilling rig anchor system to allow maximum pushing and pulling capacity.
4. Well materials must be designed for the stresses of horizontal well completion. Casing and screen joints must be able to withstand the axial and lateral tensional stresses imposed on the well materials during well installation.

**Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992**

**Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3**

THIS PAGE INTENTIONALLY LEFT BLANK

9.0 RECOMMENDATIONS AND SUGGESTIONS FOR FUTURE ACTIVITIES

9.1 Recommendations

During the course of this demonstration drilling procedures and design specifications were altered as original plans were proved inadequate. The following are major recommendations for consideration if future projects of this nature are planned.

1. Surface-launched boreholes require that the drilling rig is anchored firmly to the ground and that the anchorage is able to resist the maximum pushing and pulling capacity of the drilling rig.
2. The steering system should be proven as an accurate survey tool or should be supplemented by a secondary system to confirm the location of the down-hole assembly.
3. Pre-drilling activities should include:
 - A thorough description of the target zone and surrounding geology should be made available to the well designers and the drilling subcontractor.
 - A description of the well completion requirements such as well screen size, filter pack size (if needed), and material specifications of the well string material should be evaluated and discussed.
 - A thorough design of the borehole should be prepared. The design should include the locations of the entry hole and exit hole (if needed), the location of the well screen, and the radius of curvature required to place the well screen correctly.
 - An engineering calculation brief that describes and sums the forces experienced by the well materials during well completion activities should be conducted. The calculation brief should delineate the strength requirements of the well materials and evaluate the utility of the chosen well materials.
 - The chosen well materials should be thoroughly inspected before well completion activities begin. Special emphasis should be placed on the pin and box of each piece if threaded joints are used.
 - The steering tool should be calibrated onsite by a qualified technician before each use.
 - The drilling subcontractor should be procured as early on in the design process as possible. Pre-drilling meetings should be held, and all the above items should be discussed with the drilling subcontractor.

9.2 Suggestions for Future Activities

Based on the results of field demonstration to date, the following are suggestions regarding future project activities:

1. The RF heating and SVE phase of the demonstration should be conducted as planned.
2. A horizontal well should be installed at the TNX Area using a technology other than compaction drilling (see Appendix A).
3. The compaction drilling technique performed successfully in the M Area and should be considered in future drilling programs.

REFERENCES

Aadland, R.K., Smits, A.D., and Thayer, P.A., 1992, *Geology and Hydrostratigraphy of the A/M Area, Savannah River Site (SRS), South Carolina (U)*

CDM Federal Programs Corporation, 1992, *Hydrogeologic Setting of the A/M Area: Framework for Groundwater Transport, Second Draft, WSRC-TR-92-355.*

Eddy, C.A., Looney, B.B., Dougherty, J.M., Hazen, T.C., and Kaback, D.S., 1991, *Characterization of the Geology, Geochemistry, Hydrology and Microbiology of the In-Situ Air Stripping Demonstration Site at the Savannah River Site*, USDOE Report WSRC-RD-91-21, Westinghouse Savannah River Co., Savannah River Laboratory, Aiken, SC 29808, 118p

Huddleston, P.F., and Hetrick, J.H., 1985, *Upper Eocene Stratigraphy of Central and Eastern Georgia*. Georgia Geologic Survey Bulletin 95, 78 p

Layne, R. and Ditch Witch®, Permission for photographs and information concerning X-810

Meyer, R.D., 1992, Private communication of well plan and drilling information

Nystrom, P.G., Jr., and Willoughby, R.H., 1982, "Cretaceous, Tertiary, and Pleistocene(?) Stratigraphy of Hollow Creek and Graniteville Quadrangles, Aiken County, South Carolina", in Nystrom, P.G., Jr., and Willoughby, R.H., eds., 1982, *Geological Investigations Related to the Stratigraphy in the Kaolin Mining District, Aiken County, South Carolina*. Carolina Geological Society Field Trip Guidebook 1982, South Carolina Geological Survey, Columbia, SC, pp 80-113

Nystrom, P.G., Jr., Willoughby, R.H., and Kite, L.E., 1986, *Cretaceous-Tertiary Stratigraphy of the Upper Edge of the Coastal Plain Between North Augusta and Lexington, South Carolina*. Carolina Geological Society Field Trip Guidebook, South Carolina Geological Survey

Science Applications International Corporation, 1992, *Construction Notes and Summary of Hydrostratigraphy for Hydrogeologic Cross-Sections for the Integrated Demonstration Site, Savannah River Site*. SAIC, 360 Bay Street, Suite 200, Augusta, GA 30901

Siple, G.E., 1967, *Geology and Groundwater of the Savannah River Plant and Vicinity, South Carolina*. U.S. Geological Survey Water-Supply Paper 1841, 113 p

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

THIS PAGE INTENTIONALLY LEFT BLANK

**Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992**

**Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3**

Appendix A

TNX Area Horizontal Drilling Program

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

THIS PAGE INTENTIONALLY LEFT BLANK

Appendix A

TNX Area Horizontal Drilling Program

Introduction

The TNX Area (Fig. A-1) has been the site of the SRS Pilot Plant since SRS operations began. The mission of the TNX pilot facility is to perform pilot scale tests on operations developed in the laboratory before they are implemented full-scale in SRS operations.

The TNX Area is located next to a wetland that lies in the Savannah River flood plain. Site operations have lead to VOC releases to groundwater. The groundwater flows towards the Savannah River beneath the wetlands. A horizontal well constructed perpendicular to and downgradient of the VOC plume was proposed as an interim action to prevent further migration of contaminants downgradient towards the hydrologic boundaries along the Savannah River.

Drilling Plan

The proposed horizontal well was planned to be installed at a depth of 15-25 TVD bgs (Fig. A-2) in the area southwest of the terrace on which the TNX facilities are situated (Fig. A-3). A test well was planned to be installed outside the contaminant plume to initially test the drilling method.

Technical Approach

The drilling method utilized a Jet-Trak 4/40 drilling rig with a fluid-assisted guided boring system and a patented directional drilling tool. The Jet-Trak 4/40 has a maximum pushing capacity of 40,000 lb, and it is a portable wheel-mounted rig that can be placed in remote locations. A 100-yard umbilical line connects the drilling rig to a support trailer that supplies hydraulic pressure and drilling fluids. The drilling tool produces no drill cuttings and uses approximately two gallons of water per foot of borehole drilled. The steering system consists of a down-hole sending unit and a walk-over receiving unit that indicates x-, y-, and z-coordinates from the sending unit.

Well Summary

The drilling rig was set up to drill the test well with relative ease. Problems with the hydraulic system on the drilling rig did not allow the rig to reach full pushing capacity, but it had enough force to drill through the sediments. The drilling method, however, was found to be ineffective in the geologic conditions found at that site.

Specifically, the compaction drilling technique was not able to maintain an open borehole in the water-bearing sands underlying the TNX Area. The drilling tool had no problem opening a hole in the sediments, but the hole did not remain open and collapsed behind the drilling tool. The drilling tool drilled 60 feet before the attempt was abandoned for fear that the drilling tool would become lodged and lost down-hole.

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

Conclusion and Recommendation

Although the compaction drilling method proved to be inadequate for the geologic conditions found at the TNX Area, the need for installing a horizontal well at that site remains valid. There are portable mud rotary drilling rigs available that would be able to access the TNX drilling site. A mud rotary drilling method would be able to keep the borehole open and allow successful well completion.

Figure A-1. Location of the TNX Area in the SRS

Figure A-2. Proposed Horizontal Well Schematic for the TNX Area

Figure A-3. Proposed Locations of Horizontal Wells in the TNX Area

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

THIS PAGE INTENTIONALLY LEFT BLANK

**Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992**

**Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3**

Appendix B

Proposed Drilling Plans for a Horizontal Well at the Integrated Demonstration Site Adjacent to the M-Area Basin, Savannah River Site

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

THIS PAGE INTENTIONALLY LEFT BLANK

**PROPOSED DRILLING PLAN FOR A HORIZONTAL WELL
AT THE INTEGRATED DEMONSTRATION SITE ADJACENT TO THE
M-AREA BASIN, SAVANNAH RIVER SITE**

Date Prepared: 3-19-92

OBJECTIVE:

The objective of this program is to demonstrate a new horizontal drilling technology that utilizes compaction for installation of well screen and casing. Importantly, the equipment proposed for this installation was designed to virtually eliminate drilling fluids and cuttings return. This means that minimal liquids are added to contaminated sites. Application of this new technology at contaminated sites offers tremendous potential for improving environmental restoration methodologies to assure operations that minimize migration of contaminants and maximize safety.

Once installed, the proposed horizontal well will be utilized for a demonstration of radio frequency (RF) heating as a method to enhance the removal of volatile organics from clays by vacuum extraction.

BACKGROUND:

Sandia National Laboratories (SNL) and the Charles Machine Works, Inc. (DITCH WITCH-Tm), an industrial developer of trenchless technology for the underground utilities installation industry, established a partnership in 1990 to develop hybrid machinery for use in horizontal access beneath waste sites, buried tanks, and process buildings. Location and directional control of the penetration point or boring head is accomplished using either an onboard transmitter and a walk-over surface receiver or by the use of a more sophisticated onboard electronics package. The development work has included installation of horizontal test holes at the SNL and CMW test ranges and at an Oklahoma refinery.

Several trenchless technology machines have recently been adapted for environmental work. New machinery specifically designed for environmental work has been developed and is ready for demonstration. The basic philosophy underpinning this work is that the operational methods and machinery used to characterize, monitor and remediate a site should not cause additional environmental impact and should not generate secondary waste. The newly developed drilling method results in virtual elimination of both drilling fluids and spoils return to surface because compaction, rather than cutting, is the dominant process. Limited use of bentonite fluids may be required in some sediments.

The location of the proposed horizontal well is the integrated demonstration field test site along the process sewer line between M Area and the closed M-Area Settling Basin. The well will be installed at a depth of approximately forty feet, following the path of the abandoned process sewer line. Installation of the new well is proposed directly above the recently drilled (1991) horizontal wells that were emplaced by Eastman Christensen

using their new slant-rig drilling technology. A map showing the proposed drilling location is attached as Figure 1.

The proposed well targets a shallow clay layer that has been identified in core data from previous characterization studies in the vicinity. These studies indicate a significant residual VOC contamination held up in this clay layer. The horizontal position of the borehole is over 80 feet above the water table and above the existing horizontal test wells at the site. Schematic diagrams showing the proposed borehole in cross section are shown in Figures 2 and 3. Figure 2 shows the proposed trajectory in relation to the water table and existing wells. Figure 3 provides additional details on the proposed completion.

DRILLING PLAN:

The preferred drilling methodology for this equipment involves a surface launch or shallow pit launch at a shallow angle, penetration to a target zone, transition to horizontal in the target zone, then transition to a trajectory for a proper surface exit. After the exit is accomplished, the penetration point or boring head is removed and a backreamer or expansion cone and casing pulling system are attached. When the drill pipe is retracted, the completion casing is simultaneously pulled into place. This basic technique has been used by the utilities installation and river crossing industries for many years.

The prototype penetration equipment intended for use at this location will use dry-bore compaction technology. The primary machine for this work will be the X810 Rod Pusher, currently under development as part of the Sandia/Ditch Witch industrial partnership. This machine is a larger version of the commercial P-80 with the capability to simultaneously cut and compact the soil. The new machine does not normally use fluids, but a capability for the addition of air or water is included in the design. As a contingency, less than 2.5 gpm (less than approximately 1000 total gallons) of potable water with bentonite and/or polymer additive may be needed while emplacing the borehole if the soil is found to be unacceptable to dry-bore methods. The X810 is currently a proprietary machine in development. To eliminate divulging proprietary information to commercial competitors, access to the site will be limited to regulatory agency personnel, SRS staff, and others approved by Ditch Witch.

The target depth will be approximately forty feet in the shallowest clay zone, known to contain elevated levels of VOCs as identified in the characterization program at the Integrated Demonstration Site and in soil borings collected for the vadose zone characterization program. The precise position of the horizontal borehole will be determined by factors such as location and steering accuracies and geologic formation properties. The trajectory will be carefully controlled to avoid any damage to existing monitoring wells or planned monitoring well locations.

WELL CONSTRUCTION:

The slotted screen to be installed will consist of heat resistant, flexible, synthetic (thermoplastic or composite) material, Schedule 40 or greater, three or four inches in diameter. The well will be screened throughout the horizontal section in the clay interval and will be cased throughout the curved sections at both ends (Figure 3). The casing in the curved risers will be PVC or equivalent material threaded to mate to the heat resistant screen. The casing and screen is supported in compression by an internally tensioned cable while the pull-back is being accomplished.

Existing well standards and regulations were written for traditional vertical well emplacement. Horizontal boreholes differ in geometry but the basic intent and philosophy of protecting the ground water is the same as for vertical wells. Horizontal wells reduce the potential for inappropriate communication between geologic layers. In all cases, the well must be constructed to eliminate drainage of surface water into the hole. The proposed M Area borehole will be completed with a casing that has a diameter that is nominally 1" less than the boring with no gravel pack. The entry and exit points will be sealed as shown in Figure 3 to protect the borehole from surface water. Termination of the casing, sealing as appropriate, surface pads, protective barricades and required locking mechanisms will be installed. Both ends of the well will be permanently marked with the well identification and information on the trajectory and completion.

QUALITY ASSURANCE:

A South Carolina certified driller and an independent technical oversight in accordance with WSRC Procedure Manual 3Q5 Hydrogeologic Data Collection will oversee the drilling operations when the horizontal borehole is being constructed and completed.

SAFETY:

Project safety requirements in WSRC Procedure Manual 3Q5 Hydrogeologic Data Collection, Chapter 2, will be followed.

DESCRIPTION OF RF HEATING AND PROPOSED MONITORING BOREHOLES FOR THE REMEDIATION DEMONSTRATION:

The horizontal well will be used for an in-situ RF heating test. Westinghouse Electric Corporation and KAI Technologies are acting as joint participants. The proposed remediation demonstration consists of dielectric heating of a short section (approximately 20 feet) of the horizontal well using a single dipole RF applicator. The system will operate at a maximum frequency of 13.6 MHz within the industrial (ISM) band. These frequencies are appropriate for coupling to typical sediments for heating and are made available by the FCC for industrial use. The demonstration will investigate the enhanced VOC recovery during vacuum extraction resulting from increased contaminant volatility and sediment permeability and the steam stripping caused by RF heating. An unheated control area along the same horizontal well will be characterized to allow direct evaluation of the value of the RF heating.

The horizontal well position was chosen to focus the RF energy within the clay lenses 35 to 50 feet below surface. A large fraction of the VOC (TCE and PCE) within the vadose zone of M Area is trapped within this type of material. Removal of VOCs from these zones using conventional vacuum extraction is a slow process due to the low permeability of the clays. The current plan calls for raising the temperature within a roughly 20 foot radius of influence to approximately 100 °C. A maximum temperature in the immediate vicinity of the well will be in the 150 to 200 °C range. The contaminated soil vapor will be extracted with a vacuum blower operating at approximately 200 SCFM and approximately 6 to 10 "Hg vacuum. The offgas from the blower will be treated to greater than 95% destruction of VOCs using a commercially available halocarbon catalytic oxidation system. An air permit for the heating demonstration will be prepared later this year.

Approximately 10 boreholes (Figure 4) will be drilled before and after the demonstration. These holes will be installed to a depth of approximately 50 feet and will be continuously cored. The core will be analyzed at closely spaced intervals for VOC concentration, microbiological community characterization, and moisture content. The pretest core will be examined for lithology, dielectric properties and other bulk properties. Each of the pretest boreholes will be instrumented with three piezometer tubes to observe changes in subsurface pressure/vacuum and soil gas concentration. In these same holes, 5 to 7 temperature monitors will be installed (currently, fiber optic temperature monitors that are not affected by the RF fields are planned). We anticipate that the electrical properties of the contaminated clay zones will preferentially capture the RF energy, focusing the applied power precisely in the zones that need to be heated. Figure 4 is a schematic diagram of the proposed demonstration test and monitoring.

Figure 1. Location Map for Horizontal Well at M Area

* AMH4 is a 6 inch HDPE well installed for future vadose zone remediation tests

** AMH3 is a 6 inch HDPE well installed for future groundwater remediation tests

FIGURE 2
Schematic of the proposed horizontal RF Heating/Vacuum Extraction Well:
Position relative to Existing Test Wells AMH 3 and AMH4

* Use of materials less than 4 inch diameter allows installation without reaming

** Flush threaded to mate to ends.

Slot size ~ 0.01 inches.

Slot spacing ~ 0.125 to 0.25 inches

Pipe must be non metallic for RF heating. Teflon or composite currently being considered.
Expected maximum temperature in the vicinity of the well ~ 150 to 200 °C.

FIGURE 3. SCHEMATIC DIAGRAM OF M-AREA INSTALLATION AND DESCRIPTION OF COMPLETION

Each monitoring location will be continuously cored before and after the test. Hollow stem auger and split spoon samples will be used. Detailed depth discrete VOC analysis of core will be performed by headspace analysis.

□ = temperature monitor
● = pressure and concentration monitor

FIGURE 4. PROPOSED RE HEATED MONITORING

Proposed Well Path for AMH-5

M Area Bore Trajectory - South to North @ Surface - Top of Target ^{01/24/92} _{16.2}

Angle	R L	H	Entry	Surface MSL	MSL Bore				
20	0	0	0	356	356				
	10	9.4	5.4		352.6				
	20	18.8	6.8		349.2				
	30	28.2	10.3		345.7				
	40	37.6	13.7		342.3				
	50	47	17.1		338.9				
20	60	56.4	-20.5		335.5				
17.7	70	65.9	23.5		332.5				
15.4	80	75.6	26.2		329.8				
13.1	90	85.3	28.5		327.5				
10.8	100	95.1	30.3		325.7				
8.5	110	105	31.8		324.2				
6.2	120	115	32.9		323.1				
3.96	130	124.9	33.6		322.4				
1.67	140	134.9	33.9		322.1				
+ .63	150	144.9	33.7		322.3				
+ .84	160	154.9	33.6		322.4				
	170	164.9	33.5		322.5				
	180	174.9	33.3		322.7				
	190	184.9	33.2		322.8				
	200	194.9	33.0		323				
	210	204.9	32.9		323.1				
	220	214.9	32.7		323.3				
	230	224.9	32.6		323.4				
	240	234.9	32.7		323.5				
	250	244.9	32.3		323.7				
	260	254.9	32.1		323.9				
	270	264.9	32.0		324				
	280	274.9	31.8		324.2				
	290	284.9	31.7		324.3				
	300	294.9	31.5		324.5				
	310	304.9	31.4		324.6				
	320	314.9	31.3		324.7				
	330	324.9	31.1		324.9				
	340	334.9	31.0		325				
	350	344.9	30.8		325.2				
	360	354.9	30.7		325.3				
	370	364.9	30.5		325.5				
	380	374.9	30.4		325.6				
	390	384.9	30.2		325.8				

M-Area Bore Trajectory - South to North - Top of Target (Page 1 of 2)

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

Angle	R L	H	Depth to Entry	m.s.l Surface	m.s.l Base
.84	400	394.9	30.1		325.9
	410	404.9	29.9		326.1
.84	420	414.9	29.8		326.2
3.13	430	424.9	29.3		326.7
5.42	440	434.8	28.3		327.7
7.7	450	444.8	27.0		329
10.0	460	454.6	25.2		330.8
12.3	470	464.4	23.1		332.9
14.6	480	474.0	20.6		335.4
16.9	490	483.6	17.7		338.3
19.2	500	493.1	14.4		341.6
21.5	510	502.4	10.7		345.3
23.8	520	511.5	6.7		349.3
26.1	530	520.5	2.3		353.7
28.3	540	529.3	-2.5		358.5
30.6	550	537.9	-7.5		363.5
32.9	560	546.3	12.9	364	368.9

B-13

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

M-Area Bore trajectory - South to North @ Surface. Btm of Target

Angle	Rd	H.	FI Entry	Surface MSL	MSL Bore			
-20	0	0	0	356	356			
-20	10	9.4	-3.4		352.6			
-20	20	18.8	-6.8		349.2			
-20	30	28.2	-10.3		345.7			
-20	40	37.6	-13.7		342.3			
-20	50	47	-17.1		338.9			
-20	60	56.4	-20.5		335.5			
-20	70	65.8	-23.9		332.1			
-20	80	75.2	-27.4		328.6			
-17.7	90	84.7	-30.4		325.6			
-15.4	100	94.3	-33.1		322.9			
-13.1	110	104.1	-35.3		320.7			
-10.8	120	113.9	-37.2		318.8			
-8.5	130	123.8	-38.7		317.3			
-6.2	140	133.7	-39.8		316.2			
-3.9	150	143.7	-40.4		315.6			
-1.67	160	153.7	-40.7		315.3			
+0.6	170	163.7	-40.6		315.4			
+0.84	180	173.7	-40.5		315.5			
	190	183.7	-40.3		315.7			
	200	193.7	-40.2		315.8			
	210	203.7	-40		316			
	220	213.7	-39.9		316.1			
	230	223.7	-39.7		316.3			
	240	233.7	-39.6		316.4			
	250	243.7	-39.4		316.6			
	260	253.7	-39.3		316.7			
	270	263.7	-39.1		316.9			
	280	273.7	-39		317			
	290	283.7	-38.8		317.2			
	300	293.7	-38.7		317.3			
	310	303.7	-38.5		317.5			
	320	313.7	-38.4		317.6			
	330	323.7	-38.3		317.7			
	340	333.7	-38.1		317.9			
	350	343.7	-38		318			
	360	353.7	-37.8		318.2			
	370	363.7	-37.7		318.3			
	380	373.7	-37.5		318.5			
+0.84	390	383.7	-37.4		318.6			

M-Area Bore Trajectory - South to North - Bottom of Target (Page 1 of 2)

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

10/12/2014

292

M-Area Bore Trajectory – South to North – Top of Target (Page 2 of 2)

**Proposed Path (in Cross Section) of Horizontal Well in M Area
 (Vertical Exaggeration $\times 10$)**

Proposed South End Entry (in Cross Section) of Horizontal Well in M Area
 (Vertical Exaggeration $\times 10$)

Proposed North End Exit (in Cross Section) of Horizontal Well in M Area
(Vertical Exaggeration $\times 10$)

**Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992**

**Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3**

Appendix C

Daily Activity Reports

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

THIS PAGE INTENTIONALLY LEFT BLANK

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992
OSR 30-2 (Rev 12-89)

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

DAILY ACTIVITIES REPORT

PROJECT <i>Horizontal Well Technology Development</i>		DRILLING SUBCONTRACTOR <i>Charles Machine Works/SNL</i>	
WELL NUMBER <i>DW-1</i>		DRILLER	
TECHNICAL OVERSIGHT <i>Dave Wilson</i>		OVERSIGHT FIRM <i>COM / Federal Programs Corp</i>	
LOCATION <i>M Area Basin</i>		DATE <i>6/16/92</i>	PAGE <i>1</i>

START	STOP	DESCRIPTION OF ACTIVITIES; REMARKS
1045		Drilling oversight began after badge was obtained - Charles Machine Works (Ditch Witch) was assembling & putting in place the drilling rig. Ditch Witch personnel are Roger Meyers & Jim Wilda
1100		Meeting with D. Kabach, R. Nichols of SRS, R. Wimple & R. Layne of SNL, R. Meyer of Ditch Witch, and Dave Wilson of COM. In the meeting the drilling plan was discussed and a copy was given to D. Wilson.
1130		Bryan Looney explained surface completion to R. Wimple.
		- Tremie in sand until the sand is stable
		- Tremie in bentonite pellets & wet
		- ground to surface
		- put in cement plug & (post?)
1412		After preparing equipment and taking a lunch break the crew began drilling
1423		Hydraulic Fluid leaked out of the Drill Rig Power Pack. Don Poulos of WSRRC was notified of the non-critical leak, the Fluid was absorbed & the absorbent surrounding soil & plastic drop cloth was bagged and labeled as petroleum contaminated soil and waste. The clean up operation ended at 1540
1618		The crew ^{was} having trouble with Flex sub on the downhole assembly. It appeared to be cross threaded
1709		The crew decided to take ^{not} take the downhole assembly to the machine shop for repair. Activities will resume at 0730 hr on 6/17/92. site
1730		Left site - Daily Visitor roster is attached

TECHNICAL OVERSIGHT SIGNATURE *Dave D. Wilson* DATE *6/16/92*

DAILY ACTIVITIES REPORT

PROJECT <i>Horizontal Well Technology Development</i>		DRILLING SUBCONTRACTOR <i>Charles Machine Works / SNL</i>	
WELL NUMBER <i>DW-1</i>		DRILLER <i>Roger Layne</i>	
TECHNICAL OVERSIGHT <i>Dave Wilson</i>		OVERSIGHT FIRM <i>CDM / Federal Programs</i>	
LOCATION <i>M Area Basin</i>		DATE <i>6/12/92</i>	PAGE <i>1</i>

START	STOP	DESCRIPTION OF ACTIVITIES; REMARKS
		<i>Visita Roster attached.</i>
<i>0735</i>		<i>Arrived on site - weather overcast, cool, with a slight wind, varying in speed and direction (generally the wind was from the east). - Flex sub had not been repaired at that time.</i>
<i>0810</i>	<i>0830</i>	<i>Held a Health & Safety meeting. Items discussed were:</i> <div style="margin-left: 20px;"> <i>- Project organization</i> <i>Westinghouse</i> <i>- Responsibility of personnel</i> <i>CDM/FPC</i> <i>CDM/SNL</i> <i>- CDM/FPC: Technical oversight</i> <i>and Health & Safety</i> <i>- SNL/CMW: veto power on the site access</i> </div>
<i>0840</i>		<i>Began drilling - Background HNU reading: 0.2 ppm</i>
<i>0920</i>		<i>Drill team tripping tripped out of hole to check the drilling tool temperature, the rotation pressure got too high as 5000 psi. The downhole distance was ~20 ft.</i>
<i>0946</i>		<i>The drill team decided to rig the drilling Fluid system to be able to send water to the bit for lubrication & cooling. It is not their intention to circulate fluid. A leak was found in the system, that development and the fact that the Flex sub was not repaired caused the drilling team to put off drilling until later.</i>
<i>1250</i>		<i>Drilling began once more, still drilling dry</i>
<i>1322</i>		<i>Drill met with resistance at 45 ft downhole, started using water</i>
<i>1338</i>		<i>Tripped out of hole to add a more aggressive drill tool with carbide cutters.</i>
<i>1430</i>		<i>Began drilling again with new bit & using water</i>
<i>1620</i>		<i>The downhole distance was at 40 ft. but they lost the signal from the downhole sensor. They are tripping out.</i>
<i>1727</i>		<i>The Drill Scout sensor is broken and will be replaced</i>
<i>1745</i>		<i>Left site - drilling begins tomorrow at approx. 0715 hrs.</i>

TECHNICAL OVERSIGHT SIGNATURE

Dave Wilson

DATE

6/12/92

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992
OSR 30-2 (Rev 12-89)

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

DAILY ACTIVITIES REPORT

PROJECT <u>Horizontal Well Technology Development</u>		DRILLING SUBCONTRACTOR <u>Charles Machine Works/TNK</u>	
WELL NUMBER <u>DW-1</u>		DRILLER <u>Roger Layne</u>	
TECHNICAL OVERSIGHT <u>Dave Wilson</u>		OVERSIGHT FIRM <u>CDM/Federal Programs</u>	
LOCATION <u>M Area Basin</u>		DATE <u>6/15/92</u>	PAGE <u>1 of 3</u>

START	STOP	DESCRIPTION OF ACTIVITIES; REMARKS
0711		Arrival on site - drilling activity had not yet started. The drill team wanted to get a thermometer for the BHA to measure Temp. at the drill foot.
0740	0755	Held a Tail gate meeting, items discussed were: (1) schedule - drilling won't start until the mixer arrives. (2) No Health & Safety concerns (3) A pit may be dug for the drill rig to a) catch returns and b) give more thrust to the rig. (4) Some site personnel will go inspect the TNX site.
0813	0930	Left to inspect TNX site - Health & Safety concerns discussed: (1) Bug spray will be available on site (2) A hand rope will be put up along the path from the service road down the hill to the drill site. (3) WISRS was asked to get someone to flag poison ivy along work area and paths.
0940	1040	The drill team calibrated the Drill Scout sensor
1058		The decision ^{decision} was made to begin drilling without the thermometer. Joints in the hole.
Time	Joint #	Length Cumulative length
1058	BHA	~5 ~5
1100	1	5 10
1106	2	5 15
1112	3	5 20
1117	4	5 25 - Drilling is hard
1121	5	5 30
1126	6	5 35
1133	7	5 40 - HNU reading in entry pit = 30 ppm, Applying H2O down hole

TECHNICAL OVERSIGHT SIGNATURE

Dave D. Wilson

DATE

6/15/92

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

OSR 30-2 (Rev 12-89)

DAILY ACTIVITIES REPORT

PROJECT <i>Horizontal Drilling Technology Development</i>				DRILLING SUBCONTRACTOR <i>Charles Machine Works / SNL</i>	
WELL NUMBER <i>DW-1</i>		TECHNICAL OVERSIGHT <i>David R. Wilson</i>		DRILLER <i>Roger Layne</i>	
LOCATION <i>M Area Basin</i>				OVERSIGHT FIRM <i>CDM Federal Programs</i>	
				DATE <i>6/15/92</i>	PAGE <i>2 of 3</i>

START	STOP	DESCRIPTION OF ACTIVITIES; REMARKS	
TIME	JOINT #	Length	Cum. Length
1146	8	5	45 - NNU reading at entry hole ~ 1.5 ppm
1156	9	5	50 - Rotational pressure ~ 3500 Ft-lbs
1214	10	5	55 - NNU reading at entry hole 0.0 ppm, mud in pit
1225	11	5	60
1231	12	5	65
1241	13	5	70
1247	14	5	75
1325	15	5	80 - Horiz dist - 70', vert. dist 23'
1335	16	5	85
1342	17	5	90
1400	18	5	95' - Began building angle on hole to go to horizontal
1410	19	5	100 - NNU reading at entry - 0.0 ppm
1416	20	5	105
1430	21	5	110
1438	22	5	115
1505	23	5	120
1517	24	5	125 - NNU reading at entry - 0.0 ppm
1525	25	5	130
1537	26	5	135 - Bubble in mud in pit gives transient NNU reading of 0.4-1.0 ppm
1545	27	5	140
1555	28	5	145
1613	29	5	150
1620	30	5	155
1630	31	5	160
1637	32	5	165
1646	33	5	170
1706	34	5	175

TECHNICAL OVERSIGHT SIGNATURE *David R. Wilson* DATE *6/15/92*

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

OSR 30-2 (Rev 12-89)

DAILY ACTIVITIES REPORT

PROJECT <i>Horizontal Drilling Technology Development</i>		DRILLING SUBCONTRACTOR <i>Charles Machine Works / SNC</i>	
WELL NUMBER <i>DW-1</i>		DRILLER <i>Roger Lopez</i>	
TECHNICAL OVERSIGHT <i>Dave Wilson</i>		OVERSIGHT FIRM <i>CDM Federal Programs</i>	
LOCATION <i>M Area Basin</i>		DATE <i>6/19/92</i>	PAGE <i>1 of 2</i>

START	STOP	DESCRIPTION OF ACTIVITIES; REMARKS
0720		Arrived on site
0720	0950	Drilling Team busy with maintenance and repairs on drilling equipment. Fixed leak in hydraulic fluid on Power Pack; repaired Fuel pump on water trailer power pack.
0953	1010	Health + Safety meeting (see attached roster), items discussed: ① No H+S problems ② Schedule a) complete pilot hole 6/19 b) install well 6/20 c) set up at TRX area on 6/21 d) start drilling at TRX on 6/22
1020		Started drilling after Fishing sensor went out of the stem
Time	Joint #	length Cumulative length
1020	35	5 180
1025	36	5 185
1031	37	5 190 - 0.0 inclination, borehole at horizontal
1040	38	5 195 - Drill team took a break until 1100 hrs
1102	39	5 200 - NNU reading in entry pit - 0.4 ppm
1111	40	5 205
1122	41	5 210
1129	42	5 215
1143	43	5 220
1154	44	5 225 - Break For lunch until 1235
1244	45	5 230 - Drilling became extremely difficult. The drill team decided to trip out to inspect the BHA & drill bit.
1435		Completed trip out of hole. Crew took a break

TECHNICAL OVERSIGHT SIGNATURE *David D. White* DATE *6/19/92*

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

DAILY ACTIVITIES REPORT

PROJECT		DRILLING SUBCONTRACTOR	
WELL NUMBER		DRILLER	
LOCATION		DATE	
TECHNICAL OVERSIGHT		OVERSIGHT FIRM	
PAGE		PAGE	
Horizontal Drilling Technology Development		Charles Machine Works / SNL	
DW-1		Roger Layne	
M Area Basin		CDM Federal Programs	
6/15/92		2 of 2	
START	STOP	DESCRIPTION OF ACTIVITIES; REMARKS	
1456		Resumed work, the water pump was moved next to the hole and the chiller filled the hole with water. We hoped that the water will soften the formation. While tripping out the chiller reports that little or no resistances was met along the drill rod. That leaves him to believe that the hole is staying open.	
		Gamma readings during the trip out were generally around 5 ppm at the borehole opening, transient readings ^{on 6/15/92} got as high as 30 ppm. At no time did readings taken greater than 12" from the borehole get above 1 ppm.	
1521		Started back downhole with the drill stem.	
1555		Tripping out to repair the sensor wire. The wire lost continuity and needed repair.	
1620		Stopped work because of lightning, wire ^{was} had been repaired.	
1639		Resumed work - putting drill stem downhole.	
1654		Stopped work again because of lightning.	
1702		Decided to resume work to trip out of the hole again to recalibrate the drill scout. There was only 5 joints downhole.	
1744		There is a chance that the hole is 5° off to the west. Work is stopped for the day. Tomorrow the drill team will survey the hole at the surface with a downhole sensor and a walk over receiver.	

TECHNICAL OVERSIGHT SIGNATURE

DATE _____

AIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301/587-8202

Centimeter

Inches

MANUFACTURED TO AIM STANDARDS
BY APPLIED IMAGE, INC.

2 of 2

Demonstration of a Utility Industry Horizontal Drilling
 System: Horizontal Well AMH-5 Installation Report
 CDM Federal Programs Corporation
 December 31, 1992
 OSA 30-7 TR-7 12-92

Westinghouse Savannah River Company
 Subcontract No. AA46325P
 Task Order No. 3

DAILY ACTIVITIES REPORT

OBJECT <i>Horizontal Well Drilling Technology Development</i>		DRILLING SUBCONTRACTOR <i>Charles Machine Works/SM</i>	
WELL NUMBER <i>DW-1</i>		DRILLER <i>Roger Layne</i>	OVERSIGHT FIRM <i>CDM Federal Programs</i>
LOCATION <i>M-Area Basin</i>		DATE <i>6/20/92</i>	PAGE <i>1 of 3</i>
START	STOP	DESCRIPTION OF ACTIVITIES; REMARKS	
0730		Arrived on site. Weather: clear, sunny, humid, hot, no wind	
0745		Health & Safety meeting (Roster Attached) items discussed:	
		(1) There were no H&S problems	
		(2) Schedule	
		a) 1 st calibrate Drill scout sensor	
		b) 2 nd survey the hole with the walk over detector and the downhole beacon.	
0750	0815	- Calibrated inclination devices of drill scout.	
0822	0915	Performed downhole survey - the survey showed that the borehole is parallel to and one foot to the west of the proposed line.	
0935		Resumed drilling activities	
Time	Tool #	length	Cumulative length
0946	BHA	~ 5	5
0949	1	5	10
0951	2	5	15
0954	3	5	20
0958	4	5	25
1001	5	5	30
1002	6	5	35
1009	7	5	40
1011	8	5	45
1012	9	5	50
1018	10	5	55
1019	11	5	60
1020	12	5	65
1023	13	5	70
1028	14	5	75

TECHNICAL OVERSIGHT SIGNATURE

Wendell W. W.

DATE

6/20/92

Demonstration of a Utility Industry Horizontal Drilling
 System: Horizontal Well AMH-5 Installation Report
 CDM Federal Programs Corporation
 December 31, 1992
 OSA 30-2 (REV 12-90)

Westinghouse Savannah River Company
 Subcontract No. AA46325P
 Task Order No. 3

DAILY ACTIVITIES REPORT

OBJECT <i>Horizontal Well Drilling Technology Development</i>		DRILLING SUBCONTRACTOR <i>Charles Machine Works / SNL</i>
WELL NUMBER <i>DW-1</i>		DRILLER <i>Robert Lyons</i>
TECHNICAL OVERSIGHT <i>Dave Wilson</i>		OVERSIGHT FIRM <i>CDM Federal Programs</i>
LOCATION <i>M Area Basin</i>		DATE <i>6/20/92</i>
		PAGE <i>2 of 3</i>

START	STOP	DESCRIPTION OF ACTIVITIES; REMARKS	
Time	Joint [™]	Length	Cumulative Length
1029	15	5	80
1035	16	5	85
1036	17	5	90
1041	18	5	95
1042	19	5	100
1045	20	5	105
1046	21	5	110
1052	22	5	115
1053	23	5	120
1056	24	5	125
1057	25	5	130
1059	26	5	135
1102	27	5	140
1104	28	5	145
1112	29	5	150
1114	30	5	155
1116	31	5	160
1118	32	5	165
1121	33	5	170
1124	34	5	175
1130	35	5	180
1219	36	5	185
1221	37	5	190
1224	38	5	195
1227	39	5	200
1240	40	5	205
1243	41	5	210

1130 - The azimuth readings appeared to be in error, reads 000 instead of 334
 1134 - switched out sensor console, the problem continued

1217 - The decision was made to advance the drill without azimuth data.

1223 - Azimuth reading has returned to console.

TECHNICAL OVERSIGHT SIGNATURE *David R. Wilson* DATE *6/20/92*

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992
OSR 30-2 (Rev 12-92)

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

DAILY ACTIVITIES REPORT

PROJECT <i>Horizontal Well Drilling Technology Development</i>		DRILLING SUBCONTRACTOR <i>Charles Machine Works/SNL</i>	
WELL NUMBER <i>DW-1</i>		DRILLER <i>Roger Layne</i>	
TECHNICAL OVERSIGHT <i>DAVE Wilson</i>		OVERSIGHT FIRM <i>CDM Federal Programs</i>	
LOCATION <i>M Area Basin</i>		DATE <i>6/20/92</i>	PAGE <i>3 of 3</i>

START	STOP	DESCRIPTION OF ACTIVITIES; REMARKS	
<i>Time</i>	<i>Joint #</i>	<i>Length</i>	<i>Cumulative Length</i>
<i>1246</i>	<i>42</i>	<i>5</i>	<i>215</i>
<i>1253</i>	<i>43</i>	<i>5</i>	<i>220</i>
<i>1258</i>	<i>44</i>	<i>5</i>	<i>225</i>
<i>1300</i>	<i>45</i>	<i>5</i>	<i>230 - Reached bottom of the borehole</i>
<i>1308</i>	<i>46</i>	<i>5</i>	<i>235</i>
<i>1312</i>	<i>47</i>	<i>5</i>	<i>240</i>
<i>1316</i>	<i>48</i>	<i>5</i>	<i>245</i>
<i>1321</i>	<i>49</i>	<i>5</i>	<i>250 - drilling became harder - Rotation - 3000 Ft-lbs</i>
<i>1330</i>	<i>50</i>	<i>5</i>	<i>255</i>
<i>1345</i>	<i>51</i>	<i>5</i>	<i>260</i>
<i>1411</i>	<i>52</i>	<i>5</i>	<i>265</i>
<i>1417</i>	<i>53</i>	<i>5</i>	<i>270</i>
<i>1433</i>	<i>54</i>	<i>5</i>	<i>275</i>
<i>1449</i>	<i>55</i>	<i>5</i>	<i>280</i>
<i>1520</i>	<i>1556</i>	<i>Checked water system to make sure the system is putting water to the drill bit.</i>	
<i>1626</i>		<i>They pulled back 4 joints and pumped water down the drill stem, the water ports appeared to be open.</i>	
<i>1732</i>		<i>Reached bottom of the hole again</i>	
<i>1746</i>		<i>The drilling is very very difficult; push thrust is 60000 lbs</i>	
<i>1806</i>		<i>The drill team has decided to pull out two joints and quit for the day. Tomorrow they will trip out & check the bit.</i>	
<i>1820</i>		<i>Left site. Note: The entry pit was filled with water in the morning and it stayed there the entire day, no bubbles were in the water, no indication of gas. Therefore no H₂S readings were taken</i>	

TECHNICAL OVERSIGHT SIGNATURE *David D. Wilson* DATE *6/20/92*

DAILY ACTIVITIES REPORT

PROJECT <i>Horizontal Well Drilling Technology</i>		DRILLING SUBCONTRACTOR <i>Charles Machine Works / SMC</i>	
DEVELOPMENT <i>Development</i>		DRILLER <i>Roger Layne</i>	
WELL NUMBER <i>DW-1</i>	TECHNICAL OVERSIGHT <i>Dave Wilson</i>	OVERSIGHT FIRM <i>CDM Federal Programs</i>	
LOCATION <i>M-Area Basin</i>		DATE <i>6/21/92</i>	PAGE <i>1 of 3</i>

START	STOP	DESCRIPTION OF ACTIVITIES; REMARKS
<i>0750</i>		<i>Arrived on site - Weather clear + hot</i>
<i>0815</i>	<i>0830</i>	<i>Health & Safety meeting (roster attached)</i>
		<i>items discussed were:</i>
		<i>① H&S - try not to become lax in safety issues, keep casual observers from drilling area, watch out for trip hazards + hand crunching hazards</i>
		<i>② Schedule - We will trip out of the hole, put a new bit on the BHA and go back in the hole</i>
<i>0912</i>		<i>Preparing to trip out of hole</i>
<i>0940</i>		<i>Trip out of hole began.</i>
<i>0951</i>		<i>Calibrated MNA to 69 ppm with 150 duty tone</i>
<i>0955</i>		<i>MNA reading in pit - 0.4 ppm</i>
<i>1119</i>		<i>above pit - 0.4 ppm</i>
		<i>Trip out of the hole is complete - The hole had been kept full of water and the sediment around the bit is soft and can be removed by hand. The check valve on the water port was sticking out.</i>
<i>1134</i>		<i>There wasn't any material blocking the water port. The drill bit showed excessive wear, at least 1/4" of steel had been worn off in some spots.</i>
<i>1500</i>		<i>Robert Meyers returned with the new drill bit. He left the site to take the new drill bit to get machined.</i>
<i>1509</i>		<i>Dawn Kabach + Ralph Nichols + Brian Rooney were on site, Dawn + Brian left at this time.</i>
<i>1518</i>		<i>The Drill Scout has been recalibrated - Trip is started</i>
<i>1535</i>		<i>Storm clouds are in the area, lightning occurred in the clouds. I told the crew to take a break at 1537 and wait until the storm subsides.</i>

TECHNICAL OVERSIGHT SIGNATURE

David H. Weber

DATE

6/21/92

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992
OSR 50-2 (Rev. 12-80)

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

DAILY ACTIVITIES REPORT

PROJECT <i>Horizontal Well Drilling Technology</i>				DRILLING SUBCONTRACTOR <i>Charles Machine Works / SNL</i>			
DEVELOPMENT <i>DW-1</i>				DRILLER <i>Roger Layne</i>			
WELL NUMBER		TECHNICAL OVERSIGHT		OVERSIGHT FIRM			
<i>DW-1</i>		<i>DAVE Wilson</i>		<i>CDM Federal Program</i>			
LOCATION <i>M-Area Basin</i>				DATE <i>6/21/92</i>		PAGE <i>2 of 3</i>	

START	STOP	DESCRIPTION OF ACTIVITIES; REMARKS					
Time	Joint #	Length	Cum. Length	Time	Joint #	Length	Cum. Length
1530	BHA	5	5	1658	27	5	140
1532	1	5	10	1701	28	5	145
1535	2	5	15	1703	29	5	150
1537	3	5	20	1705	30	5	155
1555	4	5	25	1707	31	5	160
1557	5	5	30	1709	32	5	165
1559	6	5	35	1711	33	5	170
1600	7	5	40	1717	34	5	175
1623	8	5	45	1719	35	5	180
1607	9	5	50	1721	36	5	185
1610	10	5	55	1723	37	5	190
1612	11	5	60	1725	38	5	195
1614	12	5	65	1728	39	5	200
1615	13	5	70	1729	40	5	205
1617	14	5	75	1739	41	5	210
1619	15	5	80	1741	42	5	215
1623	16	5	85	1746	43	5	220
1631	17	5	90	1751	44	5	225
1634	18	5	95	1809	45	5	230
1636	19	5	100	1814	46	5	235
1638	20	5	105	1817	47	5	240
1640	21	5	110	1821	48	5	245
1642	22	5	115	1825	49	5	250
1644	23	5	120	1828	50	5	255
1646	24	5	125	1830	51	5	260
1648	25	5	130	1833	52	5	265
1654	26	5	135	1835	53	5	270

TECHNICAL OVERSIGHT SIGNATURE *David D. Wilson* DATE *6/21/92*

OSR 30-2 (Rev 12-89)

Task Order No. 3

DAILY ACTIVITIES REPORT

[illegible]

TECHNICAL OVERSIGHT SIGNATURE

DATE 6/21/92

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992
OSR 30-2 (Rev 12-89)

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

DAILY ACTIVITIES REPORT

OBJECT <i>Horizontal Well Drilling Technology Development</i>		DRILLING SUBCONTRACTOR <i>Charles Machine Works / SNL</i>	
WELL NUMBER <i>OW-1</i>		DRILLER <i>Roger Wayne</i>	OVERSIGHT FIRM <i>CDM Federal Program</i>
TECHNICAL OVERSIGHT <i>Dave Wilson</i>		DATE <i>6/22/92</i>	PAGE <i>1 OF 2</i>
LOCATION <i>M-Area Basin</i>			

START	STOP	DESCRIPTION OF ACTIVITIES; REMARKS	
0706		Arrived on site - weather partly cloudy, cool, breezy	
0750		Health & Safety meeting (notes attached), items discussed	
		(1) No new H&S concerns. Borehole monitoring with the NMu is still negative.	
		(2) We will finish OW-1 today (borehole drilling).	
Time	Joint #	Length	Cumulative length
0809	60	5'	305
0824	61	5'	310
0835	62	5'	315
0855	63	5'	320
0913	64	5'	325
0923	65	5'	330
0933	66	5'	335
0940	67	5'	340
0947	68	5'	345
0957	69	5'	350
1004	70	5'	355
1012	71	5'	360
1026	72	5'	365
1047	73	5'	370
1127	74	5'	375
1138	75	5'	380
1146	76	5'	385
1157	77	5'	390
1211	78	5'	395
1255	79	5'	400
1304	80	5'	405
1312	81	5'	410

TECHNICAL OVERSIGHT SIGNATURE *Dave Wilson* DATE *6/22/92*

Demonstration of a Utility Industry Horizontal Drilling
 System: Horizontal Well AMH-5 Installation Report
 CDM Federal Programs Corporation
 December 31, 1992
 OSR 30-2 Rev 12-89

Westinghouse Savannah River Company
 Subcontract No. AA46325P
 Task Order No. 3

DAILY ACTIVITIES REPORT

PROJECT <i>Horizontal Well Drilling Technology Development</i>		DRILLING SUBCONTRACTOR <i>Charles Machine Works / SNL</i>	
WELL NUMBER <i>DW-1</i>		DRILLER <i>Roger Lynne</i>	
TECHNICAL OVERSIGHT <i>Dave Wilson</i>		OVERSIGHT FIRM <i>CDM Federal Programs</i>	
LOCATION <i>M. Area Basin</i>		DATE <i>6/22/92</i>	PAGE <i>2 of 2</i>

START	STOP	DESCRIPTION OF ACTIVITIES; REMARKS	
<i>Time</i>	<i>Point #</i>	<i>Length</i>	<i>Cumulative Length</i>
<i>1323</i>	<i>82</i>	<i>5</i>	<i>415</i>
<i>1335</i>	<i>83</i>	<i>5</i>	<i>420 - Water pressure at the bit jet is 450 psi</i>
<i>1345</i>	<i>84</i>	<i>5</i>	<i>425</i>
<i>1358</i>	<i>85</i>	<i>5</i>	<i>430 - Horiz. distance - 424', Elev. 325.6, Vert. depth 30.4</i>
<i>1409</i>	<i>86</i>	<i>5</i>	<i>435</i>
<i>1419</i>	<i>87</i>	<i>5</i>	<i>440</i>
<i>1428</i>	<i>88</i>	<i>5</i>	<i>445</i>
<i>1434</i>	<i>89</i>	<i>5</i>	<i>450</i>
<i>1440</i>	<i>90</i>	<i>5</i>	<i>455</i>
<i>1445</i>	<i>91</i>	<i>5</i>	<i>460</i>
<i>1450</i>	<i>92</i>	<i>5</i>	<i>465</i>
<i>1459</i>	<i>93</i>	<i>5</i>	<i>470</i>
<i>1507</i>	<i>94</i>	<i>5</i>	<i>475</i>
<i>1518</i>	<i>95</i>	<i>5</i>	<i>480</i>
<i>1545</i>	<i>96</i>	<i>5</i>	<i>485</i>
<i>1600</i>		<i>Drilling ^{gms} stopped to reset anchors on rig.</i>	
<i>1623</i>		<i>New anchors will be put on the drill rig in the anchor holes in the center of the rig.</i>	
<i>1641</i>		<i>The crew needs to ^{only} wait until 10/23/92 to get a backhoe to put in the anchors. Work has stopped for the day.</i>	

TECHNICAL OVERSIGHT SIGNATURE *David D. Wink* DATE *6/22/92*

DAILY ACTIVITIES REPORT

PROJECT <i>Horizontal Well Drilling Technology Development</i>		DRILLING SUBCONTRACTOR <i>Charles Machine Works / SNL</i>	
WELL NUMBER <i>DW-1</i>		TECHNICAL OVERSIGHT <i>Dave Wilson</i>	DRILLER <i>Roger Lupton</i>
LOCATION <i>M - Area Basin</i>		OVERSIGHT FIRM <i>CDM Federal Programs</i>	
		DATE <i>6/22/92</i>	PAGE <i>1</i>

START	STOP	DESCRIPTION OF ACTIVITIES; REMARKS
0720		Arrived on site. The drill team was waiting for a backhoe to assist them in anchoring the drill rig to the earth. To this time the drill team has used about 1500 gal of water.
1022		The backhoe arrived on site.
1138		The anchors were placed in the ground.
1146		One drill rod was drilled in to test anchors.
1152 - 1218		Lunch break
1218		Crew determines that the drill rig needs to have additional push resistance - they wanted to use the backhoe as an added or shape additional weight.
1320		
1357		Crew waited for backhoe operator.
1427		Drilling resumed.
1600		The drill bit exited the ground approximately 27 ft. to the west of the target.
1645		A ^{27 ft} deep pit was dug at the exit hole to facilitate the installation of the well materials. The pit was filled with water; the purpose of the water was to help lubricate the hole.
1750		60 Feet of PVC casing was placed in the borehole.
2035		160 Feet (total) of PVC casing was placed in the borehole.
2050		The teflon screen was not strong enough to be pushed into the borehole. The screen must be reinforced at the threads to be able to install it in the well.
2115		The drill crew has decided to quit for the night and solve the teflon screen problem tomorrow.
2130		Left site.

TECHNICAL OVERSIGHT SIGNATURE

Dave Wilson

DATE

6/22/92

DAILY ACTIVITIES REPORT

PROJECT <i>Horizontal Well Drilling Technology</i>		DRILLING SUBCONTRACTOR <i>Charles Machine Works / SNL</i>	
DEVELOPMENT <i>Development</i>		DRILLER <i>Roger Lyons</i>	
WELL NUMBER <i>DW-1</i>	TECHNICAL OVERSIGHT <i>Dave Wilson</i>	OVERSIGHT FIRM <i>CDM Federal Programs</i>	
LOCATION <i>McAuley Basin</i>		DATE <i>6/24/92</i>	PAGE <i>1</i>

START	STOP	DESCRIPTION OF ACTIVITIES; REMARKS
1140		Arrived on site - Drilling crew had not yet solved teflon screen problem
1300		SR5 personnel D. Kubach & R. Nichols began looking into purchasing alternative well materials to substitute for the teflon screen. The drill team has investigated different methods of bending the teflon joints together. One method - heating - welding has proven not feasible. The manufacturer of the screen has been ^{and will} be of help to the drill team.
1400		I have recommended that the tests be performed on the teflon screen before it is used in the borehole/well completion. I pointed out that the teflon could break while in the hole even though it looked fine at the surface. I also recommended that if the well is completed today that HDPE screen should be used.
1408		I left the site to run around. At the time that I left no drilling or well activities were expected.
1620		I Arrived back on site. During my absence SR5 personnel decided to proceed with installation of the teflon screen. About 32' of teflon ^{and HDPE} screen was put into the hole before a part of the casing or screen was broken off in the hole.
~1500	1527	The drill team attempted to push the well materials out of the hole with the drill rig while pulling on the cable attached to the swab. The cable was being pulled with a truck wrench at the back hole. The cable eventually broke and no well materials were recovered.
1740		Left the site

TECHNICAL OVERSIGHT SIGNATURE *Dave Wilson* DATE *6/24/92*

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

DAILY ACTIVITIES REPORT

SUBJECT Horizontal Well Drilling Technology Development		DRILLING SUBCONTRACTOR Charles Machani Works/SRL DRILLER Rose Luyne	
WELL NUMBER DW-1		TECHNICAL OVERSIGHT Dave Wilton	
LOCATION M-Aren Basin		OVERSIGHT FIRM CDR Federal Programs DATE 6/25/92	
		PAGE 1	

START	STOP	DESCRIPTION OF ACTIVITIES; REMARKS
0710		Arrived on site.
0720	953	Drill team tripped drill stem and at the hole. The swab and pulling Tool were recovered. No metal items were left in the hole.
1113	1815	The drill team drilled through the borehole and exited the hole at the same location as before. None of the previously installed well material were recovered. At point during the drilling it appeared as though the drill may have been drilling through a mass of hardened up well material. Starting at 495 feet (borehole distance) From entry the rotational pressure reached 5000 Ft-lbs consistently. This is in a spot which we would expect to find distorted well materials. At 1717 I notified SRL personnel that the backhoe used to anchor the drill rig was leaking Hydraulic Fluid. We put down a layer of compound and a plastic sheet to prevent contamination of the soil.
1830		Work ceased. Left site.

TECHNICAL OVERSIGHT SIGNATURE

DATE _____

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992
OSR 30-2 (Rev 12-88)

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

DAILY ACTIVITIES REPORT

PROJECT <i>Horizontal Well Drilling Technology Development</i>		DRILLING SUBCONTRACTOR <i>Charles Machine Works/SNL</i>	
WELL NUMBER <i>WH 1</i>		DRILLER <i>Roger Layne</i>	
TECHNICAL OVERSIGHT <i>Dave Wilson</i>		OVERSIGHT FIRM <i>CDM/FPC</i>	
LOCATION <i>M AREA BASIN</i>		DATE <i>6/26/92</i>	PAGE <i>1 of 2</i>

START	STOP	DESCRIPTION OF ACTIVITIES; REMARKS			
0710		Arrived on site.			
0830	0857	Drill team ^{on site} assembled well material. The plan was to pull 180' of 4" casing and then pull 3" screen and casing behind it. Bob Meyers assembled the 4"-3" reducing joint.			
0900	1220	Drill team assembled 4" pvc and attached it to the borehole swab & swivel.			
1225		The pull back began.			
Time	Joint #	Material	Length	Diameter	
1230	1	PVC	10	4"	- The first PVC joint was bolted
1240	2	PVC	20	4"	to the swiveled swab. After that,
1300	3	PVC	30	4"	the PVC joints were glued at
1303	4	PVC	40	4"	the threads as they were
1307	5	PVC	50	4"	screwed together. Before the
1310	6	PVC	60	4"	glue was applied a primer was
1319	7	PVC	70	4"	put on the primer the plastic.
1323	8	PVC	80	4"	They began by putting 5 joints
1330	9	PVC	90	4"	together at one time, but at
1333	10	PVC	100	4"	1318 the decided that it took
1344	11	PVC	110	4"	too long and put only 2 joints
1346	12	PVC	120	4"	together at a time.
1354	13	PVC	130	4"	
1357	14	PVC	140	4"	
1403	15	PVC	150	4"	
1406	16	PVC	160	4"	
1408	17	PVC	170	4"	
1412	18	PVC	180 (8'4")	4"	
1414	19	PVC	190 (8'9")	3"	

TECHNICAL OVERSIGHT SIGNATURE *Dave Wilson* DATE *6/26/92*

December 31, 1992
OSR 30-2 (Rev. 12-90)

Task Order No. 3

DAILY ACTIVITIES REPORT

[illegible]

TECHNICAL OVERSIGHT SIGNATURE

DATE 6/26/92

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992
OSR 30-2 (Rev 12-89)

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

DAILY ACTIVITIES REPORT

PROJECT <i>Horizontal Well Drilling Technology Development</i>		DRILLING SUBCONTRACTOR <i>Chandler Machine Works / SNC</i>	
WELL NUMBER <i>OW-1 - TNX-E1</i>		DRILLER <i>Roger Layne</i>	
TECHNICAL OVERSIGHT <i>Dave Wilson</i>		OVERSIGHT FIRM <i>CDM Federal Programs</i>	
LOCATION <i>M-Area Basin - TNX area</i>		DATE <i>6/27/92</i>	PAGE <i>1 of 1</i>
START	STOP	DESCRIPTION OF ACTIVITIES; REMARKS	
<i>0735</i>		<i>- Arrived at M-Area Basin site.</i>	
<i>0740</i>	<i>0820</i>	<i>Obtained 1" PVC pipe to use to push down entry exit hole to determine length of pipe.</i>	
<i>0850</i>		<i>We pushed 134' of PVC down the hole and didn't meet any obstruction.</i>	
<i>0912</i>		<i>We pulled 10' of PVC (1 joint) out of the entry hole. Therefore it was judged that the well string broke at the first PVC-PVC joint and that there is 250' of well material in the hole at the exit hole.</i>	
<i>1000</i>	<i>1019</i>	<i>Traveled to TNX site.</i>	
<i>1057</i>		<i>began assembling the drill rig</i>	
<i>1240</i>		<i>ready to begin drilling</i>	
<i>1255</i>		<i>began drilling</i>	
<i>1411</i>		<i>Drilling is very difficult, it takes about 30 min per 10' joint</i>	
<i>1503</i>		<i>After drilling in the 6th joint (10 ft.) The drill team determined that the sediment in the hole falling back behind the drill bit and they are afraid of losing the drill string in the hole and are pulling out.</i>	
<i>1520</i>	<i>1604</i>	<i>Attempted to sample the formation but the sampler broke.</i>	
<i>1616</i>		<i>Decided to ask the state if we can drill with mud. we had to wait until Monday for answer.</i>	
<i>1645</i>		<i>Work ceased - left site</i>	

TECHNICAL OVERSIGHT SIGNATURE

Dave Wilson

DATE

6/27/92

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992
OSR 30-2 (Rev 12-90)

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

DAILY ACTIVITIES REPORT

PROJECT Horizontal Drilling Technology Development		DRILLING SUBCONTRACTOR Charles Machine Works	
WELL NUMBER DW-1		DRILLER Roger Layne	
TECHNICAL OVERSIGHT Dave Wilson		OVERSIGHT FIRM CDM Federal Programs	
LOCATION M-Area Basin		DATE 9/20/92	PAGE 1 of 1

START	STOP	DESCRIPTION OF ACTIVITIES; REMARKS
0730		Arrived on site. The drill crew consisting of SNL & CMW personnel (see attached site log) were on site and almost ready to drill. A pit 16' x 16' x 5' deep has been dug & the drill rig has been placed in it.
0950		The crew has calibrated the Drill Scout steering tool, propped up the drilling water system & hydraulic system. We held a Health & Safety meeting and also discussed organizational structure. Items discussed were: 1) Technical Representatives from each organization will make decisions. The representatives were SNL - Dave Wilson SNL - Bob Wimple CMW - Roger Layne 2) H&S issues regarding the pit on above
0950		Drilling began from the pit.
1238		The crew has decided that the drill has entered the first borehole.
1248		I contacted Owen Kuback and informed her the crew thinks that we are in the old hole and would like to try and complete the project in the old hole. Owen agreed to the change in plans.
1535		The crew remained in the old hole. Drilling resistance was met at point #51 or 285 feet down hole. This coincide with the location of the PVC pipe from the previous attempted completion.
1704		Continued drilling until point #75 (283'30") stopped work for the day. Left the site.

TECHNICAL OVERSIGHT SIGNATURE

Dave D. Wink

DATE

9/22/92

Demonstration of a Utility Industry Horizontal Drilling
 System: Horizontal Well AMH-5 Installation Report
 CDM Federal Programs Corporation
 December 31, 1992
 OSR 30-3 (Rev 12-89)

Westinghouse Savannah River Company
 Subcontract No. AA46325P
 Task Order No. 3

DAILY ACTIVITIES REPORT

PROJECT <i>Horizontal Drilling Technology Development</i>		DRILLING SUBCONTRACTOR <i>Charles Machine Works</i>	
WELL NUMBER <i>DW-1</i>		DRILLER <i>Roger Luyar</i>	
TECHNICAL OVERSIGHT <i>Dave Wilson</i>		OVERSIGHT FIRM <i>CDM Federal Programs</i>	
LOCATION <i>M-Area Basin</i>		DATE <i>9/23/92</i>	PAGE <i>1 of 2</i>

START	STOP	DESCRIPTION OF ACTIVITIES; REMARKS
0653		Arrived on site
0724		Crew arrived on site at 0711 started drilling at 0723. The crew is running water down the hole to "slide it by" to ease drilling pressures.
0830		SNL crew is preparing the exit hole site for the pipe pull back.
0856		Drilling stopped until we could get the electricity turned-off in the line that runs near the exit hole. The ^{day} Elec. power turned off - drilling continues.
0911		
0930		The backhoe dug up the concrete plug at the exit site.
0942		Joint # 106 (500') not refined. We went to shorter drill bit.
		Push pressure at 1800 lbs in low gear (~ 8000 lbs).
1001		The drilling tool exited the ground.
1045		Meeting with Tim Jurasek, B. Meyer, and Dave Wilson. We decided on the following well string configuration:
		4 - solid casing
		10 - slotted casing
		5 - solid casing
1143		Pipe pull back began
1243		Drill crew a heavy trouble with rod break-off unit. NNN readings:
		Back from - 2 ppm
		In drilling pit - 2 ppm
		At back hole - 3 ppm
1248		Pull back continued
1315		Met resistance at same point as when they pushed, using ~ 3000 lb pulling pressure in low gear
1420		We have decided to stop stop work for the day. For

TECHNICAL OVERSIGHT SIGNATURE

David H. Wilson

DATE

9/23/92

OSR 30-2 (Rev 12-89)

Task Order No. 3

DAILY ACTIVITIES REPORT

[illegible]

TECHNICAL OVERSIGHT SIGNATURE

DATE _____

OSR 30-2 (Rev 12-89)

Task Order No. 3

DAILY ACTIVITIES REPORT

PROJECT		DRILLING SUBCONTRACTOR	
Horizontal Well Technology Development		Charles Machine Works	
WELL NUMBER		DRILLER	
DW-1		Roger Layne	
TECHNICAL OVERSIGHT		OVERSIGHT FIRM	
Dave Wilson		CDM Federal Programs	
LOCATION		DATE	PAGE
M-Area Burn		9/24/92	1
START	STOP	DESCRIPTION OF ACTIVITIES; REMARKS	
0726		Crew arrived on site - it looks as though it has been raining all night, the pit is beginning to deteriorate.	
0745		The casing is being pulled back with a pull pressure between 2000-3000 lbs. (60000-140000 lbs).	
0805		Pull pressure is down below 2000 lbs at rod 79 (395' downhole).	
1005		pull pressure below 1000 lbs at ~ 150' downhole.	
1056		The pulling tool is out off the hole.	
1140		The pulling tool is off and the casing is sticking out of the entrance hole.	
1345		The NW corner of the pit has fallen in.	
1405		The crew has pushed up the equipment and left the site. A crane will come tomorrow to pull the rig out of the pit.	

TECHNICAL OVERSIGHT SIGNATURE

DATE _____

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

THIS PAGE INTENTIONALLY LEFT BLANK

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

Appendix D

M-Area Horizontal Drilling Photographs

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

THIS PAGE INTENTIONALLY LEFT BLANK

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

Figure D-1. X-810 Drilling Rig Held in Place by a Wheeled Backhoe

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

THIS PAGE INTENTIONALLY LEFT BLANK

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

View of X-810 drilling rig with M-Area Basin in the background.

Figure D-2. X-810 Drilling Rig

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

THIS PAGE INTENTIONALLY LEFT BLANK

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

Figure D-3. Surface Launch of Borehole

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

THIS PAGE INTENTIONALLY LEFT BLANK

Note rod wiper on drill rod used to remove drilling spoils during pull-back of the drill stem.

Figure D-4. Surface Launch of Borehole

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

THIS PAGE INTENTIONALLY LEFT BLANK

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

Note the water jet spray.

Figure D-5. Drilling Tool Exiting Ground Surface

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

THIS PAGE INTENTIONALLY LEFT BLANK

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

Note the target stake (with red flag) in the background.

Figure D-6. Down-Hole Assembly Exiting Ground Surface

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

THIS PAGE INTENTIONALLY LEFT BLANK

Note water hose for filling exit pit with water.

**Figure D-7. Exit Pit with Down-Hole Assembly Exiting Ground Surface
During Second Completion Attempt**

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

THIS PAGE INTENTIONALLY LEFT BLANK

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

Figure D-8. Cable Tension Device Used During First and Second Completion Attempts

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

THIS PAGE INTENTIONALLY LEFT BLANK

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

Figure D-9. Drilling Rig Set Up for Pit-Launched Third Completion Attempt

**Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992**

**Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3**

THIS PAGE INTENTIONALLY LEFT BLANK

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

Figure D-10. Side View of Drilling Pit

**Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992**

**Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3**

THIS PAGE INTENTIONALLY LEFT BLANK

Driller's console shown at bottom right.

**Figure D-11. Down-Hole View of Pit-Launch Drilling During
Third Completion Attempt**

**Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992**

**Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3**

THIS PAGE INTENTIONALLY LEFT BLANK

Note the sensor wire being threaded through the drill stem.

**Figure D-12. Crew Adding Drill Stem while Drilling During
Third Completion Attempt**

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

THIS PAGE INTENTIONALLY LEFT BLANK

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

Figure D-13. Oblique View of Drilling Pit

**Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992**

**Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3**

THIS PAGE INTENTIONALLY LEFT BLANK

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

**Figure D-14. Down-Hole Assembly Exiting Ground Surface During
Third Completion Attempt**

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

THIS PAGE INTENTIONALLY LEFT BLANK

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

Figure D-15. Steel Collar Used to Attach Fiberglass Well Materials to Pulling Device During Third Completion Attempt

**Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992**

**Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3**

THIS PAGE INTENTIONALLY LEFT BLANK

Note that the steel cable threaded through the casing was inserted to provide a means of pulling items through the well.

**Figure D-16. Steel Collar Being Connected to Fiberglass Well Materials
During Third Completion Attempt**

**Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992**

**Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3**

THIS PAGE INTENTIONALLY LEFT BLANK

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

**Figure D-17. Steel Collar Attached to Pulling Device Used During
Third Completion Attempt**

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

THIS PAGE INTENTIONALLY LEFT BLANK

This location does not weaken the pin joint.

Figure D-18. O-Ring at Open End of Fiberglass Pipe

**Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992**

**Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3**

THIS PAGE INTENTIONALLY LEFT BLANK

**Figure D-19. Fiberglass Casing Being Pulled into Borehole During
Third Completion Attempt**

**Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992**

**Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3**

THIS PAGE INTENTIONALLY LEFT BLANK

**Figure D-20. Fiberglass Casing Extending Out of Exit Hole After Successful
Third Well Completion Attempt**

Demonstration of a Utility Industry Horizontal Drilling
System: Horizontal Well AMH-5 Installation Report
CDM Federal Programs Corporation
December 31, 1992

Westinghouse Savannah River Company
Subcontract No. AA46325P
Task Order No. 3

THIS PAGE INTENTIONALLY LEFT BLANK

**DATE
FILMED**

8/12/93

END