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5090.3a

DEPARTMENT OF THE NAVY
CRANE DIVISION
NAVAL SURFACE WARFARE CENTER
300 HIGHWAY 361
CRANE INDIANA 47522-5001

IN REPLY REFER TO:
5090/S4.7.1
Ser RP3/5159

9 MAY 2005

U.S. Environmental Protection Agency, Region V
Waste, Pesticides, & Toxics Division
Waste Management Branch
Corrective Action Section
77 West Jackson Blvd.
Chicago, IL 60604

Dear Mr. Ramanauskas:

Crane Division, Naval Surface Warfare Center submits the Draft Addendum No. 3 to the Quality Assurance Project Plan (QAPP) for Solid Waste Management Units (SWMUs) 12, 13, 16, and 19 (Mine Fill A, Mine Fill B, B146 Incinerator, and the Pyrotechnic Test Areas, respectively). The purpose of the QAPP Addendum #3 is to set forth the long-term monitoring proposal for SWMU 12. One copy of the QAPP Addendum is found as enclosure (1). The permit required Certification Statement is provided as enclosure (2).

If you require any further information, my point of contact is Mr. Thomas J. Brent, Code RP3-TB, at 812-854-6160, email thomas.brent@navy.mil.

Sincerely,

Christine D. Freeman
for JAMES M. HUNSICKER
Manager, Environmental Protection
By direction of the Commanding Officer

Enclosures: 1. QAPP Addendum No. 3 for SWMUs 12, 13, 16, & 19
2. Certification Statement

Copy to:
ADMINISTRATIVE RECORD
SOUTHNAVFACENGCOM (Code ES31) (w/o encl)
IDEM (Doug Griffin)
TTNUS (Ralph Basinski) (w/o encl)

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Christine D. Freeman

SIGNATURE

for

Manager, Environmental Protection — 9 MAY 2005

TITLE — DATE

Quality Assurance Project Plan Addendum No. 3

for

Mine Fill A (SWMU 12) Mine Fill B (SWMU 13) Cast High Explosives Fill/ B146 Incinerator (SWMU 16) and Pyrotechnic Test Area (SWMU 19)

RCRA Facility Investigation

Naval Surface Warfare Center Crane

Crane, Indiana

NAVFAC
Naval Facilities Engineering Command

Southern Division
Naval Facilities Engineering Command

Contract Number N62467-94-D-0888

Contract Task Order 0357

May 2005

Revison 0
May 2005

QUALITY ASSURANCE PROJECT PLAN
ADDENDUM NO. 3
FOR
MINE FILL A (SWMU 12), MINE FILL B (SWMU 13), CAST HIGH EXPLOSIVES FILL/B146 INCINERATOR (SWMU 16) AND PYROTECHNIC TEST AREA (SWMU 19)

RCRA FACILITY INVESTIGATION

NAVAL SURFACE WARFARE CENTER, CRANE
CRANE, INDIANA

COMPREHENSIVE LONG-TERM ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT

Submitted to:
Southern Division
Naval Facilities Engineering Command
2155 Eagle Drive
North Charleston, South Carolina 29406

Submitted by:
Tetra Tech NUS, Inc.
661 Andersen Drive
Foster Plaza 7
Pittsburgh, Pennsylvania 15220

CONTRACT NUMBER N62467-94-D-0888
CONTRACT TASK ORDER 0357

MAY 2005

RALPH R. BASINSKI, QEP
TASK ORDER MANAGER
TETRA TECH NUS, INC.

DEBRA M. HUMBERT
PROGRAM MANAGER
TETRA TECH NUS, INC.

PAUL V. FRANK
QUALITY ASSURANCE MANAGER
TETRA TECH NUS, INC.

ALLEN DEBUS
QUALITY ASSURANCE COORDINATOR
U.S. EPA REGION 5

PETER RAMANAUSKAS
PERMITTING PROJECT MANAGER
U.S. EPA REGION 5

TOM BRENT
SITE MANAGER
NSWC CRANE

KATHY KREPPS
LABORATORY DIRECTOR
LAUCKS TESTING LABORATORIES, INC.

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LIST OF ACRONYMS

(°F)	Fahrenheit
FOL	Field Operations Leader
gpm	gallons per minute
HASP	Health and Safety Plan
MFA	Mine Fill A
Mgd	Glen Dean Limestone of Mississippian age
NSWC	Naval Surface Warfare Center
NOAA	National Oceanic and Atmospheric Administration
NEESA	Naval Energy and Environmental Support Activity
Plz	Lower Pennsylvanian water-bearing zone
Pmz	Middle Pennsylvanian water-bearing zone
Puz	Upper Pennsylvanian water-bearing zone
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
RDX	Hexahydro-1,3,5-trinitro-1,3,5-triazine
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
SSO	Site Safety Officer
SWMU	Solid Waste Management Unit
SOPs	standard operating procedures
TtNUS	Tetra Tech NUS, Inc.
TOM	Task Order Manager
U.S. EPA	United States Environmental Protection Agency

1.0 INTRODUCTION

The purpose of this report is to define the long-term monitoring program (Rounds 3 through 9) to be conducted at the Naval Surface Warfare Center (NSWC) Crane Solid Waste Management Unit (SWMU) 12 – Mine Fill A (MFA).

NSWC Crane prepared a Quality Assurance Project Plan (QAPP) [Tetra Tech NUS, Inc. (TtNUS), 2003a] for a Phase III Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) at SWMUs 12, 13, 16, and 19. Upon approval of this QAPP by the United States Environmental Protection Agency (U.S. EPA) Region 5, Round 1 field investigations were conducted for SWMUs 13 and 16.

SWMUs 12 and 13 both had similar contamination patterns for explosives in soil. The ground water data collected at SWMU 13 indicated a relationship between historical explosives contamination in soil and ground water explosives contamination. A review of these data shows that modifications were necessary to the monitoring well network at SWMU 12 to more completely delineate anticipated explosives contamination in ground water during the initial round of ground water monitoring well installation and sampling.

NSWC Crane therefore prepared a QAPP Addendum No. 1 (TtNUS, 2003b) which was approved by U.S. EPA Region 5 in October 2003. This QAPP addendum described the modified Round 1 field program for SWMU 12. However, no investigation was conducted at SWMU 12 at that time.

Round 1 field activities at SWMU 12 were conducted from August through November, 2004. After Round 1 activities were completed at SWMU 12, the results were used to develop the Round 2 field program. This program was described in a letter to US EPA Region 5, dated January 20, 2005. This submittal addressed the US EPA comments obtained in a conference call on January 12, 2005. Round 2 activities were then conducted in February and March, 2005. All work performed was conducted in accordance with the procedures and methodologies described in the US EPA approved QAPP Addendum No. 2 (TtNUS, 2004) as well as the subsequent letter of January 20, 2005.

Figures 1-1 and 1-2 present validated data for Round 1(typed) and unvalidated data for Round 2 (hand written) for explosives (RDX) in groundwater and surface water, respectively, at SWMU 12.

Explosives contamination was the basis for the selection of monitoring wells and surface water locations for the long-term monitoring program at SWMU 12 which is further discussed in Section 3.0.

2.0 PHYSICAL CHARACTERISTICS OF THE STUDY AREA

2.1 PHYSIOGRAPHY AND TOPOGRAPHY

MFA is located on top of a ridge that was flattened to some extent in the 1940s in preparation for site development (roads, rail lines, buildings, parking lots). The areas that lie between roads and buildings are mostly grass covered. The active operations of MFA lie within a trapezoidal area that is elongated in a northwest-southeast direction. A primary road (Highway 45) and the main rail line run along the northwest side of MFA. Rail spurs and paved roads also run along the length of MFA on the northeast and southwest sides. The main loading activities took place in buildings 0151 through 0154 and 0157 through 0159.

MFA is surrounded by a chain-link fence and a perimeter road. The land surface drops in elevation rather abruptly on the northeast and southwest sides of MFA, and decreases gradually south of MFA. Slopes on the northeast and southwest sides of MFA (outside of the fenced area) range from about 15 to 20 percent. Slopes south of MFA are more gradual (about 6 to 12 percent).

A large unnamed tributary of Turkey Creek (east tributary) flows north to south, about 1000 to 1500 feet east of the MFA fenceline. Another smaller, unnamed tributary (west tributary) lies 200 to 800 feet west of MFA, and it too flows southward into Turkey Creek. Turkey Creek is one of the main creeks within NSWC Crane and it drains a large central section of the facility. The main stem of Turkey Creek lies approximately 3,600 feet south-southeast of MFA (Figure 2-3). The land is heavily forested between MFA and the unnamed tributaries and Turkey Creek.

Elevations throughout the MFA ridgetop range from about 720 to 750 feet amsl. The maximum elevations at MFA (745-750 feet amsl) generally occur near the buildings along the northeast side of MFA (e.g., 3110, 2512, and 0152). Most of the land surface of MFA slopes gently to the southwest. The elevations along the small unnamed tributary (west tributary) range from 700 feet amsl up near the top of the ridge down to about 615 feet amsl where it enters Turkey Creek (Figure 2-3), a drop of 185 feet in elevation. The larger, eastern tributary is more deeply incised into the ridge and drops in elevation from about 600 feet amsl at 12SW/SD13 down to approximately 520 feet amsl where the tributary enters Turkey Creek. The total topographic relief around MFA is about 240 feet.

2.2 METEOROLOGY

NSWC Crane is located in a warm, temperate climatic zone. In general, the summers are warm and humid, and winters are mild with occasional short cold periods. The temperature ranges from an average maximum July temperature of 89 degrees Fahrenheit (°F) to an average minimum January temperature of 26°F. Precipitation is fairly evenly distributed throughout the calendar year; the maximum precipitation occurs during the spring and early summer. The average annual precipitation at the facility is 44 inches and consists of 42 inches of rain and 15 inches of snow. The average humidity ranges from 40 to 90 percent in summer and 60 to 90 percent in winter. Long-term climatological records for the area indicate that the monthly prevailing wind direction is from the southwest from April through December and from the northwest during January through March [National Oceanic and Atmospheric Administration (NOAA), 1988]. The annual prevailing wind direction for the region is from the southwest, and the annual average wind speed for the area is about 9.6 miles per hour. Figure 2-1 is a wind rose summarizing the mean wind direction and wind speed distribution at the Indianapolis International Airport over a 5-year period (1985 to 1989).

2.3 SURFACE WATER HYDROLOGY

The topography at MFA consists of a ridge that lies on the east side of Highway 45 and runs in a northeast-southwest orientation. The slopes across MFA ridgetop are very gradual. The crest of the ridge runs through Buildings 0151, 0155, and 0160, approximately, which is more on the northeast side of the ridge. Hence, most of the surface runoff from SWMU 12 drains south and southeast. Surface drainage at MFA is routed away from buildings and roads via storm sewers, culverts, and ditches located throughout the relatively flat portion of the ridgetop. The ditches and storm sewers lead to larger drainageways and gullies that flow down both sides of the ridge in northeast and southwest directions. The sides of the ridge consist of steeper slopes that lead down to the adjacent stream valleys.

Drainage from the northwestern side of the ridge crest flows to the northwest, down the side of the ridge, and into the unnamed tributary of Turkey Creek. Drainage ditches and gullies on the far northeast side of MFA (e.g., sampling locations 12SW/SD28, 12SW/SD30, 12SW/SD12, 12SW/SD31, 12SW/SD32 and 12SW/SD14, see Figure 2-3) flow eastward and coalesce prior to reaching 12SW/SD13. The gully then proceeds southeast down the hillside where it joins the primary tributary stream near sampling point 12SW/SD16. Three other gullies drain the east side of MFA (sampling points 12SW/SD15, 12SW/SD18, and 12SW/SD20, Figure 2-3). Staff gauges 12SG02, 12SG03, and 12SG04, respectively, were also installed at these locations to measure flow rates more accurately. These gullies drain eastward down

the hillside where they were sampled again at stations 12SW/SD17, 12SW/SD18, and 12SW/SD20, respectively, just prior to entering the main tributary creek.

The western side of MFA drains to the west and southward via four primary gullies. The northernmost gully is sampled at stations 12SW/SD29, 12SW/SD01, and 12SW/SD04 (Figure 2-3). Moving southward, the next gully is sampled at stations 12SW/SD02 and 12 SW/SD05. The third main gully on the west side has been sampled at 12SW/SD06. The fourth major gully has been sampled at 12SW/SD03. Staff gauges 12SG07, 12SG06, and 12SG05 were installed on the first, second, and fourth gully where they flow under the SWMU 12 perimeter road in order to better estimate the flow rates of surface water leaving the SWMU during storm events. These gullies all empty into the unnamed western tributary creek, which has been sampled from north to south at stations 12SW/SD07, 12SW/SD09, 12SW/SD10, and 12SW/SD11. A staff gauge (12SG12) was also collocated with sampling station 12SW/SD10 in order to better estimate flow rates at specific points in time.

Two rounds of surface water sampling and flow measurements were conducted during the RFI. Based on visual observations and measurements, estimates of surface water flow were made at each surface water sampling station and at each staff gauge on one or more occasions during the two rounds (Table 2-1). Even during the fall and winter months (e.g., period during Rounds 1 and 2 sampling) when surface flow should be more likely, there was very little or no surface flow at many of the sampling stations or staff gauges in the gullies up near the ridgetop (e.g., 12SW/SD01, 12SW/SD03, 12SW/SD04, 12SW/SD06, 12SW/SD14, 12SW/SD18-22, 12SW/SD28-36, and 12SG01-12SG05). It is likely that the gullies and the upper reaches of the unnamed tributary creeks are not flowing much of the year, especially in summer and fall months.

During Round 1 (October-December 2004), the flow rates measured near the mouth of the eastern tributary (stations 12SG09 and 12SW/SD24) were about 250 to 300 gallons per minute (gpm) and were about 75 to 150 gpm near the mouth of the western unnamed tributary (stations 12SG12 and 12SW/SD10, Table 2-1). During Round 2 (March 2005), the flow rates in these two tributaries of Turkey Creek were in the range of 200 to 300 gpm. These are relatively low flow rates compared to the 4,000 to 9,000 gpm that was estimated to be flowing in Turkey Creek at the time. Turkey Creek is probably flowing through a large proportion of the year where it receives drainage from SWMU 12.

2.4 GEOLOGY

Bedrock underlying NSWC Crane consists of sedimentary rocks from the Lower Pennsylvanian-age Mansfield Formation of the Raccoon Creek Group and the underlying Upper Mississippian-age

Stephensport and West Baden Groups (Figure 2-2). The Pennsylvanian-age sandstones, siltstone, shales, coal beds, and thin limestone units of the Mansfield Formation can reach thicknesses of 250 to 300 feet at NSWC Crane in the central and western portions of the facility. Because the pre-Pennsylvanian bedrock is dipping to the west-southwest toward the center of the Illinois structural basin, the Mississippian-age rocks are closer to the surface and crop out along the stream valleys and lower slopes on the eastern side of NSWC Crane (Figure 2-3). On the eastern side of NSWC Crane (e.g., near the Dye Burial Ground, Ammunition Burning Ground, and Rockeye), Pennsylvanian bedrock is confined to the uppermost portions of hills and ridges. At SWMU 9 (Pest Control Area), which lies about 1,000 feet west of the northern end of SWMU 12, the USACE drilled a well (09C01) through the top of the ridge to a total depth of 150 feet. This well penetrated 13 feet of overburden soil and 132.5 feet of Pennsylvanian (Mansfield) shales, sandstones, siltstone, and coal seams. It also encountered 5.5 feet of Mississippian limestone at the bottom of the boring which the USACE and Indiana Geological Survey identified as the Glen Dean Limestone (Barnhill and Hansley,1993). The elevation of the Pennsylvanian-Mississippian unconformity at this location (SWMU 9) is approximately 575 feet amsl. Five monitoring wells were installed at Dump Site A (SWMU 25) in 1981 (Figure 2-4). Four of these wells (WES-7-2-81 through WES-7-5-81) are screened in sandstone, shale, and limestone which appear to be right at the Pennsylvanian-Mississippian unconformity. Based on the limestone present in WES-7-3-81, the elevation of the unconformity at this location is estimated to at 592 feet amsl. At SWMU 12, Mississippian limestone (presumably Glen Dean Formation) was encountered in monitoring wells 12MWT41, 12MWT44, and 12MWT49 at elevations of 595.10, 590.81, and 607.96 feet amsl, respectively. These elevations show that the Pennsylvanian-Mississippian unconformity is dipping in general from east (12MWT49, 607.96 feet amsl) to the west (09C01, 575 feet amsl), which is consistent with the mapping performed by Barnhill (1993) and Kvale and Barnhill (1994) that shows the paleoerosion surface dipping to the west in Section 23 (R4W, T5N).

SWMU 9 lies on the eastern side of a pre-Pennsylvanian valley that trends north-south (Kvale and Barnhill, 1994). The Pennsylvanian Mansfield Formation subsequently filled in the paleo-valley, meaning that the Pennsylvanian-age rocks thicken to the west toward the centerline of the paleo-valley. Using a basal elevation of about 600 feet amsl, the Pennsylvanian rock at SWMU 12 is up to 140 feet thick.

Below the Pennsylvanian rocks lie Mississippian-age limestone and sandstone formations of the Stephensport Group, including the Glen Dean, Golconda, and Beech Creek Limestones, the Big Clifty Sandstone, and the Hardinsburg Formation (siltstone and shale) (Figure 2-2). Only the uppermost Glen Dean Limestone has been penetrated by drilling at SWMUs 9 and 12. Altogether, there is vertically about 60 to 70 feet of Mississippian rocks from the unconformity down to creek level on the eastern side of SWMU 12. According to geologic mapping performed throughout NSWC Crane (see Figure 2-3), the Big

Clifty Formation (sandstone member) is the uppermost bedrock in the bottom of the tributary valley on the eastern side of SWMU 12. The upper surface of the Beech Creek Limestone should therefore lie a short distance below the creek level.

During the RFI of SWMU 12, a total of 51 monitoring wells were installed. The date of installation, the total depth, the ground surface elevation, the screen elevations, and other physical characteristics of each of the 51 monitoring wells are listed in Table 2-2. The boring logs and well construction logs for these wells are included in Appendix B. The locations of the 51 monitoring wells are shown on Figure 2-2. Figure 2-4 illustrates the locations of four hydrogeological cross sections that have been prepared, including select borings, through SWMU 12. Figures 2-5, 2-6, 2-7, and 2-8 show hydrogeologic cross sections A-A', B-B', C-C', and D-D', respectively.

The ridgetop containing SWMU 12 is blanketed with residual soils and reworked soils that range from 2.5 to 14.5 feet thick. The bulk of the ridge is composed of Pennsylvanian bedrock, which consists of discontinuous layers of siltstones, sandstones, shales, and coal seams up to 140 feet thick near the center of the ridge. These rock units extend from the ridgetop down to about 590 to 600 feet amsl (see Figures 2-5 through 2-8). The approximate location of the Pennsylvanian-Mississippian unconformity is shown on each cross section.

The SWMU 12 ridge is capped by silty sandstone and sandstone (Figures 2-5 through 2-8). The upper half of this sandstone unit is weathered, oxidized (brown to tan in color), and generally soft. The lower half is gray (less weathered) and medium hard. The basal elevation of the sandstone cap generally runs from about 700 to 710 feet amsl; however, in places the base of the sandstone runs a little deeper (e.g., 688 feet amsl in 12MWT42, see Figure 2-5). Altogether, this uppermost sandstone is about 20 to 40 feet thick. Groundwater was consistently encountered in the ridge-capping sandstone unit. Since it is the shallowest water-bearing geologic unit and is present everywhere under SWMU 12, groundwater contamination if present should be encountered most frequently in this unit. As a result, the majority of monitoring wells were installed in the upper sandstone. This unit is referred to as the Upper Pennsylvanian water-bearing zone (Puz) in Section 2.6. Of the 51 monitoring wells that have been installed at SWMU 12, 36 wells are screened in the upper water-bearing unit (i.e., Puz, Table 2-2). In the northern and central portion of SWMU 12, a thin coal seam was encountered directly below the upper sandstone. Because coals are usually permeable and appeared to produce water during drilling (see boring log for 12MWT03, Appendix B), this coal seam was also included in the upper water-bearing unit (Puz).

Beneath the upper sandstone and silty sandstone unit (Puz) lies about 22 to 27 feet of shale, silty shale, mudstone, and interbedded sandstone and shale. This stratigraphic interval is a mixture of finer-grained sedimentary deposits and appears to extend beneath the entire MFA area (see Figures 2-5 through 5-8). The shale is interlayered with discontinuous siltstone and sandstone lenses. The top of the siltstone/shale unit was encountered at approximately 684 to 695 feet amsl (see Figures 2-5 through 2-8) and the bottom of the siltstone/shale unit lies at about 658 to 673 feet amsl. The total thickness of the siltstone/shale unit is about 25 feet. This siltstone/shale unit is considered to be an aquitard and greatly restricts the downward movement of groundwater (as discussed in Section 2.6).

A sandstone layer was the next lithologic unit encountered beneath the interlayered shale and siltstone unit. The top of this sandstone unit was encountered at approximately 658 to 673 feet amsl. However, the contact between the aquitard above and the sandstone below is not sharp; it is in most cases a gradual transition. Six monitoring wells located within the MFA fenced area (12MWT29 through 12MWT34) were drilled down to this interface and penetrated as much as 32 feet into the underlying sandstone. None of these six monitoring wells, however, penetrated completely through the sandstone (see Figures 2-5 through 2-8). Four additional wells (12MWT45 through 12MWT48) were installed along the railroad right-of-way partway down the hillside on the east side of SWMU 12. The ground surface at these well locations ranged from 648 up to 688 feet amsl. These borings penetrated a deeper part of the same sandstone unit (see Figures 2-7 and 2-8). Wells 12MWT30 and 12MWT48 were drilled to the lowest elevation (635.17 and 617.84 feet amsl, respectively) of the ten wells screened in the second sandstone unit; the bottom of both of these boreholes were still in the sandstone unit at those elevations. Thus, the second major sandstone unit extends down to at least 618 feet amsl and possibly a little deeper. The second sandstone unit is referred to as the middle Pennsylvanian water-bearing zone (Pmz) in Section 2.6 and the remainder of this report. It is roughly 50 feet thick.

Three monitoring wells (12MWT41, 12MWT43, and 12MWT44) were installed along a right-of-way on the southwest side of SWMU 12 close to the unnamed tributary creek (Figure 2-4). In addition, five older monitoring wells (WES-7-1-81 through WES-7-5-81) were installed around Dump Site A (a historical disposal area, SWMU 25) by the USACE in 1981. All eight of these wells are shown on Figure 2-4. Each of these wells were drilled through the lowest part of the Pennsylvanian rock strata. Monitoring well 12MWT43 is located on the right-of-way on the side of the ridge to the west-southwest of the SWMU 12 ridge. Here, the second sandstone unit is only about 17 feet thick and the interval between 606 and 647 feet amsl is occupied by 41 feet of shale and siltstone (Figure 2-7). In the eight wells southwest of MFA, the interval between approximately 606 down to about 590 feet amsl is occupied by thin beds of sandstone, hard claystone, and coal seams (Figure 2-8). Two of the eight monitoring wells (12MWT43 and WES-7-1-81) on the southwest side of SWMU 12 are screened above 590 feet amsl in the lowermost

strata of Pennsylvanian rocks. These two wells are considered to be monitoring the lower Pennsylvanian water-bearing zone (Plz).

The other six wells in this area around Dump Site A extend down into the Glen Dean Limestone or right to the Pennsylvanian-Mississippian unconformity. The unconformity is an undulatory surface, based on a cross-sectional sketch prepared by the USACE for Dump Site A (Dunbar, 1982). Well WES-7-4-81 encountered limestone at an elevation of 591.5 feet amsl while thin coal seams were logged in wells WES-7-1-81 and WES-7-3-81 at approximately the same elevation (see logs in Appendix B and Figure 2-8). Pennsylvanian-age coal, clay, and sandstone lenses filled in and draped over the irregular post-Mississippian erosion surface. Two other wells (12MWT49 and 12MWT50) are located on the southeast side of SWMU 12 and they were drilled down into Mississippian limestone. In well 12MWT49, the top of the limestone was encountered at an elevation of 608 feet amsl, which is approximately 16 feet higher in elevation than at Dump Site A. As described previously, the Pennsylvanian-Mississippian unconformity decreases in elevation toward the west. The six wells on the southwest side of SWMU 12 and the two wells on the southeast side of SWMU 12 together are grouped together as wells that monitor the Glen Dean Limestone of Mississippian age (Mgd).

The Glen Dean Limestone is only about 20 to 30 feet thick at the most, when it was not eroded at the Pennsylvanian-Mississippian unconformity or as a result of post-Pennsylvanian erosion (Figure 2-2). Based on the general geology of NSWC Crane, the Big Clifty Sandstone and Beech Creek Limestone should be present in the deepest parts of the unnamed creeks and Turkey Creek valley bottom. The valley bottom also has a veneer of alluvium that overlies the Mississippian rock (see Figure 2-3), but the thickness and the coarseness of the alluvial deposits are unknown.

2.5 SOILS

A veneer of natural soil blankets the top and the sideslopes of the MFA ridge. The soils are the result of Pennsylvanian-age rocks (mostly sandstone, shales, and siltstone) weathering in place. These residual soils derived from Pennsylvanian rock are the most prevalent soils at NSWC Crane. The maximum thickness of residual soil (14.5 to 17 feet) was found at monitoring wells 12MWT40 and 12MWT44 on the southwest side of SWMU 12 (Figure 2-5). The residual soils on the ridgetop and sideslopes consist predominantly of fine materials, including varying amounts of clay, silt, and sand.

2.6 HYDROGEOLOGY

The maximum thickness of soil encountered on the ridgetop or sideslopes of MFA was 17 feet in 12MWT44 (Figure 2-5). Elsewhere, the residual soil was generally less than 10 feet thick. While drilling through the overburden on top of the ridge, no saturated conditions or flowing water was observed in the soil, which is the most common condition. Therefore, it is concluded that very little if any groundwater is stored at the interface between bedrock and overburden. Surface water located in drainage gullies is not hydraulically connected to the bedrock groundwater; therefore, water elevations measured at staff gauges on top of the ridgetop (12SG01 through 12SG07, Figure 2-3) are not considered during preparation of the potentiometric surface maps for the Upper Pennsylvanian water-bearing zone. The surface water at these locations is believed to be perched on top of the clayey residual soils overlying the bedrock surface.

In general, the ridgetop sandstone aquifer (Puz) is recharged by downward infiltration through the residual soil, and recharge occurs more readily where the soil is thin or disturbed and supplanted with fill material.

Depth to groundwater and groundwater elevations were measured on three different occasions, and data are listed in Table 2-2. The first set of water levels were measured in October 2004 before all of the 51 RFI monitoring wells were installed. The second set of water levels was collected in December 2004 after the 51 wells were installed. The third set of water levels were measured in January 2005; this data set included the measurement of water levels in all accessible wells at SWMU 9 (Pesticide Control Area) and SWMU 25 (Dump Site A) which lie to the west and southwest of SWMU 12. The third set of water levels is the most comprehensive and includes wells from a much wider area. The third data set (i.e., January 18, 2005) was used to prepare potentiometric surface maps that are discussed below. Notice in Table 2-2 that the water levels measured in specific wells generally did not vary by more than a foot or two over the three rounds of measurements. Hence, it is felt that the third round of measurements is representative for the time period in which the measurements were made (i.e., late fall and winter months).

Figure 2-9 presents the potentiometric surface for the uppermost sandstone unit (Puz) measured in January 2005. The highest elevations (731 to 733 feet amsl) were measured in six monitoring wells at the far northwest end of SWMU 12. Two ridges of higher groundwater elevations extend from the groundwater high at the north end of Figure 2-9. The larger more pronounced ridge runs southeast along the centerline of the SWMU 12 ridgetop through wells 12MWT16, 12MWT17, AND 12MWT23. The groundwater elevations decrease gradually from 733 down to 711 along this groundwater ridge. To the northeast and southwest of this groundwater ridge, the groundwater elevations decrease rather rapidly to

the sides of the ridge. Shallow groundwater on the northeastern side of this groundwater ridge flows to the northeast and shallow groundwater on the southwestern side of the ridge flows southwest. A line representing the approximate crop line of the upper sandstone unit (i.e., the Puz) is shown on Figure 2-9 and indicates the area within which the Puz is found. The Puz is absent at elevations below this line (i.e., less than 695 feet amsl). All shallow groundwater in the Puz is presumably flowing toward the crop line and discharging to the gullies that are incised on the northwestern and southeastern sides of the ridge or discharging to the soils and gradually evaporating. The hydraulic gradients in the Puz steepen as the sideslopes of the ridge are approached.

A second ridge extends from the northern high area toward the southwest through SWMU 9. The centerline of this ridge passes near wells 09T01, 09-01, 09WTP6, and 09-10. The groundwater elevations decrease gradually along the crest of the groundwater ridge from a high of 732.75 feet amsl at well 12MWT28 down to 723.27 feet amsl at well 09-10. The groundwater elevations decrease more rapidly toward the sides of the topographic ridge to the northwest and east of SWMU 9. In other words, the shallow groundwater potentiometric surface is mimicking topography. Figure 2-9 includes arrows which depict the approximate lateral flow directions in the Puz. Groundwater is flowing toward the cropline on the sides of the ridges. As mentioned above, a line around the ridges has been added to show the approximate base of the Puz where it intersects the ground surface at about 690 to 695 feet amsl. Notice in Figure 2-9 that the groundwater flow arrows on the western side of SWMU 12 ridge and the eastern side of the SWMU 9 ridge are flowing in almost opposite directions toward the same unnamed creek. In general, shallow groundwater throughout NSWC Crane is found to be flowing toward the nearest incised gulley or creek.

Figure 2-10 shows groundwater elevations measured in the 10 monitoring wells screened in the second major sandstone unit (i.e., the Pmz) on January 18, 2005. This map covers only the SWMU 12 area, because no wells at SWMUs 9 or 25 are screened in the Pmz. Like the groundwater in the Puz, the highest groundwater elevation in the Pmz was found at the northwestern end of SWMU 12 (698.69 ft amsl at well 12MWT33). In addition, a groundwater ridge in the Pmz also extends from the northwest end of the SWMU toward the southeast. Groundwater elevations decrease toward the southeast and toward the southwest from the groundwater ridge. The lowest groundwater elevations in the Pmz were measured in wells 12MWT30 (634.90 ft amsl) on the southwest side of SWMU 12 and 12MWT48 (619.64 ft amsl) on the southeast side of SWMU 12. These groundwater elevations are approaching the base of the second sandstone unit (i.e., Pmz) which lies at approximately 610 to 615 feet amsl. Groundwater in the Pmz, like the Puz, should be discharging to the hillside but at a lower elevation. Groundwater discharge around the hillsides has not been verified yet in the field. Arrows on Figure 2-10 show the approximate flow direction for groundwater in the Pmz.

Only two wells were screened in the lower Pennsylvanian rock strata. However, a total of eight wells at SWMUs 9 and 12 are screened in the Glen Dean Limestone or immediately above or below the Glen Dean Limestone, which is the Mississippian formation lying directly below the Pennsylvanian rocks. These wells have been grouped together and are used to represent the flow system within the Glen Dean Limestone (i.e., Mgd). Water levels measured in these eight wells are presented in Figure 2-11 and are contoured to show the approximate flow groundwater flow direction in this limestone. Groundwater flow in the Mississippian limestone is moving toward the south and southeast toward Turkey Creek and the lowest reaches of the two unnamed tributaries. Note that the limestone crops out above the creek level, so the groundwater is discharging either to the ground surface along the creeks or into the alluvium which blankets the valley bottom. This suggests that Turkey Creek and perhaps the lower reaches of the two unnamed tributaries might have perennial flow in them or at least flow most of the year.

During the RFI, slug tests were performed on 14 monitoring wells screened in the Puz and five monitoring wells screened in the Pmz. In many cases, a rising head and falling head test were performed on each well. In six of the wells, only a falling head test was performed (usually because the well was very slow to recover). In four of the wells, only a rising head test was performed because the water levels in the wells were below the top of the screens (which introduces error in evaluating a falling head test). The raw data, data analysis procedures, graphs of the data, and analytical results for each test are presented in Appendix E.1. A summary of the results of slug tests performed on select monitoring wells are presented in Table 2-2. The hydraulic conductivities (K) for the Puz monitoring wells ranged from 0.0037 to 3.7 feet per day (1.3E-06 to 1.3E-03 centimeters per second [cm/s]). The median hydraulic conductivity for the shallow bedrock was approximately 0.34 foot per day (1.2E-04 cm/s). The large variation in hydraulic conductivities determined for the Puz was not surprising because the sandstone and siltstone unit ranges from partially weathered to highly weathered, and from massive (with little fracturing) to highly fractured.

Horizontal hydraulic gradients were calculated graphically at several locations for the Puz (see numbered flow arrows on Figure 2-9). The gradients were very steep (0.08 to 0.1 ft/ft) in the northeast portion of SWMU 12 represented by flow arrows 1 and 2, steep (0.05 ft/ft) along the northwest side of SWMU 12 represented by flow arrow 4, and moderately steep (0.044 ft/ft) on the southeast and southwest sides of SWMU 12 as represented by flow arrow 3 (Figure 2-9). Using the median hydraulic conductivity value for the Puz of 0.34 foot/day and an estimated porosity of 0.10 for the weathered sandstone, values of linear groundwater velocity were estimated for the Puz. These values ranged from 0.15 to 0.34 foot/day. Along the centerline of the ridge, the hydraulic gradients are relatively low and linear groundwater velocities are therefore much less. The gradients become steepest near the outer edges of the ridge where the Puz approaches its crop line. The groundwater velocities therefore increase as the groundwater approaches

the outer edge of the ridge (i.e., its discharge zone). All assumptions, data, and calculations for linear groundwater velocities are presented in Appendix E.2.

The K values for the Pmz monitoring wells (Table 2-2) ranged from 0.01 to 0.37 feet per day (3.7E-06 to 2.0E-05 cm/s) in four of the five wells tested. A very large hydraulic conductivity was calculated for the slug tests performed on the fifth Pmz well, 12MWT47 (62.4 feet per day, 0.022 cm/s). The well log indicates that sandstone is present in the screened interval and it is extensively fractured. This likely explains the unusually high hydraulic conductivity value calculated for this well. The median K value for the Pmz was actually about 50 percent of the median value determined for the Puz monitoring wells.

Horizontal hydraulic gradients were calculated graphically at several locations for the Pmz (see numbered flow arrows on Figure 2-10). The gradients are very steep (0.266 ft/ft) to the east of SWMU 12 as represented by flow arrow 1, steep (0.09 ft/ft) to the east and southeast of SWMU 12 represented by flow arrow 2, and moderately steep (0.066 ft/ft) on the southwest side of SWMU 12 as represented by flow arrow 3 (Figure 2-10). Using the median hydraulic conductivity value for the Pmz of 0.17 foot/day and an estimated porosity of 0.05 for the unweathered sandstone, values of linear groundwater velocity were estimated for the Pmz. These values ranged from 0.22 to 0.90 foot/day. Along the centerline of the ridge and on the south side of SWMU 12, the hydraulic gradients are relatively low and linear groundwater velocities are therefore much less. The gradients become steepest near the outer edges of the ridge where the Pmz approaches its crop line. The groundwater velocities therefore increase as the groundwater approaches the outer edge of the ridge (i.e., its discharge zone). All assumptions, data, and calculations for linear groundwater velocities are presented in Appendix E.2.

Horizontal hydraulic gradients were calculated graphically at several locations for the Mgd (see numbered flow arrows on Figure 2-11). The gradients are very steep (0.16 ft/ft) to the east and southeast of SWMU 12 (as represented by flow arrow 1) and near Dump Site A , and steep (0.064 ft/ft) to the southwest of SWMU 12 as represented by flow arrow 2 (Figure 2-11). Hydraulic conductivity values have not been measured for the Glen Dean Limestone or for the strata at the base of the Pennsylvanian. A K value of 1.0 foot/day and a porosity of 0.02 were used to estimate linear groundwater flow velocities at select locations in the Mgd. These values ranged from 3.2 to 8.0 feet/day. Along the centerline of the ridge and SWMU 12 and on the south side of SWMU 12, the hydraulic gradients are relatively low and linear groundwater velocities are therefore much less. The gradients become steepest near the outer edges of the ridge where the Mgd approaches its crop line. The groundwater velocities therefore increase as the groundwater approaches the outer edge of the ridge (i.e., its discharge zone). All assumptions, data, and calculations for linear groundwater velocities are presented in Appendix E.2.

Most of the groundwater within the ridge is flowing laterally eastward, southward, and westward from the centerline of the ridge. Some groundwater is likely flowing from the upper sandstone unit (Puz) downward to the second sandstone unit (Pmz) and finally down to the lowermost Pennsylvanian strata (Plz) and the Glen Dean Limestone (Mgd). The hydraulic heads measured in monitoring wells at SWMU 12 consistently drop in elevation as the elevations of the well screens decrease (Figure 2-12). This indicates that recharge occurs along the crest and along the upper slopes of the ridge; groundwater flow is mostly lateral with a small vertical component downward. The flow rates downward through the ridge are very low based on the following evidence:

- Much of the upper portion of the Pmz is dry; hence the groundwater in the Puz is perched and cannot move down to the Pmz very quickly. This strongly suggests that the aquitard between the Puz and Pmz is an effective barrier to downward groundwater flow.

- The fact that groundwater elevations decrease dramatically from top to bottom in the ridge (see Figure 2-12) indicates a large vertical hydraulic gradient exists, which reflects the low permeabilities of aquitard materials (i.e., shales and siltstones) that lie in between the Puz, Pmz, and Plz.

- Six different pairs of wells also indicate that a very large hydraulic head difference exists between the Puz and Pmz (see Figure 2-13). The average head difference between the wells in the Puz and the wells in the Pmz in January 2005 was 53 feet. The same approximate drop in hydraulic head occurs between the Pmz and the Mgd.

In section 5.0, the results of groundwater sampling will be presented. Most contaminants in groundwater in the Puz were not detected or were detected in very low concentrations in the Pmz. This information further corroborates the conceptual flow model for groundwater at this site; i.e., that groundwater within the ridge is mostly perched and flows laterally toward the outside edges of the ridge. Very little groundwater is moving downward through the core of the ridge beneath MFA.

2.7 DEMOGRAPHY AND LAND USE

The economic base of communities surrounding NSWC Crane is in transition from agriculture, mining, and quarrying to manufacturing and service industries. The patterns of settlement, population statistics, and median income are similar throughout the region. Because most of the region is covered by vegetation, the area is classified as rural.

There is no state or local planning within the vicinity of NSWC Crane. The only zoning and land use regulations are in the municipalities in the region. None of the municipalities are close enough to impact NSWC Crane. None of the areas adjacent to NSWC Crane are zoned, and zoning is not anticipated in the near future. No known land use or community actions are being considered or proposed at this time.

2.8 ECOLOGY

NSWC Crane is a heavily forested facility situated within the Western Mesophytic Forest Region, Hill Section, and Beech-Maple Forest Region (Braun, 1950). Lindsey et al. (1970) further subdivided the area of the installation into the south-central Oak and Mixed Woods Division, including the Beech-Maple and the Beech-Oak-Maple-Hickory sub-elements. Deam (1940) classified the portion of Martin County in which the facility is located as consisting of the Chestnut Oak Upland based on the dominant floral components at that time. More recently, Kuchler (1964) mapped this portion of Indiana and classified it as belonging to two distinct vegetation classes, the Oak-Hickory and the Beech-Maple forest components of the Broadleaf Forest Classification. This latter classification most closely resembles the current floristic components observed at the facility.

NSWC Crane contains old agricultural fields in various stages of biological succession. Openings on dry upland sites contain almost pure stands of grasses with some clumps of woody plants such as persimmon, sassafras, and sumac. Areas that tend to be wetter have river birch, willow, sycamore, and cottonwood. Hillside communities include hickory, white and black oak, red maple, sugar maple, tulip poplar, ash, and beech [Naval Energy and Environmental Support Activity (NEESA), 1983]. Cleared areas at the facility have various stages of grassland, old field, and scrub/shrub vegetational forms present. Dominant tree species include black oak, white oak, pignut hickory, and yellow poplar. These stands are relatively young, with the average tree diameter ranging from 6 to 12 inches. No scrubs or shrubs are present in these areas, and leaf litter, limbs, and fallen saplings cover the understory.

The wildlife habitats and vegetation types present at NSWC Crane (including many stages of forest succession, streams, ponds, Greenwood Lake, and grassy open spaces) support a diverse terrestrial and aquatic fauna. The abundance of wildlife is mainly due to the mixture of landforms and vegetation types that occur over the installation. In addition, the lack of agricultural pressures has enhanced wildlife abundance and served to provide an installation-wide "wildlife enclosure" condition. There is an adequate amount of forage materials, concealment opportunities, and shelter locations to support a highly diverse wildlife community at the site.

Terrestrial habitats (i.e., wooded and grassy areas) near the sites may provide shelter and food sources for various species of mammals such as white-tailed deer, coyote, red fox, rabbits, raccoons, and mice and for birds such as ducks, geese, wild turkey, bobwhite quail, red-tailed hawks, and American robins.

The white-tailed deer is the most conspicuous large, wild mammal at the installation. Other mammals include opossum, raccoon, rabbits, mice, bats, chipmunks, squirrels, beaver, groundhogs, gray fox, coyotes, and long-tailed weasel. Fox, coyotes, and hawks are carnivores whose presence indicates a healthy ecosystem with smaller mammals present to provide a food source (NEESA, 1983).

The birds at NSWC Crane are diverse. Previous studies identified over 100 species present at the facility during breeding seasons (Hengeveld, 1987). Because the facility is largely forested, the species found consist predominantly of those that frequent wooded habitat types. Species of waterfowl also use the facility, especially in the vicinity of Greenwood Lake. A large number of bird species frequent the non-forested grassland, old field, and scrub/shrub vegetation present over portions of NSWC Crane. The bird population includes a number of threatened, endangered, or species of special concern that use NSWC Crane as their home range. These species include the bald eagle, osprey, sharp-shinned hawk, red-shouldered hawk, broad-winged hawk, black and white warbler, hooded warbler, and worm-eating warbler [Brown & Root Environmental, 1997].

Previous studies conducted at NSWC Crane (Nelson et al., 1987) identified 21 amphibian species and 22 reptilian species including skinks, lizards, snakes, and turtles.

A total of 46 distinct fish species were collected from the installation during a 1987 inventory of fish fauna at NSWC Crane. Other than Greenwood Lake, the 1987 study observed that the greatest number of individual fish species were recorded from the largest stream, Boggs Creek, and that the smallest number of species were recorded from Turkey Creek. Boggs Creek contained 29 species, including eight species of fish characteristic of large river-type systems. This included long-nose gar, paddlefish, bowfin, gizzard shad, ribbon shiner, big mouth buffalo, channel catfish, and flathead catfish. By contrast, the Turkey Creek survey yielded 16 species of fish, none of which were unusual to the area.

TABLE 2-1

ESTIMATED FLOW RATES AT SURFACE WATER SAMPLING LOCATIONS AND STAFF GAUGES
SWMU 12 - MINE FILL A (ROUNDS 3 THROUGH 9)
NSWC CRANE
CRANE, INDIANA

	Estimated Flow Rate (gpm)			
	Round 1		Round 2	
	10/04 - 11/04		3/05	
Surface Water Sampling Station[1]				
12SW/SD01	0		3-5	
12SW/SD02	5-10		1-3	
12SW/SD03	1.4		0	ponded
12SW/SD04	0	ponded	5-10	
12SW/SD05	10-15		3-5	
12SW/SD06	5		< 1	
12SW/SD07	10-20	raining	Dry	
12SW/SD08	6		1-3	
12SW/SD09	70		101	
12SW/SD10	144		81	
12SW/SD11	0	ponded	90	
12SW/SD12	0	ponded	5-10	
12SW/SD13	NE		27	
12SW/SD14	NE		0	ponded
12SW/SD15	5-10	raining	Dry	
12SW/SD16	NE		485	
12SW/SD17	9		1-3	
12SW/SD18	5-10	raining	0	ponded
12SW/SD19	0	ponded	Dry	
12SW/SD20	1-5		1-2	
12SW/SD21	0	ponded	Dry	
12SW/SD22	< 1		Dry	
12SW/SD23	NE		180	
12SW/SD24	269		286	
12SW/SD25	NE		5,334	
12SW/SD26	76		3.4	
12SW/SD27	NE		3,817	
12SW/SD28	1-5	from pool	1.5	
12SW/SD29	1-5	raining	Dry	
12SW/SD30	12	raining	Dry	
12SW/SD31	NA		1-5	
12SW/SD32	NA		3-5	
12SW/SD33	NA		5-10	
12SW/SD34	NA		1	
12SW/SD35	NA		0	
12SW/SD36	NA		1-2	
Staff Gauge	12/15/04		1/18/05	
12SG01	0	Stagnant	0	Dry
12SG02	0	Dry	0	Dry
12SG03	0	Stagnant	0	Dry
12SG04	0	Stagnant	0	Dry
12SG05	0	Dry	0	Dry
12SG06	224		1	
12SG07	15		3-5	
12SG08	44		116	
12SG09	295		225	
12SG10	6,265		8,960	
12SG11	4,704		6,048	
12SG12	73		215	

1 - See surface water sample log sheets for flow calculations or estimates; locations shown on Figure 2-3.
NE = flow rate not estimated or recorded.
NA = not applicable
gpm = gallons per minute.

TABLE 2-2

HYDRAULIC CONDUCTIVITIES OF GEOLOGIC MATERIALS BASED ON SLUG TESTS
SWMU 12 - MINE FILL A (ROUNDS 3 THROUGH 9)
NSWC CRANE
CRANE, INDIANA

Monitoring Zone / Well No.	Screened Material	Horizontal Hydraulic Conductivity (K_h) (rising head, ft/day)	Horizontal Hydraulic Conductivity (K_h) (falling head, ft/day)	Average Horizontal Hydraulic Conductivity (Kh) (ft/day)	(cm/s)
Upper Pennsylvanian Water-Bearing Zone (Puz)					
12MWT01	coal, shale, and sandstone	3.767	3.611	3.6890	1.30E-03
12MWT03	sandstone, coal, and shaly sandstone	NA	0.0396	0.0396	1.40E-05
12MWT06	sandstone	NA	1.5120	1.5120	5.33E-04
12MWT08	sandstone	0.3363	0.5167	0.4265	1.50E-04
12MWT10	sandstone with shale intebeds	0.509	0.0487	0.2789	9.84E-05
12MWT13	sandstone, coal, and silty sandstone	0.8206	0.7497	0.7852	2.77E-04
12MWT15	sandstone and silty shale	0.545	NA	0.5450	1.92E-04
12MWT17	sandstone	0.6003	NA	0.6003	2.12E-04
12MWT21	shaly sandstone, coal, and sandstone	0.3555	NA	0.3555	1.25E-04
12MWT23	sandstone with interbedded siltstone and shale	0.3237	NA	0.3237	1.14E-04
12MWT25	shaley sandstone	NA	0.0037	0.0037	1.32E-06
12MWT28	sandstone with some interbedded shale	NA	0.0135	0.0135	4.75E-06
12MWT36	sandstone	0.05023	0.1362	0.0932	3.29E-05
12MWT38	sandstone	0.02275	0.0515	0.0371	1.31E-05
			Median Value	0.3396	1.20E-04
Middle Pennsylvanian Water-Bearing Zone (Pmz)					
12MWT29	sandstone with minor shale interbeds	NA	0.0105	0.0105	3.69E-06
12MWT33	sandstone with interbedded siltstone	0.1653	0.1771	0.1712	6.04E-05
12MWT45	sandstone and siltstone	0.3137	0.4308	0.3723	1.31E-04
12MWT46	sandstone with weathered shale partings	NA	0.0568	0.0568	2.00E-05
12MWT47	sandstone	74.44	50.36	62.40	2.20E-02
			Median Value	0.1712	6.04E-05

NA = Not analyzed

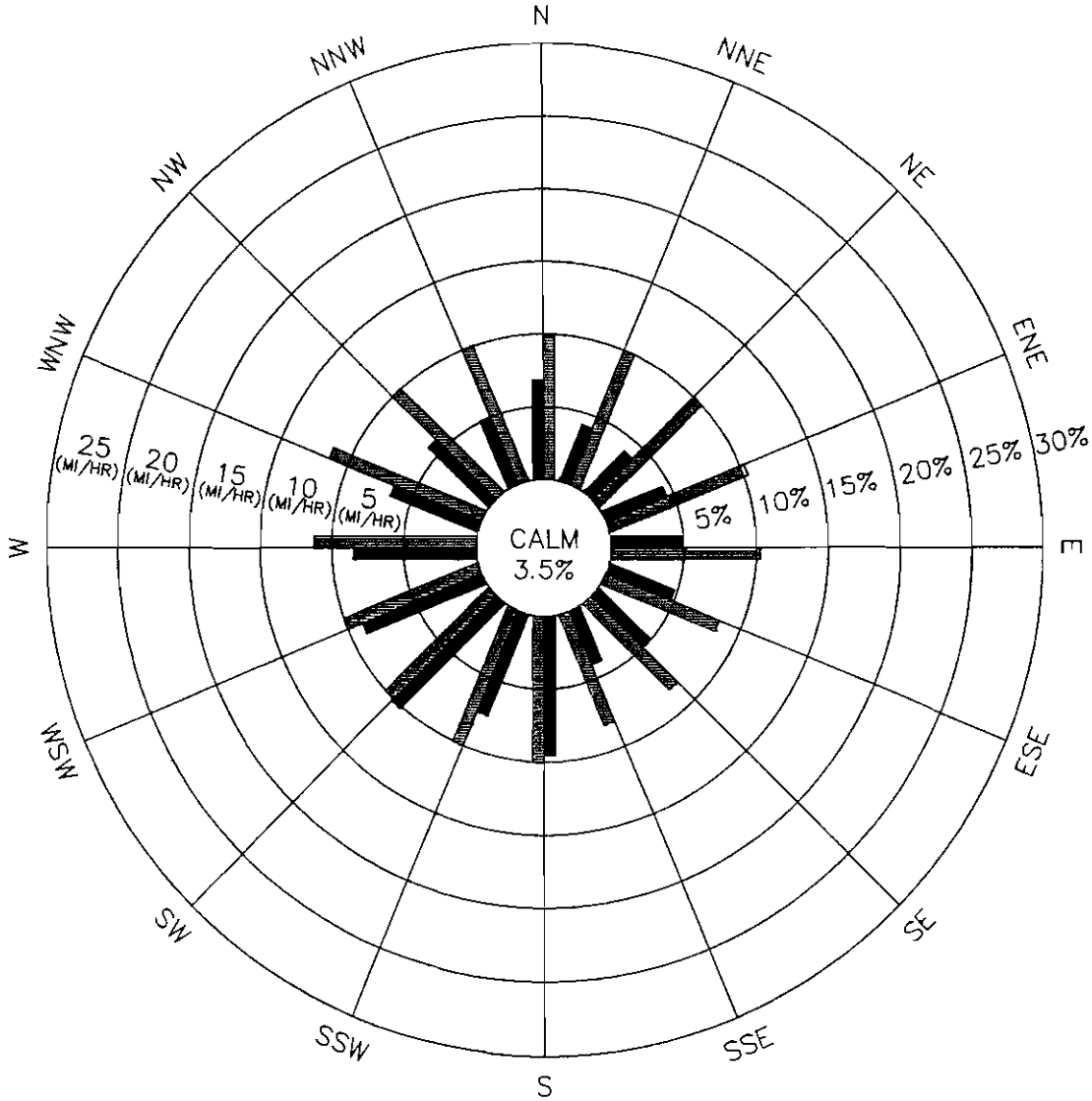
TABLE 2-2

HYDRAULIC CONDUCTIVITIES OF GEOLOGIC MATERIALS BASED ON SLUG TESTS
SWMU 12 - MINE FILL A (ROUNDS 3 THROUGH 9)
NSWC CRANE
CRANE, INDIANA

Monitoring Zone / Well No.	Screened Material	Horizontal Hydraulic Conductivity (K_h) (rising head, ft/day)	Horizontal Hydraulic Conductivity (K_h) (falling head, ft/day)	Average Horizontal Hydraulic Conductivity (Kh) (ft/day)	(cm/s)
Upper Pennsylvanian Water-Bearing Zone (Puz)					
12MWT01	coal, shale, and sandstone	3.767	3.611	3.6890	1.30E-03
12MWT03	sandstone, coal, and shaly sandstone	NA	0.0396	0.0396	1.40E-05
12MWT06	sandstone	NA	1.5120	1.5120	5.33E-04
12MWT08	sandstone	0.3363	0.5167	0.4265	1.50E-04
12MWT10	sandstone with shale intebeds	0.509	0.0487	0.2789	9.84E-05
12MWT13	sandstone, coal, and silty sandstone	0.8206	0.7497	0.7852	2.77E-04
12MWT15	sandstone and silty shale	0.545	NA	0.5450	1.92E-04
12MWT17	sandstone	0.6003	NA	0.6003	2.12E-04
12MWT21	shaly sandstone, coal, and sandstone	0.3555	NA	0.3555	1.25E-04
12MWT23	sandstone with interbedded siltstone and shale	0.3237	NA	0.3237	1.14E-04
12MWT25	shaley sandstone	NA	0.0037	0.0037	1.32E-06
12MWT28	sandstone with some interbedded shale	NA	0.0135	0.0135	4.75E-06
12MWT36	sandstone	0.05023	0.1362	0.0932	3.29E-05
12MWT38	sandstone	0.02275	0.0515	0.0371	1.31E-05
			Median Value	0.3396	1.20E-04
Middle Pennsylvanian Water-Bearing Zone (Pmz)					
12MWT29	sandstone with minor shale interbeds	NA	0.0105	0.0105	3.69E-06
12MWT33	sandstone with interbedded siltstone	0.1653	0.1771	0.1712	6.04E-05
12MWT45	sandstone and siltstone	0.3137	0.4308	0.3723	1.31E-04
12MWT46	sandstone with weathered shale partings	NA	0.0568	0.0568	2.00E-05
12MWT47	sandstone	74.44	50.36	62.40	2.20E-02
			Median Value	0.1712	6.04E-05

NA = Not analyzed

ACAD: 6878KF01.dwg 04/27/05 HJB PIT



LEGEND:

WIND DIRECTION FREQUENCY (PERCENT)
(DIRECTION FROM WHICH THE WIND IS BLOWING)

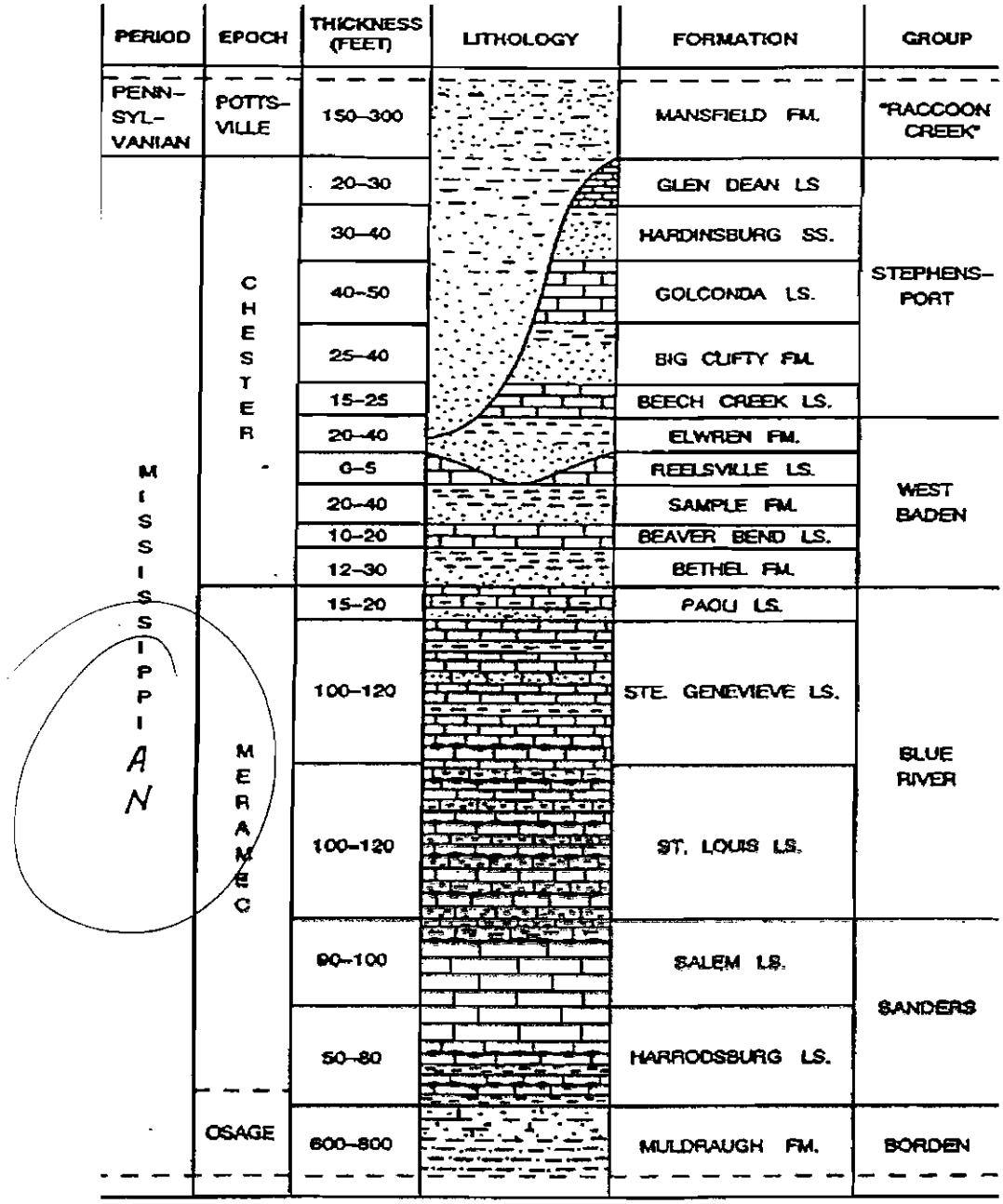
MEAN WIND SPEED (MI/HR)

DATA SOURCE: INDIANAPOLIS, INDIANA AIRPORT

PERIOD OF RECORD: 1985–1989
43,824 OBSERVATIONS

DRAWN BY DM	DATE 1/14/05	FIVE-YEAR WIND ROSE SUMMARY FOR INDIANAPOLIS, INDIANA SWMU 12 MINE FILL A NSWC CRANE CRANE, INDIANA	CONTRACT NO. 6878
CHECKED BY	DATE		OWNER NO. 0000
REVISED BY	DATE		APPROVED BY / DATE
SCALE AS NOTED		NAVFAC	DRAWING NO. FIGURE 2-1 / REV. 0

FORM CADD NO. SDIV-AV.DWG - REV 1 - 9/10/98



Source: Draft Report, RCRA Facility Investigation
Phase II Groundwater Release Assessment, SWMU 06/09
Demolition Area and Phase III Release
Characterization SWMU 07/09 Old Rifle Range
November 1995 - Figure 13
by William L. Murphy and Roy Wade

DRAWN BY	DATE			CONTRACT NUMBER	OWNER NO.
J. LAMEY	8/28/01	NAVFAC	GENERALIZED STRATIGRAPHIC COLUMN SWMU 12 MINE FILL A NSWC CRANE CRANE, INDIANA	6878	CTO 0357
CHECKED BY	DATE			APPROVED BY	DATE
J. SCHUBERT	4/22/05			—	—
COST/SCHEDULE-AREA				APPROVED BY	DATE
				—	—
SCALE AS NOTED				DRAWING NO. FIGURE 2-2	REV 0

P:\GIS\NSWC_CRANE\MINEFILL_A.APR STRATIGRAPHIC COLUMN 3D/V 4/22/05 CF

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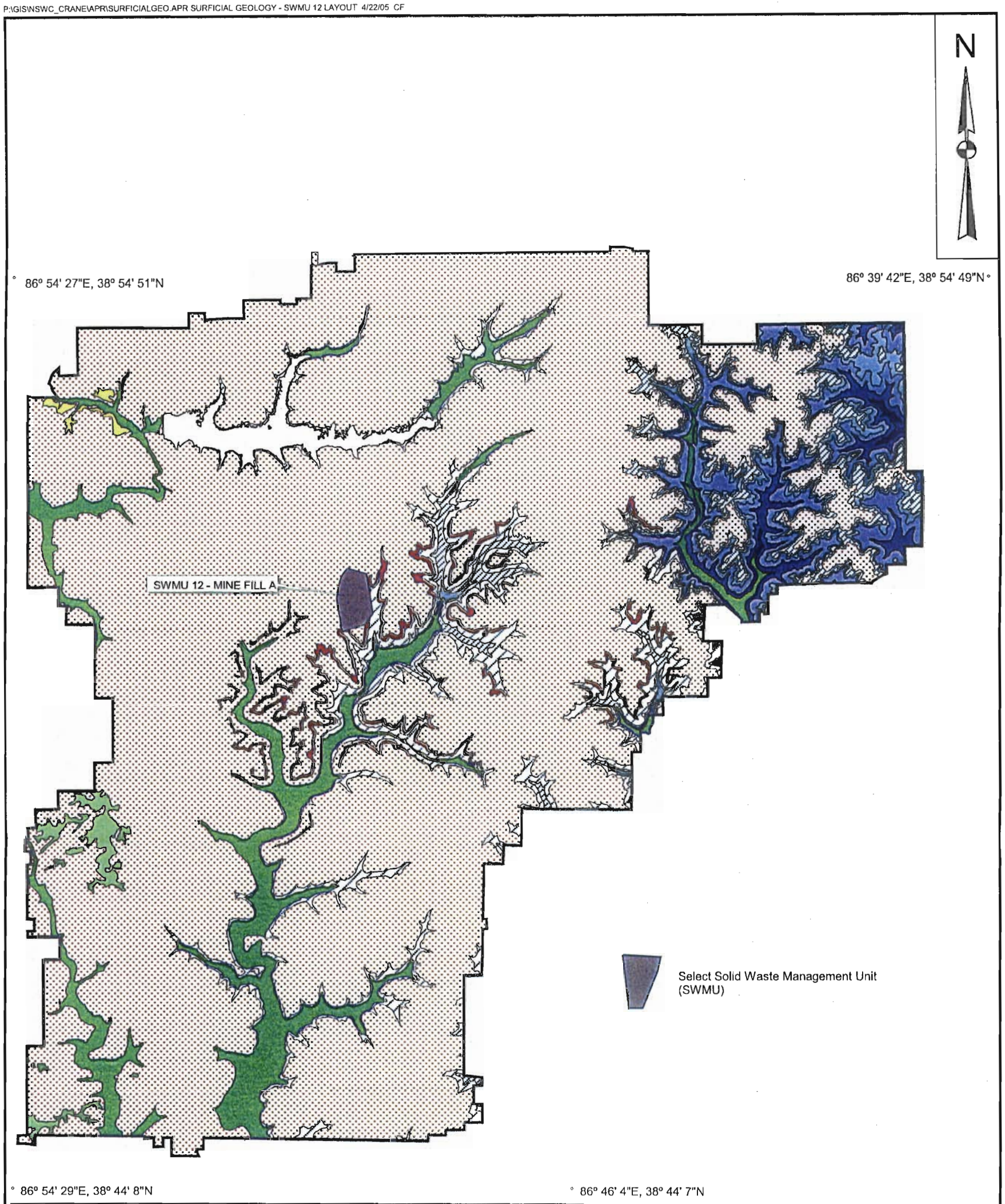


Inferred Depositional Environment		Explanation of Geology
Alluvium	Qal	*Alluvium*
Loess/Glacial Outwash	Ql	*Loess*
	Qo	*Glacial Outwash*
Residual Soil derived from Pennsylvanian bedrock/colluvium	P1	*Raccoon Creek Group and undifferentiated*
	Pa	*Sandstone-dominated horizon of Lower Pennsylvanian*
Residual soil derived from Mississippian bedrock/colluvium	M6	*Glenn Dean Ls, Hardinsburg Fm, Haney Ls, Indian Springs Shale Mbr, and undifferentiated*
	M5	*Sandstone member of the Big Clifty Fm*
	M4	*Beech Creek Ls*
	M3	*Elwren Fm, Reelsville Ls, upper Sample Fm, and undifferentiated*
	M2	*Lower part of Sample Fm, Beaver Bend Ls, Bethel Fm, and undifferentiated*
	M1	*Paoli Ls, Ste Genevieve Ls, and undifferentiated*

Source: Background Soils Report. TtNUS 2001. (Modified from Blunck, 1995).

1.5 0 1.5 Miles

6878

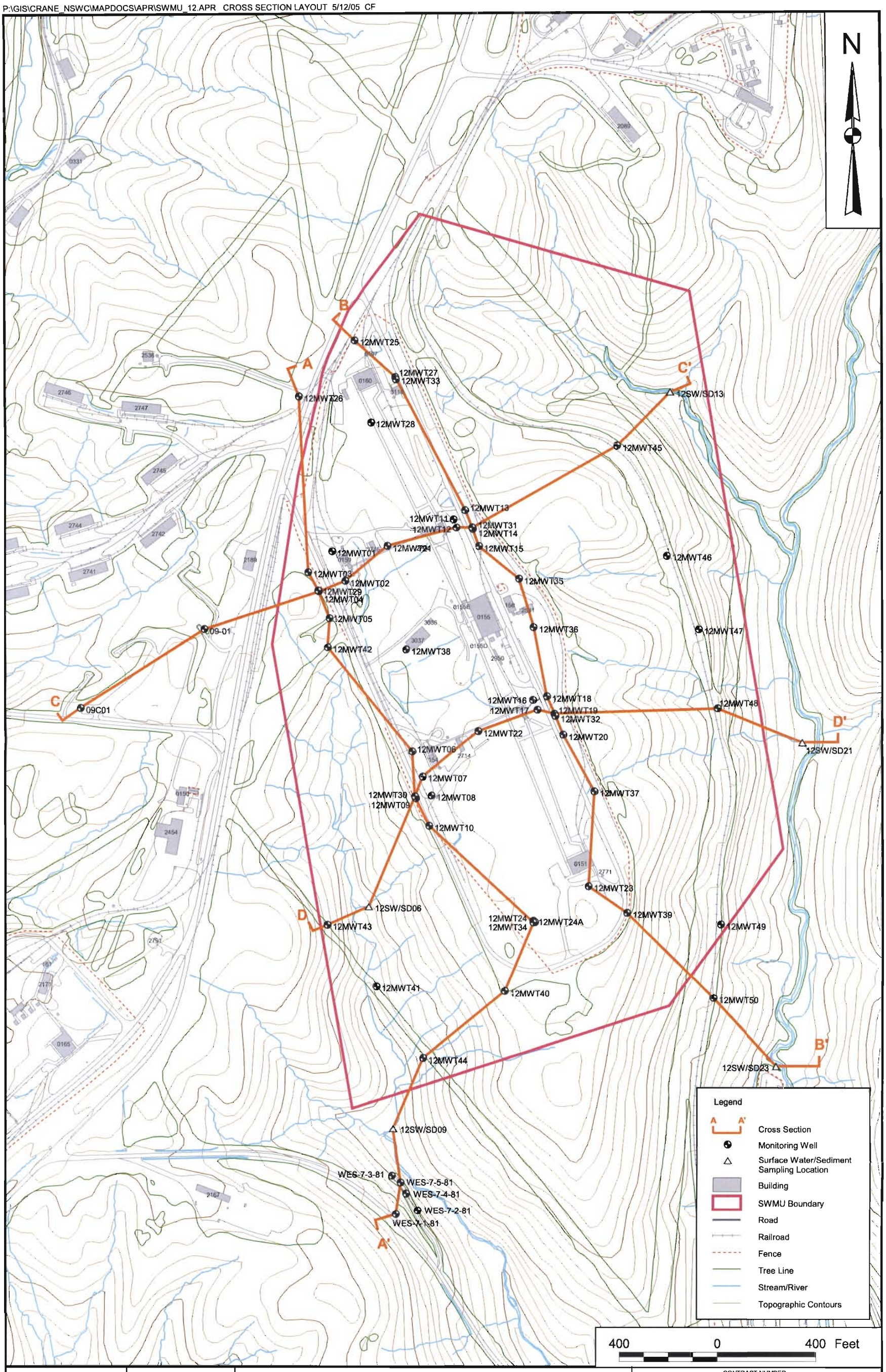
DRAWN BY	DATE
A. JANOCHA	7/09/03
CHECKED BY	DATE
J. LUCAS	4/20/04
COST/SCHEDULE-AREA	
SCALE	
AS NOTED	

NAVFAC

SURFICIAL GEOLOGY MAP
SWMU 12 MINE FILL A
NSWC CRANE
CRANE, INDIANA

CONTRACT NUMBER	CONTRACT NUMBER
6878	CTO 0357
APPROVED BY	DATE
APPROVED BY	DATE
DRAWING NO. FIGURE 2-3	REV 0

P:\GIS\CRANE_NSWC\MAPDOCS\APR\SWMU_12.APR CROSS SECTION LAYOUT 5/12/05 CF



DRAWN BY	DATE
C. FOSTER	04/25/05
CHECKED BY	DATE
J. SCHUBERT	04/25/05
COST/SCHEDULE-AREA	
SCALE	
AS NOTED	

NAVFAC

CROSS SECTION MAP

SWMU 12 - MINE FILL A

NWSC CRANE

CRANE, INDIANA

CONTRACT NUMBER	
6878	
APPROVED BY	DATE
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APPROVED BY	DATE
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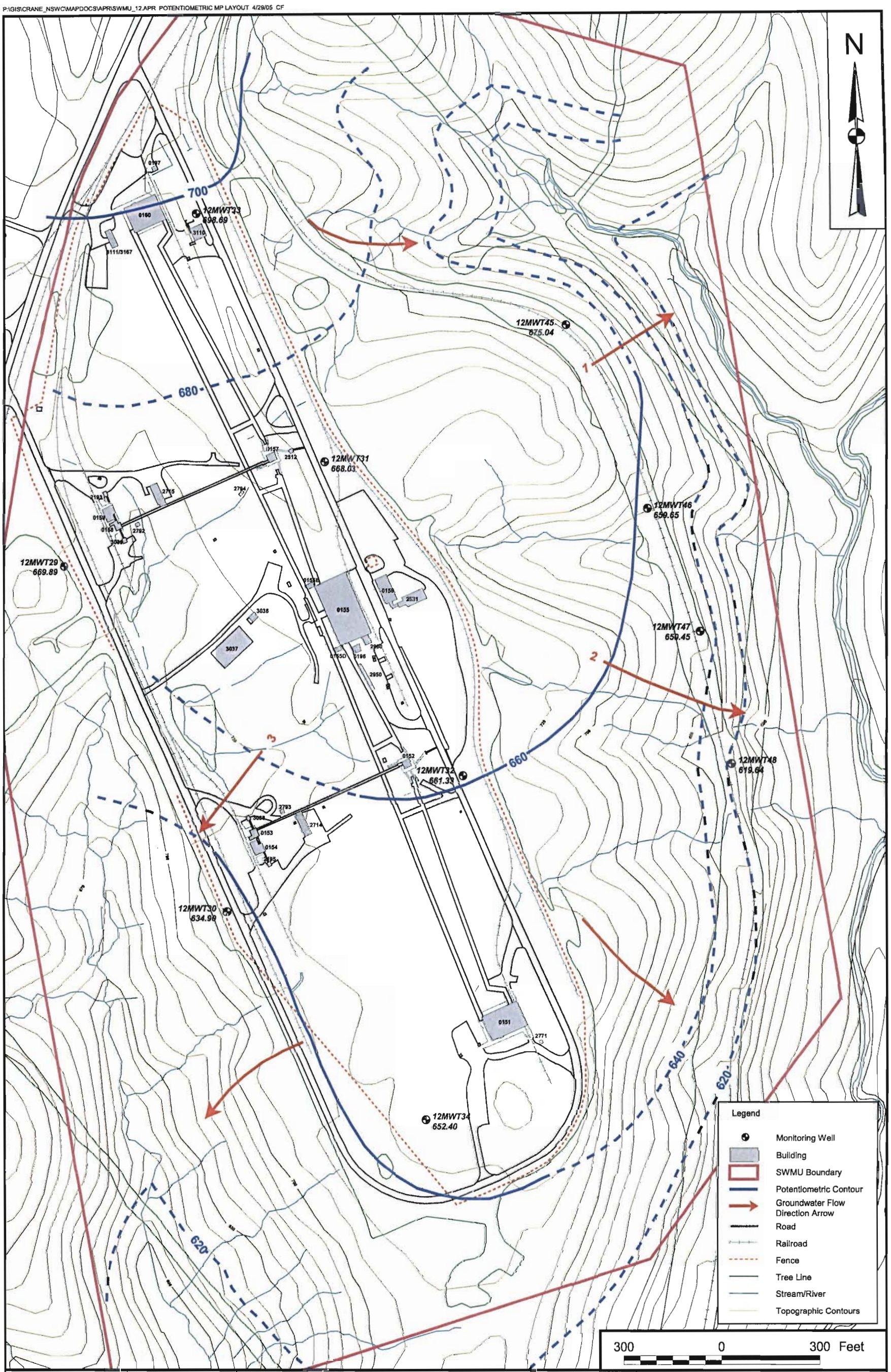
DRAWING NO.	REV
FIGURE 2 - 4	0

P:\GIS\CRANE_NSWC\MAPDOCS\APR\SWMU_12.APR POTENTIOMETRIC MP LAYOUT 4/29/05 CF



DRAWN BY	DATE
C. FOSTER	4/28/05
CHECKED BY	DATE
COST/SCHEDULE-AREA	
SCALE AS NOTED	

NAVFAC

POTENTIOMETRIC SURFACE MAP FOR THE MIDDLE PENNSYLVANIAN WATER-BEARING ZONE - JANUARY 18, 2005

SWMU 12 MINE FILL A

CRANE NSWC

CRANE, INDIANA

CONTRACT NUMBER 6878	
APPROVED BY	DATE
APPROVED BY	DATE
DRAWING NO. FIGURE ~~4-10~~ 2-10	REV 0

P:\GIS\CRANE_NSWC\MAPDOCS\APR\SWMU_12.APR POTENTIOMETRIC GD LAYOUT 4/29/05 CF

CONTRACT NO. 6878

APPROVED BY — DATE

APPROVED BY — DATE

DRAWING NO. FIGURE 2-11 REV 0

POTENTIOMETRIC SURFACE MAP FOR THE GLEN DEAN LIMESTONE (MISSISSIPPIAN) AQUIFER
SWMU 12 MINE FILL A
CRANE NSWC
CRANE, INDIANA

NAVFAC

DRAWN BY C. FOSTER — DATE 4/28/05

CHECKED BY — DATE

COST/SCHED-AREA

SCALE AS NOTED

FIGURE ~~4-12~~ 2-12. GROUNDWATER ELEVATIONS IN MONITORING WELLS VERSUS WELL SCREEN DEPTH

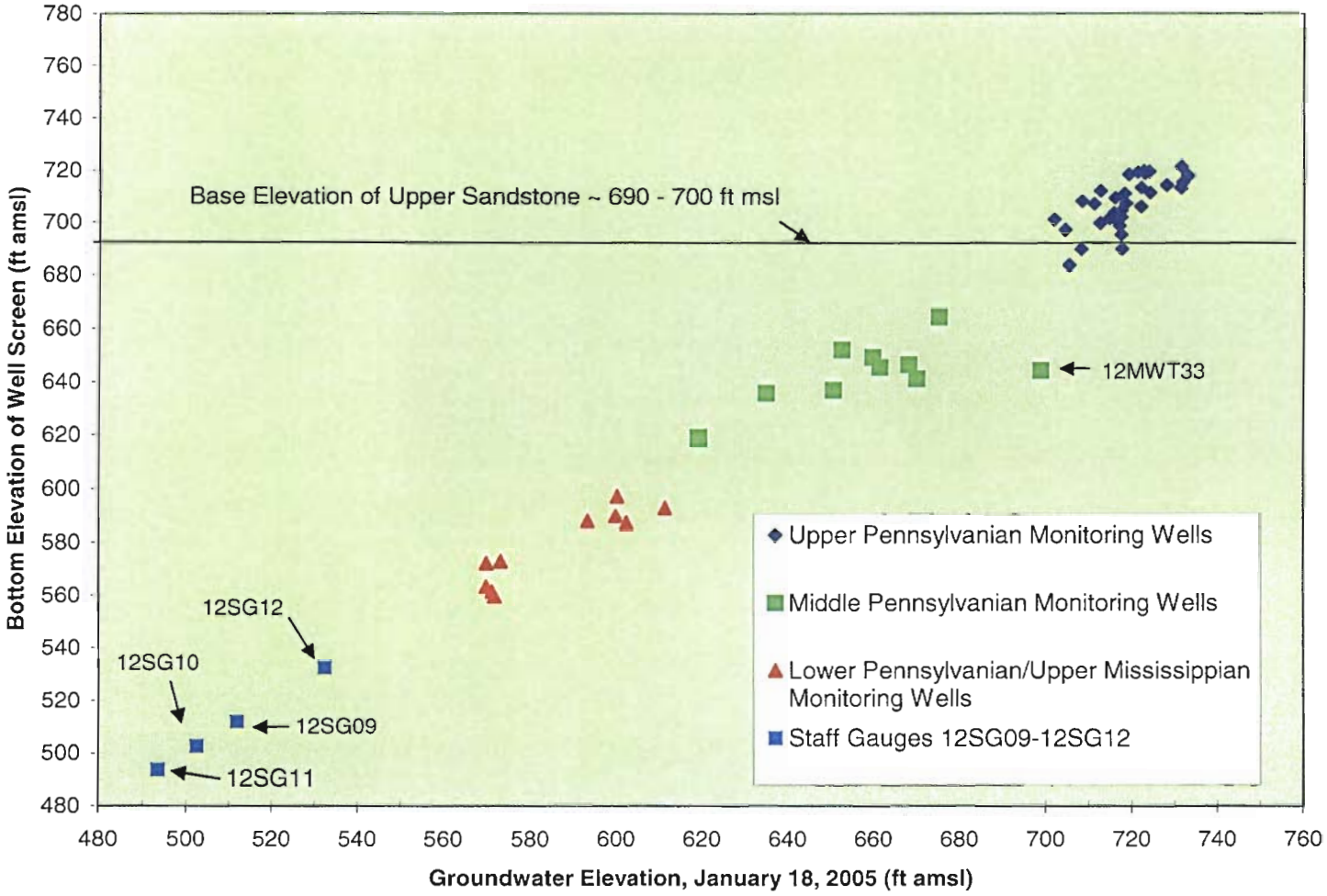
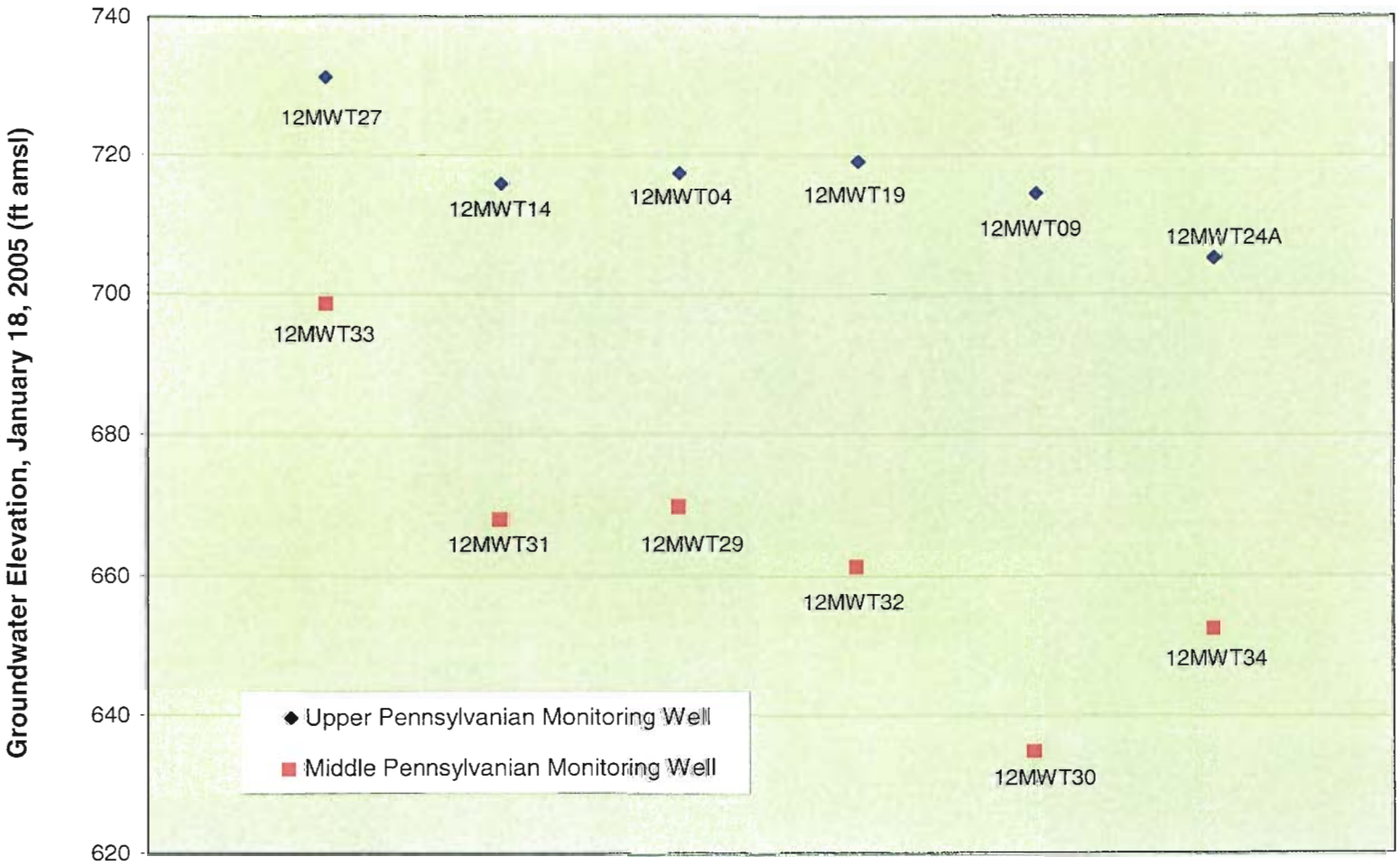


FIGURE ~~4-13~~ 2-13. COMPARISON OF GROUNDWATER ELEVATIONS IN WELL PAIRS



3.0 SAMPLING AND ANALYSIS PLAN

3.1 GENERAL APPROACH

This section describes sampling locations and rationales for the sampling activities to be conducted during the long-term monitoring program at SWMU 12 – MFA (Rounds 3 through 9). The equipment and procedures to be used for collecting, handling, preserving, recording, logging, and shipping the samples to the analytical laboratory is presented in the approved QAPP Addendum No. 2 (TtNUS, 2004) and therefore, are not repeated here. The field standard operating procedures (SOPs) can be found in Appendix C of the QAPP Addendum No. 2. A separate Health and Safety Plan (HASP) was prepared for SWMU 12 which describes the specific health and safety requirements, concerns, and information related to the site activities.

Prior to each sampling round, the Task Order Manager (TOM) will ensure that all field personnel read and understand the QAPP Addendum and the HASP. The documents will be read and understood by each person working at the site. Each worker or visitor to the site must sign an acknowledgment that he or she has read and understands the HASP.

The Field Operations Leader (FOL) will ensure that all required field equipment for non-health-and-safety-related operations is available and operational, and the Site Safety Officer (SSO) will ensure that all health-and-safety-related equipment is available and operational.

Two rounds of drilling, well installation, and multimedia sampling have already been performed at SWMU 12. Seven additional rounds (Rounds 3 through 9) of groundwater and surface water samples will be collected at selected wells within SWMU 12 to provide information on trends in groundwater and surface water contamination for explosives.

3.2 SAMPLING LOCATIONS, ANALYSES, AND RATIONALES

This section presents sampling locations, quality assurance/quality control (QA/QC) samples to be collected, analyses to be performed, and rationales for the sampling and analytical program. Sampling locations are shown on Figures 1-1 and 1-2.

3.2.1 Groundwater Sampling Activities

Explosives in groundwater may be naturally degrading. If explosives are naturally degrading, concentrations of explosives would be expected to decrease over time. The primary purpose of Rounds 3 through 9 is to provide information on the temporal trends of concentrations of explosives and explosives degradation products in groundwater. The information from these rounds will be utilized along with information from Rounds 1 and 2 to establish long-term trends in concentrations of explosives in groundwater and to estimate degradation rates.

US EPA Region 5 guidance titled Transmittal of Monitored Natural Attenuation Framework dated September 27, 2000 was used as the basis for the selection of monitoring wells to be used in the SWMU 12 long-term monitoring program.

The long-term monitoring program includes selected wells. Table 3-1 lists these wells and the rationale for their selection. Table 3-2 lists the selected wells along with the sample identification and laboratory analyses for each round. Table 3-3 presents a summary of groundwater analyses and quality control samples. Each sample of Rounds 3 through 9 will be analyzed for explosives. In addition, samples collected in even-numbered rounds (i.e., 4, 6, and 8) will also be analyzed for explosive degradation products. Note that wells or parameters monitored in Rounds 3 through 9 may be deleted and/or added based on ongoing results and whether the wells produce sufficient water.

New dedicated bladder pumps and Teflon tubing will be installed in each well that is part of the long-term monitoring program. Details of pumps and pump installation are presented in Section 3.5.6 of the QAPP Addendum No. 2 and SOP CTO166-23.

3.2.2 Surface Water Sampling Activities

Surface water sampling is proposed for SWMU 12 in Rounds 3 through 9. For each proposed sampling location, a surface water sample will be collected when possible. Surface water may not be present at some of the sampling locations depending on flow conditions at the time of sampling.

The surface water samples collected during Rounds 3 through 9 will be analyzed for explosives and explosive degradation products only. The information from these rounds will be utilized along with information from Rounds 1 and 2 to establish long-term trends in concentrations of explosives in surface water at SWMU 12.

The long-term monitoring program includes selected surface water locations. Table 3-4 lists these locations and the rationale for their selection. Table 3-5 lists the selected locations along with the sample identification and laboratory analyses for each round. Table 3-6 presents a summary of surface water analyses and quality control samples. Each sample of Rounds 3 through 9 will be analyzed for explosives. In addition, samples collected in even-numbered rounds (i.e., 4, 6, and 8) will also be analyzed for explosive degradation products.

Surface water samples will be collected using the methods described in Section 3.5.10 of the QAPP Addendum No. 2 (TtNUS, 2004). Each surface water sample will be analyzed for the analyte groups listed in Table 3-3. Surface water QA/QC samples will be collected as detailed in Table 3-4. No rinsate blanks will be collected because the sample bottles will be filled directly, as discussed in Section 3.5.10 of the QAPP Addendum No. 2 (TtNUS, 2004). The field duplicate will be analyzed for all parameters. The MSD will be analyzed for all parameters except inorganics, which will have an MS and a laboratory duplicate. The total number of analyses, including QA samples, for surface water samples is presented in Table 3-4.

TABLE 3-1

PROPOSED LOCATIONS AND RATIONALE FOR SELECTION OF QUARTERLY GROUNDWATER MONITORING WELLS
SWMU 12 - MFA (ROUNDS 3 THROUGH 9)
NSWC CRANE
CRANE, INDIANA

Plume Name	Well No.	Location Relative to Plume	Aquifer Designation	Comments and Selection Rationale[1]
Bldg. 157 Plume	12MWT11	source area	Puz	Highest concentration of RDX in plume
	12MWT12	center of plume	Puz	Second highest RDX concentration; downgradient of 12MWT11
	12MWT42	leading edge of plume	Puz	Located on southwestern edge of plume
	12MWT38	leading edge of plume	Puz	Located on southern edge of plume
	12MWT36	leading edge of plume	Puz	Located on southeastern edge of plume
	12MWT28	upgradient of plume	Puz	Located upgradient (i.e., northwest) of Building 157 plume
	12MWT03	laterally downgradient of plume	Puz	Located west of plume and somewhat side-gradient
	12MWT42	laterally downgradient of plume	Puz	Determine whether plume expansion has occurred (Rounds 5 and 9 only)
	12MWT45	laterally downgradient of plume	Pmz	Determine whether plume expansion has occurred (Rounds 5 and 9 only)
	12MWT46	laterally downgradient of plume	Pmz	Located southeast and downhill of the plume
	12MWT31	vertically below the plume	Pmz	Screened in Pmz directly below 12MWT14
Bldg. 154 Plume	12MWT43	laterially downgradient of plume	Piz	Determine whether plume expansion has occurred (Rounds 5 and 9 only)
	12MWT06	source area	Puz	Highest RDX concentration in plume
	12MWT09	center of plume	Puz	Second highest RDX concentration; downgradient of 12MWT06
	12MWT10	leading edge of plume	Puz	Well located farthest downgradient of wells in this local area, but still contaminated
	12MWT28	upgradient of plume	Puz	Located upgradient near the north end of SWMU 12
	12MWT41	laterally downgradient of plume	Mgd	Located southwest of plume downslope near unnamed creek, well is uncontaminated.
	12MWT44	laterally downgraidnet of plume	Mgd	Determine whether plume expansion has occurred (Rounds 5 and 9 only)
	12MWT30	vertically below the plume	Pmz	Screened in Pmz directly below 12MWT09 near center of plume

TABLE 3-1

PROPOSED LOCATIONS AND RATIONALE FOR SELECTION OF QUARTERLY GROUNDWATER MONITORING WELLS
SWMU 12 - MFA (ROUNDS 3 THROUGH 9)
NSWC CRANE
CRANE, INDIANA

Plume Name	Well No.	Location Relative to Plume	Aquifer Designation	Comments and Selection Rationale[1]
Bldg. 152 Plume	12MWT16	source area	Puz	Highest RDX concentration in the plume
	12MWT17	center of plume	Puz	Second highest RDX concentration; downgradient of 12MWT16
	12MWT22	leading edge of plume	Puz	Located on southwestern edge of plume
	12MWT20	leading edge of plume	Puz	Located on southeastern edge of plume
	12MWT18	leading edge of plume	Puz	Located on eastern edge of plume
	12MWT28	upgradient of plume	Puz	Located upgradient near the north end of SWMU 12
	12MWT23	laterally downgradient of plume	Puz	Located south-southeast of plume; well is uncontaminated.
	12MWT50	laterally downgradient of plume	Mgd	Determine whether plume expansion has occurred (Rounds 5 and 9 only)
	12MWT32	vertically below the plume	Pmz	Screened in Pmz directly below 12MWT19 near the eastern edge of the plume
	12MWT47	laterally downgradient of plume	Pmz	Determine whether plume expansion has occurred (Rounds 5 and 9 only)
	12MWT48	laterally downgradient of plume	Pmz	Determine whether plume expansion has occurred (Rounds 5 and 9 only)

1 Based on US EPA Region 5 guidance titled Transmittal of Monitored Natural Attenuation Framework dated September 27, 2000.

Piz = Lower Pennsylvanian water-bearing zone.
Puz = Upper Pennsylvanian water-bearing zone.
Pmz = Middle Pennsylvanian water-bearing zone.
Mgd = Mississippian Glen Dean Limestone aquifer.

TABLE 3-2

GROUNDWATER SAMPLES AND LABORATORY ANALYSES[1]
LONG-TERM MONITORING PROGRAM FOR SELECTED WELLS
SWMU 12 - MFA (ROUNDS 3 THROUGH 9)
NSWC CRANE
CRANE, INDIANA

Sample Location	Sample ID	Explosives		Miscellaneous
		Nitroaromatics and Nitramines SW-846 8330	RDX Degradation Products SW-846-8330, Modified	Nitrate + Nitrite (as N) EPA 353.2
Round 3				
12MWT03	12GWT0303	1		
12MWT06	12GWT0603	1		
12MWT09	12GWT0903	1		
12MWT10	12GWT1003	1		
12MWT11	12GWT1103	1		
12MWT12	12GWT1203	1		
12MWT16	12GWT1603	1		
12MWT17	12GWT1703	1		
12MWT18	12GWT1803	1		
12MWT20	12GWT2003	1		
12MWT22	12GWT2203	1		
12MWT23	12GWT2303	1		
12MWT28	12GWT2803	1		
12MWT30	12GWT3003	1		
12MWT31	12GWT3103	1		
12MWT32	12GWT3203	1		
12MWT36	12GWT3603	1		
12MWT38	12GWT3803	1		
12MWT41	12GWT4103	1		
12MWT42	12GWT4203	1		
12MWT46	12GWT4603	1		
Round 4				
12MWT03	12GWT0304	1	1	1
12MWT06	12GWT0604	1	1	1
12MWT09	12GWT0904	1	1	1
12MWT10	12GWT1004	1	1	1
12MWT11	12GWT1104	1	1	1
12MWT16	12GWT1604	1	1	1
12MWT17	12GWT1704	1	1	1
12MWT18	12GWT1804	1	1	1
12MWT20	12GWT2004	1	1	1

TABLE 3-2

GROUNDWATER SAMPLES AND LABORATORY ANALYSES[1]
LONG-TERM MONITORING PROGRAM FOR SELECTED WELLS
SWMU 12 - MFA (ROUNDS 3 THROUGH 9)
NSWC CRANE
CRANE, INDIANA

Sample Location	Sample ID	Explosives		Miscellaneous
		Nitroaromatics and Nitramines SW-846 8330	RDX Degradation Products SW-846-8330, Modified	Nitrate + Nitrite (as N) EPA 353.2
Round 4 (Continued)				
12MWT22	12GWT2204	1	1	1
12MWT23	12GWT2304	1	1	1
12MWT28	12GWT2804	1	1	1
12MWT30	12GWT3004	1	1	1
12MWT31	12GWT3104	1	1	1
12MWT32	12GWT3204	1	1	1
12MWT36	12GWT3604	1	1	1
12MWT38	12GWT3804	1	1	1
12MWT41	12GWT4104	1	1	1
12MWT42	12GWT4204	1	1	1
12MWT46	12GWT4604	1	1	1
Round 5				
12MWT03	12GWT0305	1		
12MWT06	12GWT0605	1		
12MWT09	12GWT0905	1		
12MWT10	12GWT1005	1		
12MWT11	12GWT1105	1		
12MWT12	12GWT1205	1		
12MWT16	12GWT1605	1		
12MWT17	12GWT1705	1		
12MWT18	12GWT1805	1		
12MWT20	12GWT2005	1		
12MWT22	12GWT2205	1		
12MWT23	12GWT2305	1		
12MWT28	12GWT2805	1		
12MWT30	12GWT3005	1		
12MWT31	12GWT3105	1		
12MWT32	12GWT3205	1		
12MWT36	12GWT3605	1		
12MWT38	12GWT3805	1		
12MWT41	12GWT4105	1		
12MWT41	12GWT4105	1		
12MWT42	12GWT4205	1		

TABLE 3-2

GROUNDWATER SAMPLES AND LABORATORY ANALYSES[1]
LONG-TERM MONITORING PROGRAM FOR SELECTED WELLS
SWMU 12 - MFA (ROUNDS 3 THROUGH 9)
NSWC CRANE
CRANE, INDIANA

Sample Location	Sample ID	Explosives		Miscellaneous
		Nitroaromatics and Nitramines SW-846 8330	RDX Degradation Products SW-846-8330, Modified	Nitrate + Nitrite (as N) EPA 353.2
Round 5 (Continued)				
12MWT43	12GWT4305	1		
12MWT44	12GWT4405	1		
12MWT45	12GWT4505	1		
12MWT46	12GWT4605	1		
12MWT47	12GWT4705	1		
12MWT48	12GWT4805	1		
12MWT49	12GWT4905	1		
12MWT50	12GWT5005	1		
Round 6				
12MWT03	12GWT0306	1	1	1
12MWT06	12GWT0606	1	1	1
12MWT09	12GWT0906	1	1	1
12MWT10	12GWT1006	1	1	1
12MWT11	12GWT1106	1	1	1
12MWT12	12GWT1206	1	1	1
12MWT16	12GWT1606	1	1	1
12MWT17	12GWT1706	1	1	1
12MWT18	12GWT1806	1	1	1
12MWT20	12GWT2006	1	1	1
12MWT22	12GWT2206	1	1	1
12MWT23	12GWT2306	1	1	1
12MWT28	12GWT2806	1	1	1
12MWT30	12GWT3006	1	1	1
12MWT31	12GWT3106	1	1	1
12MWT32	12GWT3206	1	1	1
12MWT36	12GWT3606	1	1	1
12MWT38	12GWT3806	1	1	1
12MWT41	12GWT4106	1	1	1
12MWT42	12GWT4206	1	1	1
12MWT46	12GWT4606	1	1	1

TABLE 3-2

GROUNDWATER SAMPLES AND LABORATORY ANALYSES[1]
LONG-TERM MONITORING PROGRAM FOR SELECTED WELLS
SWMU 12 - MFA (ROUNDS 3 THROUGH 9)
NSWC CRANE
CRANE, INDIANA

Sample Location	Sample ID	Explosives		Miscellaneous
		Nitroaromatics and Nitramines SW-846 8330	RDX Degradation Products SW-846-8330, Modified	Nitrate + Nitrite (as N) EPA 353.2
Round 7				
12MWT03	12GWT0307	1		
12MWT06	12GWT0607	1		
12MWT09	12GWT0907	1		
12MWT10	12GWT1007	1		
12MWT11	12GWT1107	1		
12MWT12	12GWT1207	1		
12MWT16	12GWT1607	1		
12MWT17	12GWT1707	1		
12MWT18	12GWT1807	1		
12MWT20	12GWT2007	1		
12MWT22	12GWT2207	1		
12MWT23	12GWT2307	1		
12MWT28	12GWT2807	1		
12MWT30	12GWT3007	1		
12MWT31	12GWT3107	1		
12MWT32	12GWT3207	1		
12MWT36	12GWT3607	1		
12MWT38	12GWT3807	1		
12MWT41	12GWT4107	1		
12MWT42	12GWT4207	1		
12MWT46	12GWT4607	1		
Round 8				
12MWT03	12GWT0308	1	1	1
12MWT06	12GWT0608	1	1	1
12MWT09	12GWT0908	1	1	1
12MWT10	12GWT1008	1	1	1
12MWT11	12GWT1108	1	1	1
12MWT12	12GWT1208	1	1	1
12MWT16	12GWT1608	1	1	1
12MWT17	12GWT1708	1	1	1
12MWT18	12GWT1808	1	1	1
12MWT20	12GWT2008	1	1	1

TABLE 3-2

GROUNDWATER SAMPLES AND LABORATORY ANALYSES[1]
LONG-TERM MONITORING PROGRAM FOR SELECTED WELLS
SWMU 12 - MFA (ROUNDS 3 THROUGH 9)
NSWC CRANE
CRANE, INDIANA

Sample Location	Sample ID	Explosives		Miscellaneous
		Nitroaromatics and Nitramines SW-846 8330	RDX Degradation Products SW-846-8330, Modified	Nitrate + Nitrite (as N) EPA 353.2
Round 8 (Continued)				
12MWT22	12GWT2208	1	1	1
12MWT23	12GWT2308	1	1	1
12MWT28	12GWT2808	1	1	1
12MWT30	12GWT3008	1	1	1
12MWT31	12GWT3108	1	1	1
12MWT32	12GWT3208	1	1	1
12MWT36	12GWT3608	1	1	1
12MWT38	12GWT3808	1	1	1
12MWT41	12GWT4108	1	1	1
12MWT42	12GWT4208	1	1	1
12MWT46	12GWT4608	1	1	1
Round 9				
12MWT03	12GWT0309	1		
12MWT06	12GWT0609	1		
12MWT09	12GWT0909	1		
12MWT10	12GWT1009	1		
12MWT11	12GWT1109	1		
12MWT12	12GWT1209	1		
12MWT16	12GWT1609	1		
12MWT17	12GWT1709	1		
12MWT18	12GWT1809	1		
12MWT20	12GWT2009	1		
12MWT22	12GWT2209	1		
12MWT23	12GWT2309	1		
12MWT28	12GWT2809	1		
12MWT30	12GWT3009	1		
12MWT31	12GWT3109	1		
12MWT32	12GWT3209	1		
12MWT36	12GWT3609	1		
12MWT38	12GWT3809	1		
12MWT41	12GWT4109	1		
12MWT41	12GWT4105	1		
12MWT42	12GWT4209	1		

TABLE 3-2

GROUNDWATER SAMPLES AND LABORATORY ANALYSES[1]
LONG-TERM MONITORING PROGRAM FOR SELECTED WELLS
SWMU 12 - MFA (ROUNDS 3 THROUGH 9)
NSWC CRANE
CRANE, INDIANA

Sample Location	Sample ID	Explosives		Miscellaneous
		Nitroaromatics and Nitramines SW-846 8330	RDX Degradation Products SW-846-8330, Modified	Nitrate + Nitrite (as N) EPA 353.2
Round 9 (Continued)				
12MWT43	12GWT4305	1		
12MWT44	12GWT4405	1		
12MWT45	12GWT4505	1		
12MWT46	12GWT4609	1		
12MWT47	12GWT4705	1		
12MWT48	12GWT4805	1		
12MWT49	12GWT4905	1		
12MWT50	12GWT5005	1		
SWMU 12 Total Samples		162	62	62

TABLE 3-3

SUMMARY OF GROUNDWATER ANALYSES[1] AND QUALITY CONTROL SAMPLES
SWMU 12 - MFA (ROUNDS 3 THROUGH 9)
NSWC CRANE
CRANE, INDIANA

Sample Type	Explosives		Miscellaneous
	Nitroaromatics and Nitramines SW-846 8330	RDX Degradation Products SW-846-8330, Modified	Nitrate + Nitrite (as N) EPA 353.2
Total SWMU 12 Samples	162	62	62
Field Duplicate[2]	9	4	4
Trip Blank[3]	NA	NA	NA
Rinsate Blank[4]	NA	NA	NA
Source Water Blank	0	0	0
Ambient Condition Blank[5]			
Matrix Spike[6]	9	4	4
Matrix Spike Duplicate[7]	9	4	4

1 See Table 1-6 of the QAPP Addendum No. 2 for specific analysis requirements and analyte lists.
2 Field duplicates will be collected at a frequency of one per every 20 samples per SWMU.
3 Trip blanks will be submitted for analysis at a frequency of one per cooler containing samples for volatile analysis. Because the number of sample coolers shipped may vary, the number of trip blanks are estimated.
4 Rinsate blanks will be collected at a frequency of one per sampling device or instrument. These amounts are estimates and may vary.
5 Ambient condition blanks are optional samples that may be collected based on the judgment of the FOL.
6 Matrix spikes are collected for all organic and inorganic parameters at a frequency of one per every 20 field samples per matrix.
7 Matrix spike duplicates are collected for all organic parameters. Laboratory duplicates are analyzed for inorganic parameters in lieu of matrix spike duplicates. Matrix spike duplicates are collected at a frequency of one per every 20 field samples per matrix.
NA - Not applicable.

TABLE 3-4

RATIONALE FOR SELECTION OF SURFACE WATER LOCATIONS
SWMU 12 - MFA (ROUNDS 3 THROUGH 9)
NSWC CRANE
CRANE, INDIANA

Sample Location	Surface Water Location Selection Rationale[1]
12SW/SD09	Downgradient of SWMU 12 in west tributary
12SW/SD11	Mouth of western tributary
12SW/SD14	High RDX concentration on east side of SWMU
12SW/SD24	Mouth of eastern tributary
12SW/SD25	Turkey Creek, upstream of SWMU 12
12SW/SD27	Turkey Creek, downstream of SWMU 12 tributary creeks
12SW/SD31	High RDX concentration on east side of SWMU
12SW/SD34	High RDX concentration on western side of SWMU

1 Based on US EPA Region 5 guidance titled Transmittal of Monitored Natural Attenuation Framework dated September 27, 2000.

TABLE 3-5

SURFACE WATER SAMPLES AND LABORATORY ANALYSES[1]
SWMU 12 - MFA (ROUNDS 3 THROUGH 9)
NSWC CRANE
CRANE, INDIANA

Sample Location	Sample ID	Explosives		Miscellaneous
		Nitroaromatics and Nitramines SW-846 8330	RDX Degradation Products SW-846-8330, Modified	Nitrate + Nitrite (as N) EPA 353.2
Round 3				
12SW/SD09	12SW0903	1		
12SW/SD11	12SW1103	1		
12SW/SD14	12SW1403	1		
12SW/SD24	12SW2403	1		
12SW/SD25	12SW2503	1		
12SW/SD27	12SW2703	1		
12SW/SD31	12SW3102	1		
12SW/SD34	12SW3402	1		
Round 4				
12SW/SD09	12SW0903	1	1	1
12SW/SD11	12SW1103	1	1	1
12SW/SD14	12SW1403	1	1	1
12SW/SD24	12SW2403	1	1	1
12SW/SD25	12SW2503	1	1	1
12SW/SD27	12SW2703	1	1	1
12SW/SD31	12SW3102	1	1	1
12SW/SD34	12SW3402	1	1	1
Round 5				
12SW/SD09	12SW0903	1		
12SW/SD11	12SW1103	1		
12SW/SD14	12SW1403	1		
12SW/SD24	12SW2403	1		
12SW/SD25	12SW2503	1		
12SW/SD27	12SW2703	1		
12SW/SD31	12SW3102	1		
12SW/SD34	12SW3402	1		
Round 6				
12SW/SD09	12SW0903	1	1	1
12SW/SD11	12SW1103	1	1	1
12SW/SD14	12SW1403	1	1	1
12SW/SD24	12SW2403	1	1	1

TABLE 3-5

SURFACE WATER SAMPLES AND LABORATORY ANALYSES[1]
SWMU 12 - MFA (ROUNDS 3 THROUGH 9)
NSWC CRANE
CRANE, INDIANA

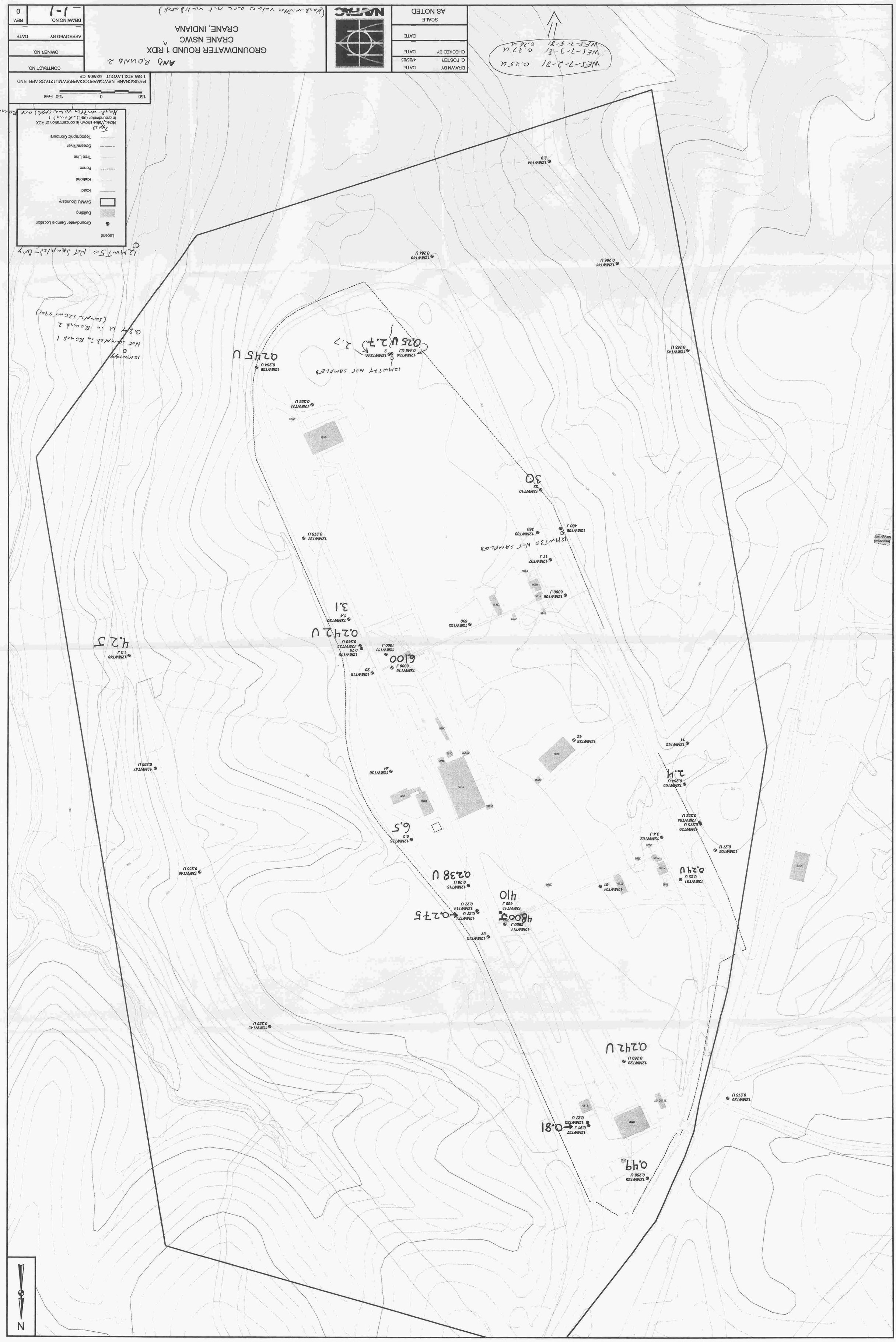
Sample Location	Sample ID	Explosives		Miscellaneous
		Nitroaromatics and Nitramines SW-846 8330	RDX Degradation Products SW-846-8330, Modified	Nitrate + Nitrite (as N) EPA 353.2
12SW/SD25	12SW2503	1	1	1
12SW/SD27	12SW2703	1	1	1
12SW/SD31	12SW3102	1	1	1
12SW/SD34	12SW3402	1	1	1
Round 7				
12SW/SD09	12SW0903	1		
12SW/SD11	12SW1103	1		
12SW/SD14	12SW1403	1		
12SW/SD24	12SW2403	1		
12SW/SD25	12SW2503	1		
12SW/SD27	12SW2703	1		
12SW/SD31	12SW3102	1		
12SW/SD34	12SW3402	1		
Round 8				
12SW/SD09	12SW0903	1	1	1
12SW/SD11	12SW1103	1	1	1
12SW/SD14	12SW1403	1	1	1
12SW/SD24	12SW2403	1	1	1
12SW/SD25	12SW2503	1	1	1
12SW/SD27	12SW2703	1	1	1
12SW/SD31	12SW3102	1	1	1
12SW/SD34	12SW3402	1	1	1
Round 9				
12SW/SD09	12SW0903	1		
12SW/SD11	12SW1103	1		
12SW/SD14	12SW1403	1		
12SW/SD24	12SW2403	1		
12SW/SD25	12SW2503	1		
12SW/SD27	12SW2703	1		
12SW/SD31	12SW3102	1		
12SW/SD34	12SW3402	1		
SWMU 12 Total Samples		56	24	24

TABLE 3-6

SUMMARY OF SURFACE WATER ANALYSES[1] AND QUALITY CONTROL SAMPLES
SWMU 12 - MFA (ROUNDS 3 THROUGH 9)
NSWC CRANE
CRANE, INDIANA

Sample Type	Explosives		Miscellaneous
	Nitroaromatics and Nitramines SW-846 8330	RDX Degradation Products SW-846 8330, Modified	Nitrate + Nitrite (as N)
Total SWMU 12 Samples	56	24	24
Field Duplicate[2]	7	3	3
Trip Blank[3]	NA	NA	NA
Rinsate Blank[4]	NA	NA	NA
Source Water Blank			
Ambient Condition Blank[5]			
Matrix Spike[6]	7	3	3
Matrix Spike Duplicate[7]	7	3	3

1 See Table 1-6 of this QAPP Addendum No. 2 for specific analysis requirements and analyte lists.
2 Field duplicates will be collected at a frequency of one per every 20 samples per SWMU.
3 Trip blanks will be submitted for analysis at a frequency of one per cooler containing samples for volatile analysis. Because the number of sample coolers shipped may vary, the number of trip blanks is estimated.
4 Environmental samples will be collected by directly filling the sample bottle. Therefore, no rinsate blanks are required for this matrix.
5 Ambient condition blanks are optional samples that may be collected based on the judgment of the FOL.
6 Matrix spikes are collected for all organic and inorganic parameters at a frequency of one per every 20 field samples per matrix.
7 Matrix spike duplicates are collected for all organic parameters. Laboratory duplicates are analyzed for inorganic parameters in lieu of matrix spike duplicates. Matrix spike duplicates are collected at a frequency of one per every 20 field samples per matrix.
NA - Not applicable.



Rev 1 TEG 5-2-05

DRAWN BY	DATE
C. FOSTER	4/25/05
CHECKED BY	DATE
	DATE
SCALE	
AS NOTED	

NAVFAC

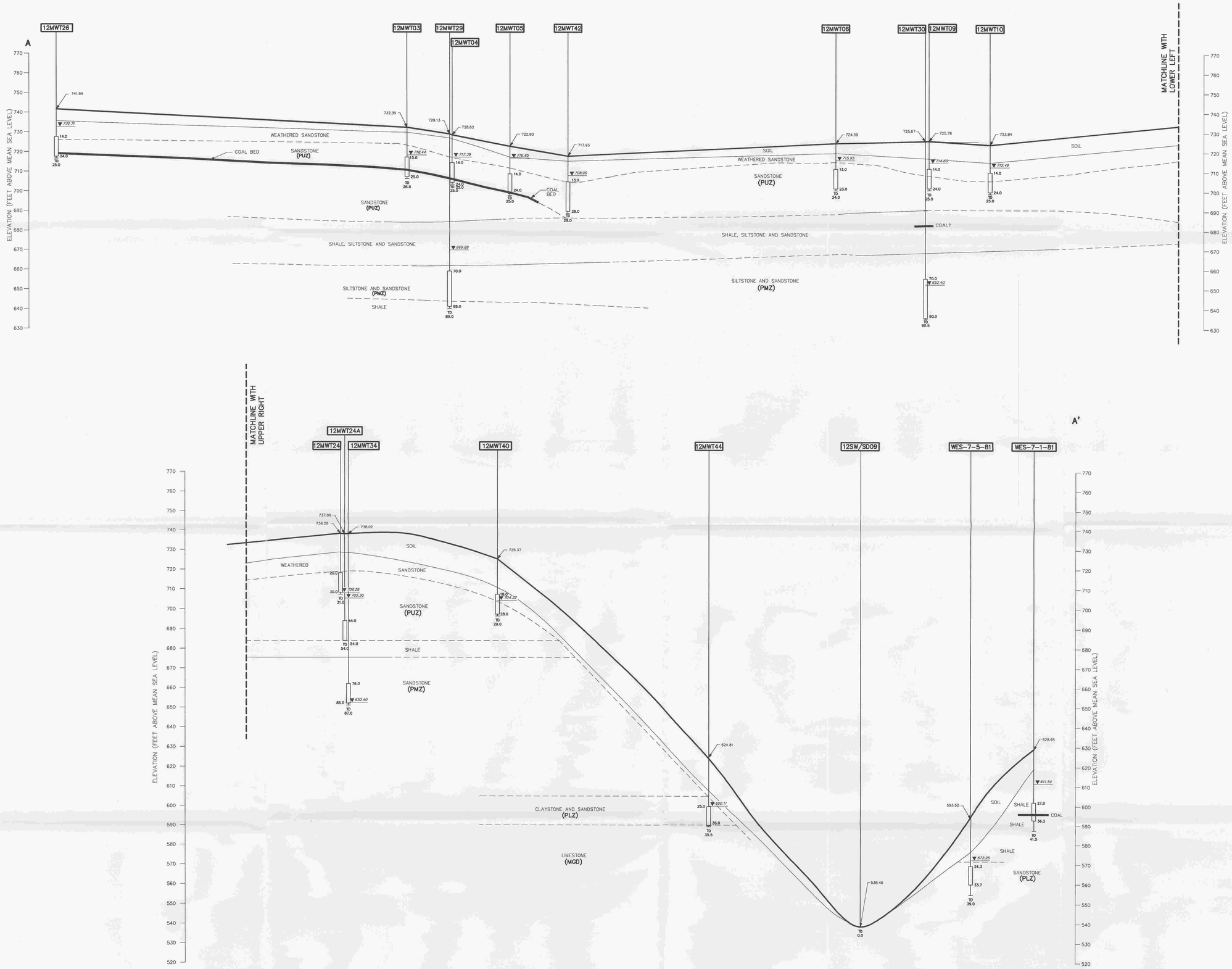
SURFACE WATER / SEDIMENT ROUND 1 RDX
CRANE NSWC
CRANE, INDIANA

CONTRACT NO.

OWNER NO.

APPROVED BY

DRAWING NO. 1-2



LEGEND:

MONITORING WELL OR BORING NUMBER — 12MWT26
GROUND SURFACE ELEVATION — 741.64
GROUND SURFACE
GROUNDWATER ELEVATION
TOP OF SCREEN INTERVAL (FT BGS) — 14.0
LITHOLOGIC CONTACT (INFERRED BETWEEN BORINGS)
BOTTOM OF SCREEN INTERVAL (FT BGS) — 24.0
TOTAL DEPTH OF WELL OR BORING (FT BGS) — TD 25.0

0 100 200 HORIZONTAL SCALE IN FEET
0 20 40 VERTICAL SCALE IN FEET

(PUZ) = UPPER PENNSYLVANIAN WATER-BEARING ZONE
(PMZ) = MIDDLE PENNSYLVANIAN WATER-BEARING ZONE
(PLZ) = LOWER PENNSYLVANIAN WATER-BEARING ZONE
(MGD) = MISSISSIPPIAN GLEN DEAN LIMESTONE

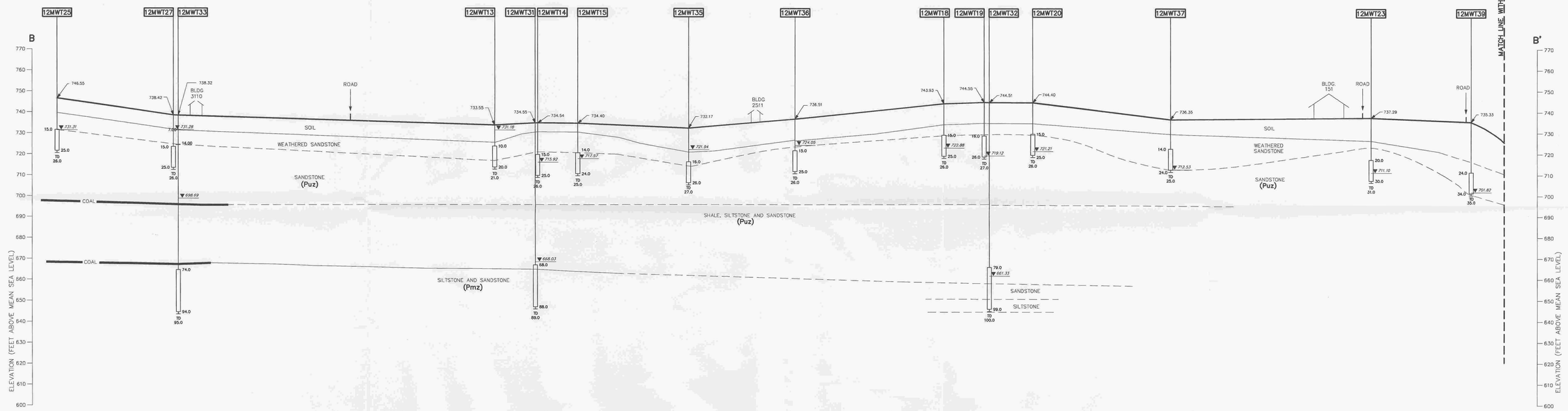
DRAWN BY DM	DATE 5/2/05	GEOLOGICAL CROSS SECTION A-A' SWMU 12 MINE FILL A NSWC CRANE CRANE, INDIANA
CHECKED BY	DATE	
REVISED BY	DATE	
SCALE AS NOTED		NAVFAC

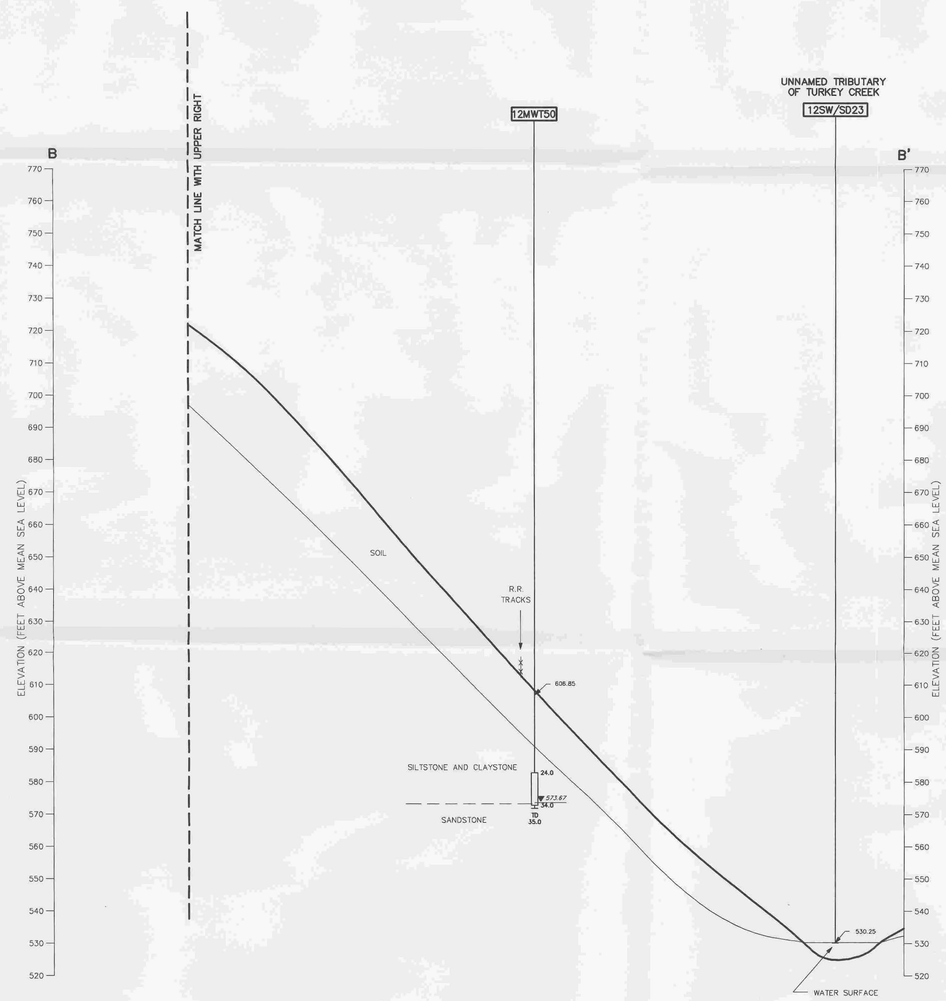
CONTRACT NO. 6878	
OWNER NO. 0000	
APPROVED BY	DATE
DRAWING NO. FIGURE 2-5	REV. 0

FORM CASD NO. 5SDV-E-STD3VG - REV 0 - 9/4/98

ACAD: 6878GX01.dwg 05/12/05 DM PIT

DRAWING NO. FIGURE 2-5 REV. 0





(Puz) = UPPER PENNSYLVANIAN WATER-BEARING ZONE
(Pmz) = MIDDLE PENNSYLVANIAN WATER-BEARING ZONE
(Plz) = LOWER PENNSYLVANIAN WATER-BEARING ZONE
(Mgd) = MISSISSIPPIAN GLEN DEAN LIMESTONE

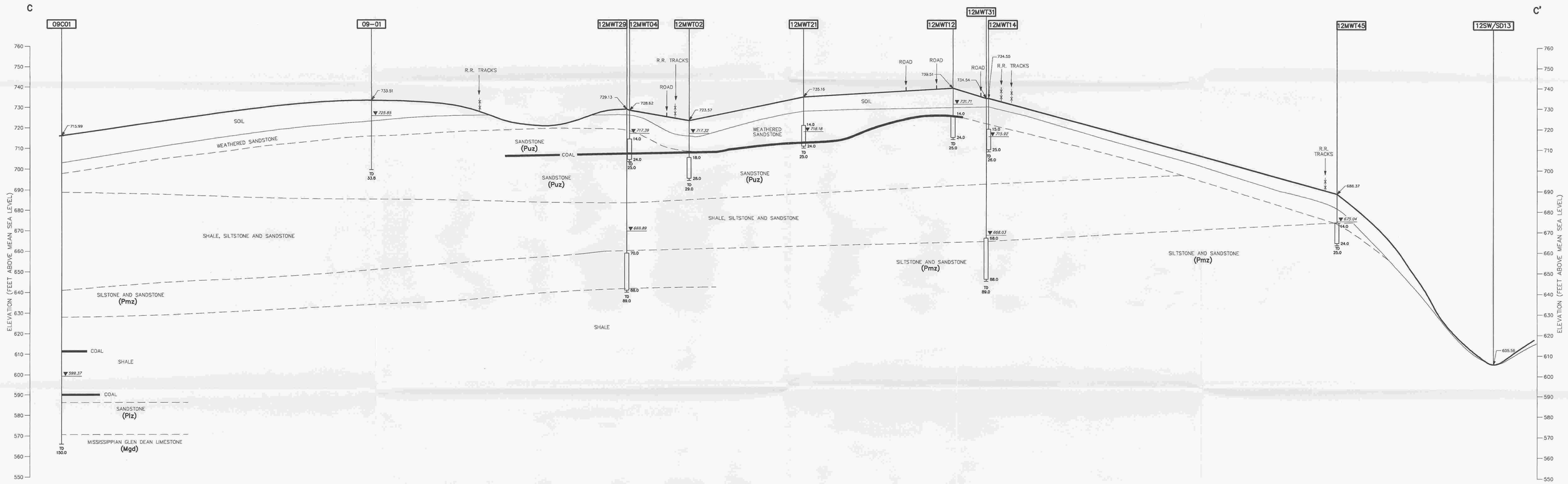
LEGEND:

MONITORING WELL OR BORING NUMBER — 12MWT36
GROUND SURFACE ELEVATION — 736.91
GROUND SURFACE
GROUNDWATER ELEVATION
TOP OF SCREEN INTERVAL (FT BGS) — 15.0
LITHOLOGIC CONTACT (INFERRED BETWEEN BORINGS)
BOTTOM OF SCREEN INTERVAL (FT BGS) — 25.0
TOTAL DEPTH OF WELL OR BORING (FT BGS) — TD 26.0

HORIZONTAL SCALE IN FEET: 0 100 200
VERTICAL SCALE IN FEET: 0 20 40

DRAWN BY DM	DATE 5/6/05	GEOLOGIC CROSS SECTION B-B' SWMU 12 MINE FILL A NSWC CRANE CRANE, INDIANA
CHECKED BY	DATE	
REVISED BY	DATE	
SCALE AS NOTED		NAVFAC

CONTRACT NO. 6878
OWNER NO. 0000
APPROVED BY — DATE
DRAWING NO. FIGURE 2-6 — REV. 0



LEGEND:

MONITORING WELL OR BORING NUMBER — 12MWT21
GROUND SURFACE ELEVATION — 735.16
GROUND SURFACE
GROUNDWATER ELEVATION
TOP OF SCREEN INTERVAL (FT BGS) — 14.00
LITHOLOGIC CONTACT (INFERRED BETWEEN BORINGS)
BOTTOM OF SCREEN INTERVAL (FT BGS) — 24.0
TOTAL DEPTH OF WELL OR BORING (FT BGS) — TD=25.0

(Puz) = UPPER PENNSYLVANIAN WATER-BEARING ZONE
(Pmz) = MIDDLE PENNSYLVANIAN WATER-BEARING ZONE
(Plz) = LOWER PENNSYLVANIAN WATER-BEARING ZONE
(Mgd) = MISSISSIPPIAN GLEN DEAN LIMESTONE

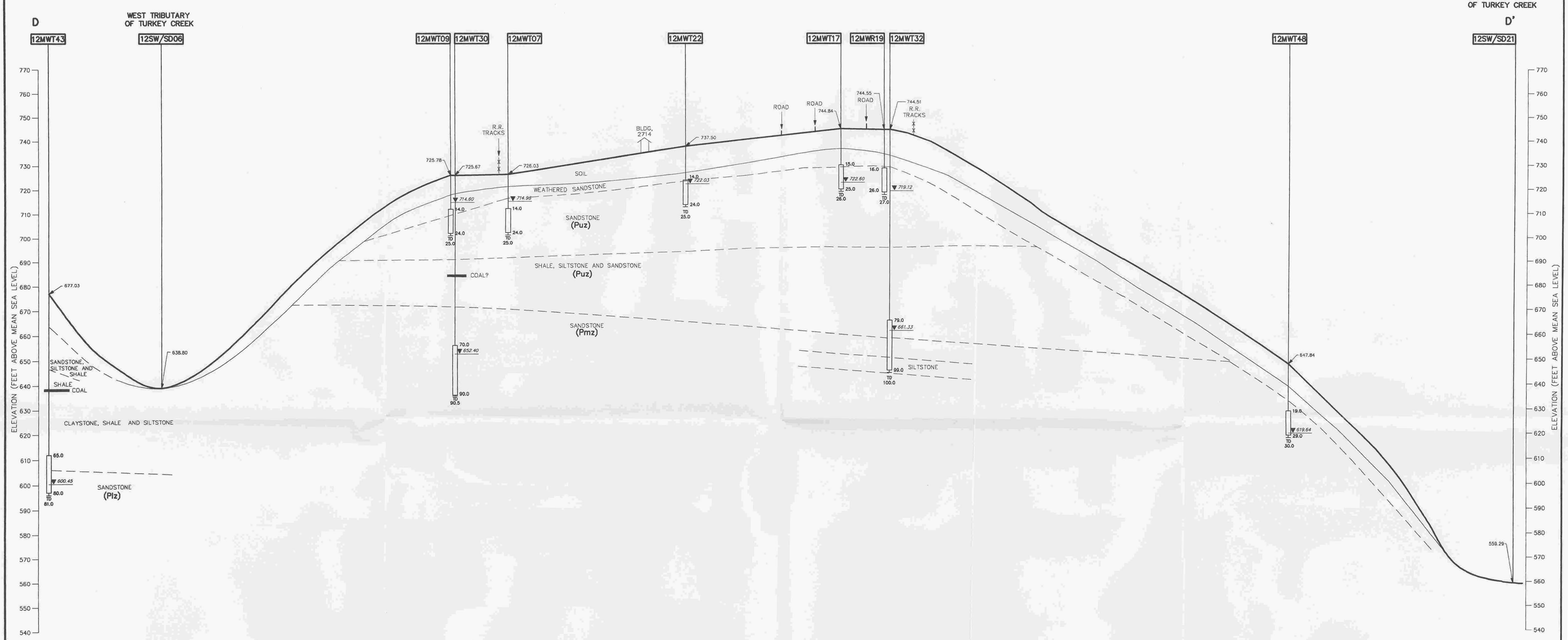
0 100 200
HORIZONTAL SCALE IN FEET
0 20 40
VERTICAL SCALE IN FEET

DRAWN BY DM	DATE 5/6/05	GEOLOGIC CROSS SECTION C-C" SWMU 12 MINE FILL A NSWC CRANE CRANE, INDIANA	CONTRACT NO. 6878
CHECKED BY	DATE		OWNER NO. CTO
REVISED BY	DATE		APPROVED BY / DATE
SCALE AS NOTED		NAVFAC	DRAWING NO. FIGURE 2-7 / REV. 0

DRAWING NO. FIGURE 2-7 REV. 0

FORM CADD NO. SIEV-C-STD.SVG - REV 0 - 9/4/98

ACAD: 6878DI04.dwg 05/12/05 DM PIT



LEGEND:

MONITORING WELL OR BORING NUMBER — 24MW15S
GROUND SURFACE ELEVATION — 32.26
GROUND SURFACE
GROUNDWATER ELEVATION
TOP OF SCREEN INTERVAL (FT BGS) — 4.00
LITHOLOGIC CONTACT (INFERRED BETWEEN BORINGS)
BOTTOM OF SCREEN INTERVAL (FT BGS) — 14.0
TOTAL DEPTH OF WELL OR BORING (FT BGS) — TD=14.0

(Puz) = UPPER PENNSYLVANIAN WATER-BEARING ZONE
(Pmz) = MIDDLE PENNSYLVANIAN WATER-BEARING ZONE
(Plz) = LOWER PENNSYLVANIAN WATER-BEARING ZONE
(Mgd) = MISSISSIPPIAN GLEN DEAN LIMESTONE

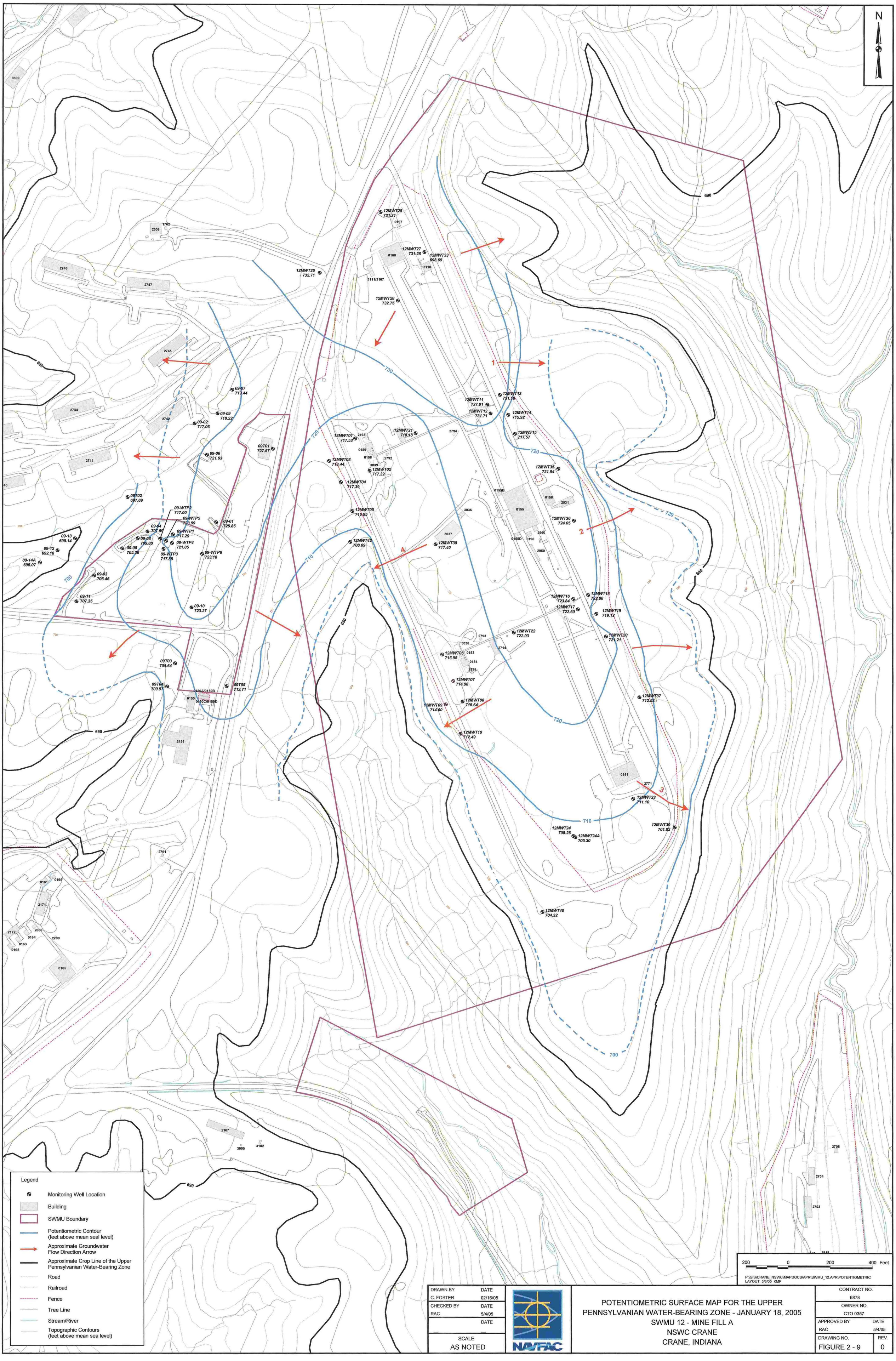
HORIZONTAL SCALE IN FEET: 0 100 200
VERTICAL SCALE IN FEET: 0 20 40

DRAWN BY DM	DATE 5/6/05	GEOLOGIC CROSS SECTION D-D' SWMU 12 MINE FILL A NSWC CRANE CRANE, INDIANA	CONTRACT NO. 6878
CHECKED BY	DATE		OWNER NO. CTO
REVISED BY	DATE		APPROVED BY / DATE
SCALE AS NOTED		NAVFAC	DRAWING NO. FIGURE 2-8 / REV. 0

FORM CADD NO. SDIV-D-STD.DWG - REV 1 - 9/14/98

ACAD: 6878GX03.dwg 05/12/05 DM PIT

DRAWING NO. FIGURE 2-8 REV. 0



DRAWN BY	DATE
C. FOSTER	02/16/05
CHECKED BY	DATE
RAC	5/4/05
	DATE
SCALE	
AS NOTED	

NAVFAC

POTENTIOMETRIC SURFACE MAP FOR THE UPPER PENNSYLVANIAN WATER-BEARING ZONE - JANUARY 18, 2005
SWMU 12 - MINE FILL A
NSWC CRANE
CRANE, INDIANA

CONTRACT NO.	
6878	
OWNER NO.	
CTO 0357	
APPROVED BY	DATE
RAC	5/4/05
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FIGURE 2 - 9	0

REFERENCES

Barnhill, Mark L., Paula L. Hansley, 1993. Sedimentology and Reservoir Characteristics of Pennsylvanian Aquifer Bodies at the McComish Gorge, Old Burn Pit, Pest Control site, and Mustard Gas Burial Grounds: A preliminary Investigation. Indiana University, Indiana Geological Survey, Bloomington, Indiana, August.

(Braun, 1950) Braun, E.L., 1950. Deciduous Forests of Eastern North America. Blakiston Company, Philadelphia, Pennsylvania.

Deam, Charles C., 1940. Flora of Indiana. Indiana Department of Conservation, Division of Forestry, Indianapolis, Indiana, Wm. B. Burford Printing Company, Indianapolis.

Hengeveld, D., 1987. "Results of the Survey of Bird Species at the Naval Weapons Support Center, Crane." In An Inventory of Natural Areas and Rare Plant Species at the Naval Weapons Support Center Crane, Indiana. Indiana Department of Natural Resources, Division of Natural Preserves, Indianapolis, Indiana.

Kuchler, A.W., 1964. Potential Natural Vegetation of the Conterminous United States. American Geographical Society, Special Publication No. 36, New York, New York.

Lindsey, A.A., D.V. Schmelz, and S.A. Nichols, 1970. Natural Areas in Indiana and Their Preservation. American Midland Naturalist, Department of Biology, University of Notre Dame, Indiana.

Nelson, C.E., M.A. Ewert, and S.A. Cortwright, 1987. "A Field Survey of Amphibians and Reptiles at Crane Naval Weapons Support Center, Martin County, Indiana with Emphasis on Rare and Unusual Species." In An Inventory of Natural Areas and Rare Plant Species at the Naval Weapons Support Center Crane, Indiana. Indiana Department of Natural Resources, Division of Nature Preserves, Indianapolis, Indiana.

TtNUS, 2003. Approved QAPP Addendum No. 1 for Mine Fill A (SWMU 12), Mine Fill B (SWMU 13), Cast High Explosives Fill/B146 Incinerator (SWMU 16), and Pyrotechnic Test Area (SWMU 19) RCRA Facility Investigation, Tetra Tech NUS, Inc., October.

TtNUS, 2004. Approved QAPP Addendum No. 2 for Mine Fill A (SWMU 12), Mine Fill B (SWMU 13), Cast High Explosives Fill/B146 Incinerator (SWMU 16), and Pyrotechnic Test Area (SWMU 19) RCRA Facility Investigation, Tetra Tech NUS, Inc., June.